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Programs Offered

Bachelor of Science in Engineering Science
(Specialization in Electronics and Communications)

Master of Science in Computer and Engineering Science
(Specialization in Communications and Photonics or
Computer Hardware and Software Systems)

As defined in *Webster's Unabridged Dictionary*, "Engineering is the science by which the properties of matter and the sources of energy in nature are made useful to [humankind]." The study of engineering science, with focus in electronics and communications, deals with the processing of information and energy in electrical and magnetic forms involving conceptualization and formulation of the ideas, design to manufacturing to applications of many diverse electrical, electronic, and magnetic devices and systems.

The focus of the BSES curriculum is electronics and communication. The program has been designed to prepare students for an exciting career in designing and manufacturing of electronic systems, communications systems and networks, microprocessors and computers, microwave and lightwave communications, and, integrated circuits. The graduates of the proposed program will be well grounded in the rigorous scientific and theoretical foundations of the discipline. This will prepare them not only to have a successful career in industry in the region and beyond but also to enter and be successful in any advanced level graduate program of their choosing. The technical and liberal arts components of the curriculum provide the students with the opportunity for gaining self-development, technical competence, and awareness of economic and ethical responsibilities.

The MS-CES curriculum is designed to further the working skills and practical knowledge of engineers, computer scientists, and similar professionals. The firm base in mathematics, computer science, and physics is augmented with a selection of engineering course options, which prepares the students for tackling real-world problems. These options include such areas as advanced analog and digital electronics, embedded systems, communications, networking, and photonics.

Careers in Engineering Science

The BSES program has been designed to prepare students for an exciting career in industries or pursue graduate degrees. The graduates will find opportunities in the industries in the areas such as:

- designing and manufacturing of electronic systems,
- communications systems,
- networking,
- computer engineering,
- telecommunications,
- optical fiber communications,
- integrated circuits,
- research and development in the above areas, or,
- sales, marketing, and management in the areas above.

Some examples of the corresponding job titles are: electronics engineer, computer engineer, hardware designer, systems engineer, communications engineer, communications analyst, telecommunications engineer, network engineer, network analyst, sales engineer, applications engineer, and field engineer.

Graduate degrees can be pursued in any one of the many fields such as electronics, communications, networking, computer engineering, and computer science.

Bachelor of Science in Engineering Science
(Emphasis in Electronics and Communications)

Consistent with the mission of the University, the mission of the Bachelor of Science in Engineering Science program is "to prepare students to be learned men and women who are capable of pursuing fulfilling careers in a changing world," and, "to fulfill the undergraduate technical education needs of the community, business, and industry of the North Bay region." A broader mission is to enable graduating engineers to acquire knowledge and experiences to prepare them to pursue lifelong learning, advanced study, and leadership roles in business and community.

The B.S. in engineering science at Sonoma State University is a focused and innovative program in which the curriculum has been designed to provide students with a basic education in engineering science based on a strong foundation of liberal arts.

The curriculum includes (1) 51 units of General Education courses; (2) a 41-unit core in mathematics, computer science, and basic sci-

ences (9 units overlap with GE units); (3) a 41-unit core in engineering sciences which includes electrical, computer, electronics, and communications engineering subjects such as circuits, analog/digital electronics, electromagnetic fields, microprocessors, analog and digital communications, and networking; and (4) 6 units of engineering science electives which provides senior-level choices for more depth in students' areas of interest. Theoretical and practical learning experiences are an important part of all course work. The senior year also gives students the opportunity to consolidate their educational experience with a capstone design project. The curriculum develops students' abilities to formulate problems, analyze alternatives, make decisions, and solve problems. Internship and co-op experiences will be encouraged to provide the students a real-world experience and enhance students' communication and interpersonal skills.

Program Educational Objectives

- Educate and prepare students to be successful in the profession of electrical engineering, particularly in the fields of electronics and communications.

- Educate students to successfully pursue graduate degrees.

- Provide a strong foundation to the students for lifelong learning and being responsible citizens.

Program Outcomes

The students will attain:

a. an ability to apply knowledge of mathematics, science, and engineering.

b. an ability to design and conduct experiments, as well as to analyze and interpret data.

c. an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.

d. an ability to function on multidisciplinary teams.

e. an ability to identify, formulate, and solve engineering problems.

f. an understanding of professional and ethical responsibility.

g. an ability to communicate effectively.

h. the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.

i. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practices.

