ECE Course Information @ NUSRI for AY2025/2026 Students

Compulsory Courses

1. GE4000 Scientific writing and communication in English (4 Credits, total 80 contact hours)
2. GE4100 Science, Technology & Entrepreneurship Seminars (4 Credits, at least 6 seminars to be completed)
3. EES4600 Final Year Project (20 Credits, 2 semesters)

ECE Elective Courses

1. Course Title: EES4725 Digital Circuits and FPGA Design (4 Credits, 39 Contact hours)
2. Course Title: EES4800 Introduction to Quantum Communication (4 Credits, 39 Contact hours)
3. Course Title: EES4408 Machine Learning: Models and Applications (4 Credits, 39 Contact hours)
4. Course Title: EES4205 Silicon Power Devices and Circuits (4 Credits, 39 Contact hours)
5. Course Title: EES4500 Semiconductor Optoelectronics (4 Credits, 39 Contact hours)
6. Course Title: EES4502 Semiconductor Fabrication Process Technology (4 Credits, 39 Contact hours)
7. Course Title: EES4402 Radio Frequency Design and Systems (4 Credits, 39 Contact hours)
8. Course Title: EES4404 Renewable Generation and Smart Grid (4 Credits, 39 Contact hours)

Cross-listed Courses offered by other departments

311 ECE students are allowed to take the following cross-listed Courses based on the recommendation from their home universities, or the request from their FYP supervisors. However, the approval of course enrolment will solely depend on the course home department, e.g. ME courses approved by the ME department.

All the following Courses may be qualified for NUS EE MSc credit transfer, subject to NUS EE MSc terms and conditions.

*** You are allowed to take at most one Course from each of other departments.**

Cross-listed course Courses with Mechanical Engineering (ME) Department:

ME4300/EES4710 Modern Control System
ME4200/EES4730 Microsystems Design and Application
ME4400/EES4740 Automation in Manufacturing
ME4600/EES 4750 Robot Mechanics and Control

Cross-listed course Courses with Materials Science and Engineering (MSE) Department:

MLE4510/EES4760 Materials for Energy Storage and Conversion
MLE4506/EES4770 Current Topics on Nanomaterials

Course Title: GE4000 Scientific writing and communication in English

Mode of Teaching

There are lectures with homework and group presentation sessions.

Syllabus

The course will cover the following topics (80 hours):

- Applying the IPA/using the dictionary/syllabic stress/punctuation/word stress
- Listening skills/processing/tone and register/key words
- Grammar in written English/verbs/nouns/adjectives/ESP(English for Specific Purposes)
- Writing Exercise/Listening Exercise/Read a presentation
    - Homework: Google Academic English/print out academic paper
- What is Academic English-writing style, vocabulary, structure/present printed out Academic paper
- Academic paper guided writing practice/language/clarity/describe a process
- Read what you have written/punctuation/enunciation/basic voice culture
- Grammar revisited: connecting verbs, articles, tense accuracy, countable-uncountable nouns, subject-verb agreement
- The Essay: Body, paragraphing, idiomatic English, Standard English
    - Homework: Essay 500 words
- Presenting a paper: effective introductions and conclusions, defining the audience , paralanguage, punctuation, delivery
- Read part of your essay: pacing, enunciation, punctuation, style, paralanguage, voice quality, connecting with an audience (peer evaluation)
- How to mark a script for pacing, word stress and punctuation
- Re-read script with annotation (peer evaluation)
- Re-visit: IPA, Academic English style
    - Homework: Google Preparing for IELTS
- IELTS Writing component

Assessment

- Homework
- Group Presentation (Peer evaluation)
- Individual Presentation

Course Title: GE4100 Science, Technology & Entrepreneurship Seminars

There are a series of seminars with industry/academic speakers from local or overseas. Students need to select 6 seminars to attend and submit a written report in the end.

Course Title: EES 4408 Machine Learning: Models and Applications
Course Lecturer: Xinchao Wang

Pre-requisite

This Course requires the following pre-requites:

- Probability and statistics
- Linear algebra
- At least one scientific programming language, preferably Matlab or Python.
- Data structure and algorithms

Course Learning Outcomes

The Course provides an in-depth coverage of machine learning models and applications. Students will not only learn the theoretical concepts of machine learning models, but also gain hands-on experience in applying machine-learning tools to real-world tasks.