Degree Requirements	Units
GE courses	51
Major requirement	41
Support courses (Basic Sciences, Computer Science, and Mathematics*)	41
Technical Electives	6
*9 units may overlap with GE units	
Total units needed for graduation	**130**

Engineering Science

ES 110: Introduction to Engineering & Lab Experience	1
ES 210: Digital Circuit & Logic Design	3+1
ES 220: Electric Circuits	3
ES 221: Electric Circuits Laboratory	1
ES 230: Electronics I	3
ES 231: Electronics I Lab	1
ES 310: Microprocessors & System Design	3+1
ES 330: Electronics II	2+1
ES 400: Linear Systems Theory	3
ES 440: Analog & Digital Communications I	2+1
ES 441: Analog & Digital Communications II	2+1
ES 443: Introduction to Optical Fiber Communication	3
ES 465: Introduction to Networking	2+1
ES 430: Electromagnetic Theory & Applications	3
Approved Technical Elective I	3
Approved Technical Elective II	3
ES 493: Senior Design Project	3
Subtotal	**47**

Current List of Technical Electives

PHYS 413: Microprocessor Applications (3)
PHYS 413L: Microprocessor Applications Laboratory (1)
ES 480: Artificial Intelligence (3)
ES 432: Physical Electronics (3)
ES 445: Photonics (3)

Computer Science

CS 110: Introduction to UNIX	1
CS 115: Programming I	4
CS 215: Programming II	3
CS 315: Data Structures	3
Subtotal	**11**

Physics

PHYS 114: Introduction to Physics I	4
PHYS 214: Introduction to Physics II	4
Subtotal	**8**

Mathematics

MATH 142: Discrete Structures I	3
MATH 161: Calculus I	4
MATH 211: Calculus II	4
MATH 241: Calculus III	4
MATH 261: Calculus IV	4
MATH 345: Probability Theory	3
Subtotal	**22**

General Education
(excluding Math, Physics, and CS courses)

ENGL 101: Expository Writing & Analytical Reading	3
Remaining GE courses	39
Subtotal	**42**

Sample Four-year Program for Bachelor of Science in Engineering Science

SEMESTER 1:: 16 Units

ES 110: Introduction to Engineering & Lab Experience	1
CS 110: Introduction to UNIX	1
CS 115: Programming I	4
MATH 142: Discrete Structures I	3
MATH 161: Calculus 1	4
ENGL 101: Expository Writing & Analytical Reading	3

SEMESTER 2:: 17 Units

PHYS 114: Introduction to Physics I	4
CS 215: Programming II	3
MATH 211: Calculus II	4
GE	6

SEMESTER 3:: 18 Units

PHYS 214: Introduction to Physics II	4
MATH 241: Calculus III	4
MATH 261: Calculus IV	4
GE	6

SEMESTER 4:: 18 Units

ES 220: Electric Circuits	3
ES 221: Electric Circuits Laboratory	1
ES 210: Digital Circuits & Logic Design (w/lab)	3+1
ES 230: Electronic I	3
ES 231: Electronics I Laboratory	1
GE	6

SEMESTER 5:: 16 Units

ES 310: Microprocessors & System Design (w/lab)	3+1
ES 440: Analog & Digital Communications I (w/lab)	2+1
ES 330: Electronics II (w/lab)	2+1
MATH 345: Probability Theory	3
ES 400: Linear Systems Theory	3

SEMESTER 6:: 15 Units

ES 441: Analog & Digital Communications II(w/lab)	2+1
ES 430: Electromagnetic Theory & Applications	3
CS 315: Data Structures	3
GE	6

SEMESTER 7:: 15 Units

ES 443: Introduction to Optical Fiber Communications	3
Approved Technical Elective I	3
ES 465: Introduction to Networking (w/lab)	2+1
GE	6

SEMESTER 8:: 15 Units

ES 493: Senior Design Project	3
Approved Technical Elective II	3
GE	9

TOTAL UNITS:: 130

Master of Science in Computer and Engineering Science

(Specialization in Communications and Photonics or Computer Hardware and Software Systems)

The Master of Science degree in Computer and Engineering Science (MS-CES) at Sonoma State University is a multidisciplinary degree built on a strong foundation of physics, mathematics, computer science, and/or electrical sciences. Specifically, this program emphasizes the application of these fields to the design, analysis, and synthesis of engineering problem solutions. The MS-CES faculty is composed of professors from Sonoma State University whose interests traverse the fields of science and engineering, as well as professionals from the local community who have cutting-edge expertise in the various engineering disciplines of interest and are qualified to be adjunct faculty at SSU.

A linkage with local industry in the form of an Industry Advisory Board (IAB) is an integral part of the program. Such an advisory board is critical to ensure the program meets local community needs. The IAB provides the program with valuable input regarding the new scientific and technological developments and educational needs of the industry. It also facilitates internship opportunities for students, joint student research/project development and supervision, faculty-scientists/engineers joint project opportunities, and equipment and financial support from the industries. Through this linkage of academic learning and practical application, students obtain a solid education indispensable for working in a professional environment. The MS-CES is a self-supported program that is underwritten by local industry as well as student tuition revenue. Therefore, as of this writing, tuition fee for this program is $500 per unit for all students, resident and non-resident. The MS-CES is a 30-33 unit program, not including any prerequisite work.

Admission to the Program
For admission, the applicant must have:

1. A baccalaureate degree in a scientific or technical discipline from a U.S. institution accredited by an appropriate accreditation body, or an equivalent baccalaureate degree from a foreign institution of high reputation.

2. Attained grade point average of at least 3.0 (A=4.00) in the last 60 semester (90 quarter) units attempted.

3. Earned a minimum score of 550 on the Test of English as a Foreign Language. This requirement applies only to applicants who have not spent at least three years of school at the secondary level (or beyond) where English is the principal language of instruction.

4. Demonstrated competency in writing by one of the Written English Proficiency Test criteria for MS-CES students given below. Generally, this requirement must be met before entering the program. One of the criteria is demonstrating competency in writing through an essay. Therefore, if this

requirement is to be met by writing an essay, it should be submitted with the application for admission.

5. Completed the following SSU courses or equivalent at the undergraduate level with a GPA of 3.0 or higher:

   - 3 semesters of Calculus (MATH 161, 211, 241).
   - 2 semesters of Calculus-based Physics (PHYS 114 and 214).
   - 1 semester of Probability Theory (MATH 345).
   - 1 semester of Analog and Digital Electronics (ES 230 and 231).
   - 2 semesters of Programming in an approved high-level Procedural Language (CS 115 and 215).
   - 1 semester of Data Structures (CS 315).
   - 2 semesters of Digital Systems Design (ES 210 and 310).

In addition, it is highly desirable, though not required, that students have knowledge of operating systems (CS 450).

Note: When possible, the program offers compressed courses, such as CES 490, which cover the basic concepts of data structures, assembly language programming, and digital systems design. Students can take these courses, when offered, to satisfy the prerequisite requirements.

Conditional Admission
The applicants whose GPA is less than 3.0 but greater than 2.5, or who lack not more than 18 units of prerequisite work (generally, 6 courses), may be accepted conditionally and must complete a program of study specified by the graduate coordinator at the time of admission before being given full admission.

Written English Proficiency Test Requirement
All students are required to demonstrate competency in written English. A student can satisfy the Written English Proficience Test (WEPT) requirement by meeting any one of the following five criteria:

1. A student who has obtained his/her bachelor's degree from a CSU institution will be deemed to have satisfied WEPT requirement.

2. A student who has obtained a bachelor's degree and a master's degree from an accredited institution(s) with English as the medium of instruction for both the degree programs will be deemed to have satisfied WEPT requirement.

3. A student who scores at least 3.5 in the analytical writing portion of the GRE test will be deemed to have satisfied the WEPT requirement.

4. A student who takes and passes the campus WEPT test.

5. A student who writes and submits an article of at least 500 words in length to demonstrate his/her writing proficiency in English. It will be evaluated by the MS-CES curriculum

committee for (i) competent analysis of complex ideas, (ii) development and support of main points with relevant reasons and/or examples, (iii) organization of ideas, (iv) ease in conveying meaning with reasonable clarity, and, (v) demonstration of satisfactory control of sentence structure and language (including spelling, punctuation, and proper use of grammar). If accepted by the curriculum committee, the student will be deemed to have satisfied the WEPT requirement.

Internship Opportunities and Financial aid
The industries in the region provide opportunities to students to work as interns on-site and enrich their academic experience at SSU with valuable hands-on practical experience. Students are also eligible to apply for financial aid in the form of low interest loans through the SSU Financial Aid Office and for part-time employment on campus as student assistants.

Program of Study
The program offers two tracks or areas of specialization:

- Track 1: Communications & Photonics - This area of specialization provides students with the expertise in the areas of (i) analog and digital electronics, (ii) semiconductor and photonics components and devices, (iii) communications techniques (wireless, wireline, and optical fiber media), (iv) local and wide area networking, and (v) broadband access technology.

- Track 2: Computer Hardware & Software Systems - This area of specialization is intended to deepen students' ability to analyze and design computer systems. This specialization includes topics such as embedded systems, digital data compression, software engineering, and computer networks.

A student chooses one of the two tracks at the time of admission but can change it in the midstream. However, that may mean taking additional courses to meet the requirements of the new track. A student's program of study consists of the following four components: a common core, a track core, culminating experience, and technical electives. Details of these components are as follows.

Common Core
All students in the program must take three core courses (9 units). These courses are designed to give students the fundamentals necessary to master advanced-level academic work. These core courses are:

- CES 400: Linear Systems Theory
- CES 440: Data Communications
- CES 432: Physics of Semiconductor devices or CES 530: Analog and Digital Microelectronics

If any of the above core courses were part of a student's undergraduate program, the student must take a 500-level course in its place approved by the student's faculty advisor. Furthermore, only two 400-level courses can be used to satisfy degree requirements. A petition must be filed with the department for any exceptions.

Track Core

A student must take 12 units of courses from the list of courses for the chosen track. The lists of courses for each track, which will be revised periodically, are given below.