Specifically, the learning outcomes include:

- Explain Bayesian decision theory, likelihood ratio, and minimum risk classification.
- Implement Maximum Likelihood Estimation, and explain Maximum a Posterior
- Apply dimensionality reduction using Principal Component Analysis, and explain EigenFace
- Implement classifiers using linear discriminant functions and Fisher's Linear Discriminant Analysis.
- Explain the difference between parametric and non-parametric approaches
- Explain the difference between generative approach and discriminant approaches.
- Implement k-nearest neighbours, and perform non-parametric classification.
- Implement Perceptron algorithm.
- Implement Minimum Squared Error algorithm.
- Explain Support Vector Machines, margin maximization, and their advantages.
- Explain decision tree model, and implement the boosting algorithm.
- Explain backpropagation for basic neural networks, and the key concepts of deep neural networks.
- Explain the basic components of convolutional neural networks and their functionalities.

Syllabus (36 hours)

1. [3 Hours] Probability theory; graph concepts; belief network
2. [3 Hours] Bayes' rules; linear algebra; subspace
3. [3 Hours] Bayesian decision theory; decisions based on 1) utilities, 2) priors, 3) posteriors, and 4) risks/losses
4. [3 Hours] Parameter estimation; Maximum Likelihood Estimation; Maximum a Posterior
5. [3 Hours] Non-parametric techniques; k-nearest neighbours; cross validation; overfitting; Bayesian parameter estimation
6. [3 Hours] Subspace selection; Principal Component Analysis; Eigenfaces; face reconstruction and classification
7. [3 Hours] Fisher's Linear Discriminant; generative and discriminative models; multi-class linear discriminant functions

8. [3 Hours] Linear regression; logistic regression; local/global minimum; gradient descent/ascent; Perceptron
9. [3 Hours] Minimum squared error; Support Vector Machines; kernel methods; multi-class Support Vector Machines
10. [3 Hours] Bagging; decision trees; decision forests; boosting
11. [3 Hours] Unsupervised learning; k-means; expectation maximization; Gaussian Mixture Models
12. [3 Hours] Deep learning; neural networks; rationale of deep learning; feature learning; convolutional neural networks.

Assessment mode: Homework, Course Project and Final Exam.

Course Title: EES 4205 Silicon Power Devices and Circuits
Course Lecturer: Yung C. Liang

Pre-requisite

This Course requires some basic knowledge on semiconductor physics for the device part. For the circuit part, it requires basic knowledge of DC circuit analyses.

Course Learning Outcome

The Course provides an in-depth introduction of MOS-bipolar power semiconductor devices, including their characteristics and behaviours in various aspects, and the applications in DC-DC power electronic circuits.

The learning outcome includes:

(a) Understanding of how power semiconductor behaves and how to use the devices
(b) Carrier Physics: Calculation of carrier lifetime under various injection levels
(c) p-n Junction electrostatics: Device junction breakdown behaviours
(d) Design of floating field rings
(e) Understanding of MOS-bipolar IGBT power semiconductor device
(f) Understanding of various DC-DC Converters
(g) Understanding device thermal management

Teaching Mode and Schedule

There are lectures with tutorials. For the teaching class schedule, please refer to the class timetable for details. Zoom sessions will be used if face-to-face teaching is not possible.

Syllabus

The Course serves as a platform for learning the carrier physics, development and design of power semiconductors and the DC-DC power electronic circuits. The Course content covers: (a) Understand power semiconductor, SOA, heatsink design and thermal management, gate drive; (b) Carrier physics in power devices on high-field high-injection mobilities, injection-dependent resistivity modulation, carrier life-time control, lifetime modulation under high-level injection; (c) Junction Electrostatics and device breakdown calculation, including junction termination, avalanche breakdown, and punch-through breakdown; (d) Specific power semiconductor device on MOS-controlled bipolar IGBT device, MOS-controlled thyristors etc.; (e) DC-DC power converter circuits and analyses, including buck, boost, buck-boost, flyback, and their analyses.