Communications and Photonics Track Courses

- CES 430: Photonics
- CES 500: Queuing and Transform Theory
- CES 532: Advanced Semiconductor and Photonics Devices
- CES 540: Digital Data Transmission
- CES 542: Digital Signal Processing
- CES 543: Optical Fiber Communications
- CES 544: Wireless Communications
- CES 546: Data Compression
- CES 547: Digital Switching: Techniques and Architectures
- CES 550: Integrated Digital Networks
- CES 552: Network Architecture and Protocols
- CES 554: Broadband Access Technology
- CES 558: Multicasting on the Internet
- CES 590: Selected Topics in Communications and Photonics

Computer Hardware and Software Systems

- CES 500: Queuing and Transform Theory
- CES 510: Intelligent Systems Design
- CES 512: Theory of Software Systems
- CES 514: Data Mining
- CES 516: High Performance Computing
- CES 520: Embedded Systems
- CES 522: VLSI Design
- CES 524: Advanced Computer Architecture
- CES 530: Analog and Digital Microelectronics
- CES 546: Data Compression
- CES 592: Selected Topics in Hardware and Software Systems

The courses are selected with the approval of the student's faculty advisor to ensure they form a cohesive plan of study in the desired subject area.

Culminating Experience Through Thesis/Design Project/Lab and Technical Report Experience

All students are required to complete a culminating experience which may take one of the following three forms:

- Research and Thesis (Plan A).
- Design Project (Plan B).
- Lab and Technical Report Experience (Plan C).

A supervisory committee is appointed for the students who choose Plan A or Plan B. A supervisory committee consists of three faculty members. One of the three members can be an adjunct faculty. A student interested in choosing Plan A or Plan B chooses a faculty member to be his/her thesis/project supervisor. The faculty supervisor becomes chairman of his/her supervisory committee. In consultation with the faculty supervisor, two other members of the committee are selected. For a student choosing Plan C, an advisor is appointed by the Program Director to guide the student through this plan.

Under Plan A, a student chooses to do thesis research and write a thesis under the guidance of his/her faculty supervisor and his/her supervisory committee.

Under Plan B, a student chooses to prepare a design project focused on the design of devices, instruments, or systems. As in the case of Plan A, the project is mentored by the student's faculty supervisor and his/her supervisory committee.

Upon approval by the student's supervisory committee, the thesis research or design project may be carried out at the student's company's site (if the student is working) under the supervision of an approved senior scientist/engineer of the company. However, a SSU faculty supervisor must oversee the research/project and regularly examine the student's progress. While not a requirement for graduation, it is expected that the results of the research/project will be presented in an appropriate technical conference and/or published in a relevant professional journal.

Plan C, Lab and Technical Report Experience (LTR Experience), provides students with the opportunity for taking more courses to develop a deeper knowledge in their areas of interest instead of carrying out research or design projects, gives extensive exposure of the state-of-the art equipment in various laboratories, and develops technical report writing skills.

Technical Electives

A student must take 3 to 9 units of technical electives approved by his/her faculty advisor depending upon the culminating experience plan chosen as given below:

Plan A	(Thesis, 30 units)
Common Core	9 units
Track Core	12 units
Electives	3 units
Thesis	6 units

Plan B	*(Project, 30 units)*
Common Core	9 units
Track Core	12 units
Electives	6 units
Design Project	3 units

Plan C	*(LTR Experience, 33 units)*
Common Core	9 units
Track Core	12 units
Electives	9 units
CES 593	3 units

The purpose of technical elective courses is to provide a student with greater depth and/or breadth in his/her area(s) of interest. A technical elective course can be from any of the two lists of the track courses and must be at 500-level.

Learning Objectives

The students of this program will acquire:

1. knowledge in multiple interrelated disciplines;

2. ability to model and analyze scientific and engineering problems;

3. knowledge of the theory of high performance computing, communications and/or networking,

4. critical thinking ability and the learning of analytical and simulation tools to do system performance evaluation;

5. ability to apply theory to design and implement efficient computing and/or communications systems;

6. ability to integrate knowledge from multiple interrelated disciplines to formulate, design, and/or implement interdisciplinary projects;

7. ability to investigate and formulate research problems and/or design projects;

8. ability to learn and research independently;

8. written and oral communication skills.

A student's plan of study is designed such that all the nine learning objectives above are covered by the courses selected.

Laboratories

The program has the following eight state-of-the art laboratories in various areas of interest located in the Cerent Engineering Sciences Complex in Salazar Hall.

- AFC Access Technologies Laboratory.

- Agilent Technologies Communications Laboratory.

- Rolf Illsley Photonics Laboratory.

- William Keck Microanalysis Laboratory.

- Networking Laboratory.

- Human-Computer Interaction Laboratory.

- Software Engineering Laboratory.

- Electronics Laboratory.

These labs provide excellent facilities to our students and faculty for hands-on experience, research, project development, implementation, and testing. Many of these labs are sponsored by the high-tech industries in the North Bay region of the San Francisco area.

Engineering Science Courses (ES)

110 INTRODUCTION TO ENGINEERING AND LABORATORY EXPERIENCE (1)
Lecture, 0.5 hr.; laboratory, 1.5 hrs. This course is designed to introduce principles of engineering to students and expose them to the electronics and computer lab environment. Students are given the opportunity to design and build simple analog and digital circuits and make measurements using various types of lab equipment.

210 DIGITAL CIRCUIT AND LOGIC DESIGN (4)
Lecture, 3 hrs.; laboratory, 3 hrs. Logic gates; combinatorial logic and analysis and design of combinatorial circuits; electronic circuits for various logic gates. Flip-flops, registers, and counters; sequential circuits and state machines. Various logic families and comparison of their electrical characteristics such as fan-out, rise and fall times, delay, etc. Concepts of machine, assembly, and high-level languages and relationship between them; basic principles of computer design. Laboratory work will include designing, building, and testing of digital circuits, logic, and sequential circuits. Prerequisite: MATH 142, Co-requisite: ES 230; or consent of instructor.

220 ELECTRIC CIRCUITS (3)
Lecture, 3 hrs.; laboratory, 0 hrs. Review of Kirchhoff's laws, circuit design, node and mesh analysis, etc.; Thevenin's theorem, Norton's theorem, steady state and transient analysis, transfer function. AC power and three-phase circuits, Y-Delta equivalents. Multi-port networks, two-port networks with energy storage, ideal transformers. Amplifiers and frequency response, filters. Prerequisites: MATH 211 and PHYS 214; or consent of instructor.

221 ELECTRIC CIRCUITS LABORATORY (1)
Lecture 0 hrs.; laboratory, 3 hrs. Laboratory work on material treated in ES 220 emphasizing elementary design principles.

230 ELECTRONICS I (3)
Lecture, 3 hrs.; laboratory, 0 hrs. This course is an introduction to electronics covering the basics of analog and digital electronics. Review of Kirchoff's laws, Thevenin's and Norton's theorems. Electronic circuits modeling and analysis, diodes, transistors, filters, operational amplifiers, single and multi-stage amplifiers; analysis and design of combinational and sequential digital circuits. Prerequisite: ES 220 and ES 221 or PHYS 214 and PHYS 216 or consent of the instructor. Must be taken concurrently with ES 231/PHYS 231. (Cross-listed with PHYS 230).

231 ELECTRONICS I LABORATORY (1)
Laboratory, 3 hrs. Laboratory work to accompany ES 230/PHYS 230. Computer-assisted design of analog and digital circuits. Diodes, filters, transistors, oscillator, amplifiers, analog-to-digital and digital-to-analog conversion, combinational and sequential logic, programmable logic devices. Prerequisite: same as ES 230/PHYS 230. Must be taken concurrently with ES 230/PHYS 230. (Cross-listed with PHYS 231).

310 Microprocessors and System Design (4)

Lecture, 3 hrs.; laboratory, 3 hrs. Hardware architecture of a microprocessor and its programming and instruction design; memory hierarchy and I/O interfaces; comparison of various microprocessor architectures and capabilities; system design using microprocessors. Laboratory work. Prerequisites: ES 210 and ES 230; or consent of instructor.

330 Electronics II (3)

Lecture, 2 hrs.; laboratory, 3 hrs. Analysis and design of high frequency amplifiers; high frequency models of transistors; operational amplifiers and applications; feedback amplifiers; oscillators, modulators, bandpass amplifiers, and demodulators for communications. Laboratory work. Prerequisite: ES 230 or consent of instructor.

400 Linear Systems Theory (3)

Lecture, 3 hrs. Correlation, convolution, Fourier, Laplace and z-transform, difference equations, fast Fourier transforms, and state variable theory. Prerequisite: One semester of differential equations (such as MATH 241) or consent of instructor. (Cross-listed with MATH 430).

430 Electromagnetic Theory & Applications (3)

Lecture, 3 hrs. Electrostatics; magnetostatics; electric currents; electromagnetic induction; electric and magnetic fields in matter; Maxwell's equations; retarded potentials; radiation reaction; light emission; simple scattering and antenna theory; properties of waveguides; relativistic formulation of electrodynamics; Fourier decomposition of fields. Prerequisites: PHYS 214, PHYS 325 or Math 241.

432 Physical Electronics (3)

Lecture, 3 hrs. Semiconductor materials, crystal structure and growth; energy bands and charge carriers, conductivity and mobility; metal-semiconductor and p-n junctions; p-n junction diodes, bipolar junction transistors, field-effect transistors, CCD's, photonic devices, and integrated circuits. Projects in photolithography; conductivity and contact resistance measurements; I-V and C-V characteristics of diodes; characterization of transistors may be assigned. Prerequisite: PHSY 314 or consent of instructor.