Assessment

The Course assessment contains components on take-home assignments, lab sessions, project work and final exam. Class test may also be used for assessment.

Course Title: EES 4500 Semiconductor Optoelectronics
Course Lecturer: Soo Jin Chua

The course will provide a good knowledge and understanding of the units of optical measurements, semiconductor LED, semiconductor laser, photo detection, HEMTS and tandem solar cells for applications in optical communication, lighting, display and sensing. The course also covers a wide background of knowledge related to optoelectronic materials, devices and applications to enable a **robust interaction with AI** and be able to detect inconsistencies in AI's response and subsequently to refine questions to guide AI to achieve a more accurate response.

Course Description
Optoelectronics is the study of the interaction of light/radiation with the electronic properties of materials, which are mainly but not exclusively semiconductor based. However, semiconductors are increasingly used because of its reliability, miniaturisation and compatibility with solid-state electronics. Semiconductor Optoelectronics is increasingly influencing the way we work and live. It is used in manufacturing for in-situ monitoring, telecommunications, lighting, displays and entertainment and in medical diagnostics. This module is designed with a mix of theory and applications, emphasizing both the fundamental principles underlying device structure, operation and their applications in the photonics industry. At the end of the module, the student will be equipped with the basic physics of optical emission, modulation and photodetection, choice of semiconductors and their applications in solar cells, displays, sensors, lighting and in optical communications. Topics covered include basic photometry, radiometry and colorimetry; bandgap engineering in III-V compound semiconductors, tandem solar cells, HEMTs, LED, semiconductor laser device structures, operation and characteristics.

Syllabus (36 Hours)
1. Photometry, Radiometry and Colorimetry (9 Hours)

Optical flux characterisation of light sources and display devices. Flux, Intensity, Incidance, Sterance and Exitance. Luminous efficiency and luminous efficacy, SI units. Color theory – CIE coordinates. Additive colour mixing, Bit depth for display, Colour temperature, Colour rendition.

2. Optoelectronic Materials and Heterostuctures (9 Hours)

Bandgap engineering in III-V and II-VI compound semiconductors, Tetrahedral bonding, Lattice matching, Band-to-band radiative, Auger and band-to-impurity state transitions. Strain engineering and dislocations. Polarization and piezo electric in III-Nitrides. Tandem solar cells, Tunnel junction. HEMT, Epitaxial Film growth – Molecular Beam Epitaxy, Metalorganic vapour phase epitaxy.

3. LEDs and photodetectors (9 hrs)

LED applications in lighting, sensing, display, medical treatments and industry. LED power/light output characteristics with respect to current and temperature. Modulation characteristics. Spectral characteristics, LED device structure. LED packaging, LED lamps. Superluminescent LED and application in optical coherence tomography. P-n junction photodetector

4. Semiconductor Lasers (9 hours)

Semiconductor laser applications in optical communication, micromanufacturing, pollution detection and Laser safety. Fabry-Perot Laser: operation, Broad contact, Gain-guided and Index-guided structures. Beam profile and astigmatism. Distributed Feedback Laser: operation, Grating dimension. Tuneable single frequency laser with external grating and fiber Bragg grating. VCSEL structures, L/I and spectral characteristics, Eye diagram for assessing optical transmission quality. High power laser structure. Quantum Cascade Lasers: operation, light current and spectral characteristics, modulation response.

Assessment mode:
Continuous assessment: 5 to 6 Quizzes/homework. Each quiz/homework comprises from 5 to 10 numerical and descriptive questions. No final examination.

Course Title: EES 4502 Semiconductor Fabrication Process Technology
Course Lecturer: Gong Xiao

In the new information age, fabrication process technology continues to be employed in the manufacturing of ultrahigh density integrated circuits such as microprocessor devices in computers. This Course focuses on the major process technologies and basic building blocks used in the fabrication of integrated circuits and other microelectronic devices (e.g., solar cells). Understanding of fabrication processes is essential for undergraduate students who wish to develop their professional career in the microelectronics industry such as in wafer fabrication plants, foundries and design houses.