440 Analog & Digital Communications I (3)

Lecture, 2 hrs.; laboratory, 3 hrs. Mathematical modeling of signals; time and frequency domain concepts; spectral density; components of a communications system; analog signal transmission. AM, FM and PM modulation and demodulation techniques; noise and bandwidth; link analysis. Laboratory work. Prerequisite: ES 230; Corequisite: ES 400; or consent of instructor.

441 Analog & Digital Communications II (3)

Lecture, 2 hrs.; laboratory, 3 hrs. Digital signals and their transmission; PCM, log-PCM, ADPCM, and DM and other low bit rate coders. Digital data transmission; data encoding; clock recovery and BER; data modulation techniques; ASK, FSK, PSK, and QAM. Link budgets for satellite, cellular, and cable systems; the effects of noise and bandwidth. Laboratory work. Prerequisite: ES 440 or consent of the instructor.

443 Introduction to Optical Fiber Communications (3)

Lecture: 3 hrs; laboratory: 0 hrs. Principles of light wave propagation, and propagation in an optical fiber; fiber characteristics; O/E and E/O conversions; coupling; WDM; modulation techniques for efficient information transmission; system design. Prerequisite: ES 441 or consent of the instructor.

445 Photonics (3)

Lecture, 3 hrs. Gaussian beams; guided-wave optics; fiber optics; optical resonators; resonant cavities; laser oscillation and amplification; laser excitation; optical pumping; solid state, gas, dye, chemical, excimer and free electron lasers; semiconductor lasers; laser spectroscopy; fiber optic communication; photomultiplier and semiconductor radiation detectors including photoconductors, junction photodiodes; p-I-in diodes, avalanche photodiodes; detector noise. Prerequisite: PHYS 314 or consent of instructor.

465 Data Communications (3)

Lecture, 2 hours; laboratory, 3 hours. The ISO reference model, theoretical basis for data communications, data transmission theory and practice, telephone systems, protocols, networks, Internetworks, with examples. Prerequisites: CS 351 and MATH 345, or consent of instructor.

480 Artificial Intelligence (3)

A survey of techniques that simulate human intelligence. Topics may include: pattern recognition, general problem solving, adversarial game-tree search, decision-making, expert systems, neural networks, fuzzy logic, and genetic algorithms. Prerequisite: CS 315 or consent of instructor.

493 Senior Design Project (3)

This is a capstone course. A major project designed to bring the knowledge gained from various courses together to analyze, design, and implement an electronic ad/or communications system in an efficient and economic manner. Prerequisite: consent of the instructor.

Master of Computer and Engineering Science Courses (CES)

400 Linear Systems Theory (3)

Lecture, 3 hrs. Analysis of linear time-invariant systems; correlation; convolution; impulse response; complex variables; Fourier series and transform; sampling; filtering; modulation; stability and causality; feedback and control systems; Laplace and Z-transform; fast Fourier transforms. Prerequisite: MATH 241 or consent of instructor.

430 Photonics (3)

Lecture, 3 hrs. Lasers, diode lasers, and LEDs; fiber optics; optical radiation detectors. Prerequisites: A course in modern Physics (such as PHYS 314) and electromagnetism (such as PHYS 430).

432 Physics of Semiconductor Devices (3)

Lecture, 3 hrs. Semiconductor materials, crystal structure, and growth; energy bands and charge carriers; conductivity and mobility; metal-semiconductor and p-n junctions; p-n junction diodes; bipolar junction transistors; field-effect transistors; CCD's; photonic devices; and integrated circuits. Projects in photolithography; conductivity and contact resistance measurements; I-V and C-V characteristics of diodes; characterization of transistors may be assigned. Prerequisite: PHYS 314 or consent of instructor.

440 Data Communications (3)

Lecture, 2 hrs.; laboratory, 3 hrs. The ISO reference model; theoretical basis for data communications; data transmission theory and practice; telephone systems; protocols; networks; internetworks with examples. Prerequisites: CS 215, MATH 345 and PHYS 214 and 216, or consent of instructor.

490 Selected Topics in CES (1-3)

Special topics to introduce new emerging fields, provide foundation for advanced graduate level courses, or augment other courses in computer and engineering science. Prerequisite: consent of instructor.

494 Directed Readings (1-3)

Independent study under a faculty. The proposal must be approved by the graduate advisor if the course is to apply toward degree requirements. Prerequisite: consent of instructor.

500 Queuing and Transform Theory (3)

Lecture, 3 hrs. Review of probability theory, fundamentals of transform theory, Fourier and Z-transforms. Markovian and discrete time queuing systems, single and multi-server queues, queuing networks and their applications. The course may require significant lab and/or project activity. Prerequisites: MATH 345 and 261 or consent of instructor.

510 INTELLIGENT SYSTEMS DESIGN (3)

Lecture, 3 hours. Introduction to adaptive systems: neural networks, genetic algorithms (GAs), fuzzy logic, simulated annealing, tabu search, etc. Specific topics include perceptions, backpropagation, Hopfield nets, neural network theory, simple GAs, parallel GAs, cellular GAs, schema theory, mathematical models of simple GAs, and using GAs to evolve neural networks. Prerequisites: CS 315 and CES 400, or consent of instructor.

512 THEORY OF SOFTWARE SYSTEMS (3)

Lecture, 3 hrs. Review of data structures and basic algorithms for sorting and string processing. Basics of logic, formal systems, grammars, and automata. Applications to some of the following areas: design of language processing tools (editor, translator etc.), software specification, testing and verification, non-numerical problem solving. The course may require significant lab and/or project activity. Prerequisite: CS 315 or consent of instructor.

514 DATA MINING (3)

Lecture, 3 hrs. Introduction to data models, data warehousing, association-rule mining, searching the Web, Web Mining: Clustering. AI techniques (neural networks, decision trees), applications, and case studies. The course may require significant lab and/or project activity. Prerequisite: CS 315 or consent of instructor.

516 HIGH-PERFORMANCE COMPUTING (3)

Lecture, 3 hrs. Algorithmic tools and techniques for problems hard to solve on a standard uniprocessor model, such as problems involving large data sets or real-time constraints; development of computational models to analyze the requirements and solutions and special hardware-based solutions; case studies to illustrate the developed models, tools, and techniques. The course may require significant lab and/or project activity. Prerequisite: CS315 or consent of instructor.

520 EMBEDDED SYSTEMS (3)

Lecture, 3 hrs. Three major topics covered in this course are: controlling specialized I/O devices with particular attention to bit patterns and priority interrupts; waveshapes and measurement tools, both hardware and software; and real-time operating systems. Prerequisites: ES 230-231 and CS 351, or consent of instructor.

522 VLSI DESIGN (3)

Lecture, 3 hrs. IC technology review; hardware description languages and describing hardware using one of the languages, modern VLSI design flow; circuit partitioning; clustering. Floorplanning; placement; global routing; area-efficient design; area-time tradeoffs. The course may require significant lab and/or project activity. Prerequisite: CES 530 or consent of instructor.

524 ADVANCED COMPUTER ARCHITECTURE (3)

Lecture, 3 hrs. Concept of advanced computing architectures, pipelining; multiprocessing and multiprogramming, single and multi-stage interconnection networks, applications/algorithms for parallel computers; local and system bus architectures; CPU and computer system performance analysis. The course may require significant lab and/or project activity. Prerequisites: CS 351 and CS 450, or consent of instructor.

530 ANALOG AND DIGITAL MICROELECTRONICS (3)

Lecture, 3 hrs. Introduction to analog/digital integrated circuits; bipolar and MOS transistor models; analysis and design of monolithic operational amplifiers; frequency response; non-linear circuits and CMOS, and Bipolar Logic Circuits. The course requires lab and/or project activity. Prerequisites: ES 230-231 and CES 432, or consent of instructor.

532 ADVANCED PHOTONICS DEVICES (3)

Lecture, 3 hrs. Optical resonators, interaction of photons with materials, LEDs, laser diodes, optical amplifiers, optical noise, photoconductors, electro-optic modulators, photonic switches, nonlinear optical materials, and devices. The course requires lab and/or project activity. Prerequisite: CES 430 or equivalent.

540 DIGITAL DATA TRANSMISSION (3)

Characteristics of base-band and bandpass channels, optimum signaling sets, and receivers for digital communications; effect of noise and intersymbol interference on probability of error; channel capacity; introduction to phase-locked loop analysis for timing and carrier synchronization. Prerequisites: CES 400 and 440, or consent of instructor.

542 DIGITAL SIGNAL PROCESSING (3)

Lecture, 3 hrs. Time/frequency analysis of discrete-time signals and systems. Fast implementations of the DFT and its relatives. IIR and FIR digital filter design, implementation, and quantization error analysis. Decimation, interpolation, and multirate processing. Prerequisite: CES 400 or consent of instructor.

543 OPTICAL FIBER COMMUNICATIONS (3)

Lecture, 3 hrs. Lightwave fundamentals; optical fiber as transmission media; losses and bandwidth; fiber cables. Optical sources, detectors. Optical components such as switches, access couplers, wavelength multiplexers and demultiplexers. Analog and digital transmission techniques; line coding techniques; optic heterodyne receivers; thermal and shot noise; bit error rates; optical transmission system design. Optical T-carrier systems and SONET; future directions. The course may require significant lab and/or project activity. Prerequisites: ES 230-231 and CES 440 or consent of instructor.