Course syllabus

1. Epitaxial growth technology with focus on metal-organic chemical vapour deposition
2. Thermal Oxidation for the formation of SiO_2 and understanding of the defects.
3. Dopant diffusion for introduction of dopant into the semiconductor.
4. Implantation and annealing techniques for introduction of dopant into the semiconductor with controlled depth, dose, defects engineering, etc.
5. Lithography technology to study how various patterns can be transferred from the mask to the wafer.
6. Plasma etching for forming patterns with desired angle, etch selectivity, etch rate, and etc.
7. Back end of line (BEOL) for the formation of interconnects to connect the transistors and the integration process flow for IC chips.

Assessment mode: Quiz, Simulation Projects and Final Exam.

Course Title: EES 4402 Radio Frequency Design and Systems
Course Lecturer: Zhang Jianwen

Synopsis and Learning Outcomes

This course begins with a review of mathematical preliminaries such as random processes and signal space concepts. It covers the design of modulation and demodulation schemes for digital communications over an additive white Gaussian noise channel. Emphasis will be placed on error rate performance for various digital signalling techniques and on error control coding techniques for reliable communications.

At the end of this Course the student will be able to:

1. Illustrate the main components in a digital RF communication system.
2. Model a basic digital communication system for channels with and without memory.
3. Evaluate the suitability of various signalling techniques for a given channel.
4. Construct and analyze error performance of error-correcting codes.

Syllabus

The course will cover the following topics (36 hours):

Introduction & Review of Mathematical Preliminaries (6 hours)
Introduction to digital communications, Examples of digital communication systems, Random variables, random process, autocorrelation, power spectral density, finite field etc.

Optimum Receiver Principle (5 hours)
Decision theory, optimum receiver for AWGN channel

Digital Modulation/Demodulation Techniques (6.5 hours)
Binary modulation, M-ary modulation, coherent detection, non-coherent detection, bit error rate performance

Signaling Over Bandlimited Channels (3.5 hours)
Intersymbol interference, correlative coding, equalizer
Block Codes & Important Classical Codes (6 hours)
Vector spaces, linear block codes, systematic encoding, ML decoding, BCH & Reed-Solomon codes.

Convolutional Codes (3.5 hours)
Transfer function matrix, state-diagram, augmented state diagram, trellis diagram, Viterbi algorithm

Performance Analysis of Channel Codes (3 hour)

Hard-decision decoding of block codes, soft-decision decoding of convolu-tional codes

Modern Codes (2.5 hours)
Parallel concatenated codes, turbo codes, LDPC codes

Simulation/Lab
Simulation of PSK modulation and block codes.

Lab Facilities Requirements

Adalm Pluto SDR Active Learning Course: 10 sets. No lab space is required.

Assessment mode: Quiz, Lab, Assignment, Final Exam.

Course Title: EES 4404 Renewable Generation and Smart Grid
Course Lecturer: Sahoo Sanjib Kumar

Through this course, students can learn about

- The basics of renewable energy and their power generation and grid technology;
- Master the basic working principle, characteristics and control methods of wind turbine and photovoltaic power generation;
- Understand the impact of renewable energy grid connection on power systems and master the basic principles of analysis and control methods for renewable energy power systems;
- Understand the importance of power electronics and smart grid technologies for renewable energy use.

In addition, it covers the following for the needing students:

- Modeling and control of power systems: bus admittance and bus impedance matrices, network building algorithms; Load flow studies: problem formulation, system stability issues;
- Fault analysis: symmetrical components, sequence impedance networks, symmetrical and unsymmetrical faults;
- Protection: components, relay coordination;

Teaching Mode and Schedule

There are lectures with tutorials. For the teaching class schedule, please refer to the class timetable for details.

Syllabus

1) Introduction (4 hours)
   Demand for electrical power; Environmental aspects of electrical energy generation;
2) Distributed Generation (12 hours)
   Distributed versus traditional power systems; Distributed generation technologies –solar thermal and solar PV, biofuels, fuel cell, hydroelectric generation, energy storage
3) Wind Energy (8 hours)
   Wind turbine types and characteristics, wind turbine generator and control, wind turbine performance and environmental impacts
4) System integration issues (6 hours)
   Overview of energy systems, secure reliable and economic operation, issues with renewable energy sources. Power quality and reliability in operation and planning
5) Economics of distributed generation (6 Hours)

Utility rate structure, energy economics, energy conservation, combined heat and power, integrated resource planning and demand side management

6) Power system control and stability (12 hours)
Load flow studies: problem formulation, system stability issues; symmetrical components, sequence impedance networks, symmetrical and unsymmetrical faults; protection components, relay coordination.

Assessment: Quiz, Project/Assignment, Final Examination.

Course Title: EES 4725 Digital Circuits and FPGA Design

Course Lecturer: Chua Dingjuan

Synopsis and Learning Outcomes

This course begins with a review of fundamental combinational and sequential logic concepts such as logic gates, k-maps, flip-flops and counters. It then introduces the modelling and design of these fundamental combinational and sequential building blocks in hardware description languages such as Verilog. Building upon the fundamentals, we will go on to explore more sophisticated functions such as adders, finite state machines, memory and the corresponding modelling and implementation of these functions on the FPGA. The final component of the course will be a project to build a complex digital system by expansion of designs using peripheral boards and devices.

At the end of this Course the student will be able to:

1. Model digital building blocks in Verilog using dataflow, behavioural and structural styles.
2. Implement digital building blocks on the FPGA
3. Design and implement finite state machines on the FPGA
4. Designing and implementing a complex digital system involving peripheral devices.

Syllabus

The course will cover the following topics (36 hours):

Review & Modelling of Combinational logic in Verilog (7 hours)

- Review of combinational logic blocks and logic manipulation (gates, kmap, Boolean algebra)
- Introduction of modelling combinational logic in Verilog using dataflow, behavioural and structural styles of modelling . Hands-on Lab for simulation and implementation of combinational logic

Review & Modelling of Sequential logic in Verilog (7 hours)

- Review of flip-flops, counters and shift registers
- Introduction of modelling of sequential logic in Verilog
- Hands-on Lab for modelling of combinational and sequential logic

Introduction & Modeling Finite State Machine (7 hours)

- Introduction to Finite State Machines
- Modeling of Finite State Machines in Verilog
- Hands-on implementation of Finite State Machines in Verilog

Introduction to Programmable Logic and FPGA Architecture (3 hours)

- FPGA logic blocks (LUTs, programmable registers, memory, I/O logic) and other blocks

Project (12 hours)

- Introduction to Project Scope and Deliverables
- Hands-on implementation of project

Lab

Design and implementation of combinational logic

Design and implementation of combinational and sequential logic

Design and implementation of finite state machine

Project

Lab Facilities Requirements

Each student requires

1 x Basys 3 Artix-7 FPGA Trainer Board

1 x Pmod OLEDrgb: 96 x 64 RGB OLED Display with 16-bit Color Resolution

Students with Windows OS laptops are required to install the Xilinx Vivado Design Suite and will be able to work directly with the FPGA development board. Students using Mac OS based laptops will not be able to install the Xilinx Vivado Design Suite and will require access to lab computers or other windows/linux based computers.

Assessment : Quiz, Lab Exercise, Lab Assignment, Lab Project.

Course Title: EES 4800 Introduction to Quantum Communication
Course Lecturer: Wang Chao

Pre-requisite

This module requires the basic knowledge on:

- Probability and statistics
- Linear algebra

Course Learning Outcomes

This module introduces the fundamental concepts of quantum communication technology. It aims to provide students with a basic understanding of quantum information processing, essential analytical skills for quantum communication devices, and insights into experimental realisations of practical quantum systems.

Specifically, the learning outcomes include:

- Understand the basic notions of quantum states, quantum operations, and quantum measurements.
- Understand the basic rules of quantum theory.
- Understand the no-signalling principle and how it can be used to design cryptographic protocols.
- Understand the basic notions of randomness and quantum randomness generation.
- Understand the basics of quantum secure communication.

Syllabus

- Bell non-locality and the power of quantum entanglement.
- Mathematical tools for quantum cryptography.
- Quantum secure communication.
- Experimental realisations of quantum secure communication.

Assessment mode: Homework, Quiz and Final Exam.