544 WIRELESS COMMUNICATIONS (3)

Lecture, 3 hrs. Introduction to mobile/wireless communication systems; cellular communication; data transmission and signaling; noise and interference; analog and digital techniques; multiple-access architecture. The course requires lab and/or project activity. Prerequisites: ES 230-231 and CES 440, or consent of instructor.

546 DATA COMPRESSION (3)

Lecture, 3 hrs. Information theory, models, lossless compression (statistical, dictionary, static, dynamic, huffman, arithmetic, context-modeling), lossy compression (scalar quantization, vector quantization, differential encoding, subband, transform, predictive), compression standards (JPEG, MPEG). Prerequisites: MATH 345 and CS 315, or consent of instructor.

547 DIGITAL SWITCHING: TECHNIQUES AND ARCHITECTURES (3)

Lecture, 3 hrs. Review of switching techniques; synchronous and asynchronous transfer modes (i.e., STM and ATM); various switch architectures. Multi-rate and multipoint-to-multipoint switching; ATM switching, signaling and call set-up; ATM switch-architectures and their performance evaluation; multicasting techniques. VLSI implementation considerations, future directions. The course may require significant lab and/or project activity. Prerequisites: MATH 345, ES 230-231, and CES 440, or consent of instructor.

550 INTEGRATED DIGITAL NETWORKS (3)

Lecture, 3 hrs. Information types and signals; definitions of services and integration; narrowband ISDN and frame relay protocols; broadband ISDN concept and protocol. Integrated environment and ATM; principles of SONET and ATM transmission; broadband ATM networking; future trends. The course may require significant lab and/or project activity. Prerequisite: CES 440 or consent of instructor.

552 NETWORK ARCHITECTURE AND PROTOCOLS (3)

Lecture, 3 hrs. ISO model, review of the physical and data link layers, network layer, and routing including for Internet; multicast routing; TCP and UDP protocols and their characteristics, performance and limitations; TCP/IP stack; applications such as FTP, e-mail, and DNS, voice over IP. The course may require significant lab and/or project activity. Prerequisite: CES 440 or consent of instructor.

554 Broadband Access Technology (3)

Lecture, 3 hrs. Review of ISDN and B-ISDN Protocols; digital subscriber loops; digital modems. The xDSL technology; xDSL family of protocols; ADSL standardization, its architecture, operation, implementation, and management; ATM; TCP/IP; Ethernet transmissions using ADSL; optical access. The course may require significant lab and/or project activity. Prerequisite: CES 440 or consent of instructor.

558 Multicasting on the Internet (3)

Lecture, 3 hrs. Multicasting fundamentals; multicast routing algorithms; IP multicast; architecture and operation of MOSPF, PIM, CBT, OCBT, HDVMRP, HPIM, BGMP; and Mbone protocols. Real-time Transport protocol and scalable reliable multicast, reliable multicast transport protocols. Multicasting in ATM networks; IP multicast over ATM; future directions. The course may require significant lab and/or project activity. Prerequisite: CES 552 or consent of instructor.

590 Selected Topics in Communications and Photonics (3)

Special topics to augment regularly scheduled graduate courses in communications and photonics will be presented. Prerequisites depend on subject material.

592 Selected Topics in Hardware and Software Systems (3)

Special topics to augment regularly scheduled graduate courses in hardware and software systems will be presented. Prerequisites depend on subject material.

593 Lab and Technical Report Experience (3)

Lecture, 1 hr.; laboratory, 6 hrs. In this course, students will learn to operate state-of-the art equipment in at least 6 laboratories, perform experiments, and write lab reports. In addition, students will write a technical report on a state-of-the art topic within the scope of the master's program of at least 3000 words excluding figures and tables. (The course cannot be taken to meet 30-unit requirement under thesis or project option unless approved by the Program Director.) Prerequisite: Permission of student's advisor.

594 Directed Readings (1-3)

Independent study under a faculty member. The proposal must be approved by the graduate advisor if it is to apply toward degree requirements. Prerequisite: consent of instructor.

595 Design Project (1-3)

The project plan, timetable, necessary resources, and expected outcome must be approved by a faculty project advisor and the program advisor at least one semester before taking the course. Prerequisite: Admission of candidacy for the Master's degree and approval of the faculty advisor.

596 Project Continuation (1-3)

Designed for students working on their thesis or design project but who have otherwise completed all graduate course work toward their degree. This course cannot be applied toward the minimum number of units needed for completion of the master's degree. Prerequisite: consent of faculty thesis/project advisor.

597 Graduate Seminar (1)

Series of lectures presented by experts from academia and industries.

598 Comprehensive Examination (1)

In this four-hour examination the students' overall understanding of important concepts of the core courses and the main subjects of each track will be tested. Prerequisites: Advancement to candidacy for the Master's degree and approval of the graduate advisor.

599 Research and Thesis (1-6)

Prerequisites: Admission of candidacy for the Master's degree and approval of the thesis advisor.