ELECTRICAL AND COMPUTER ENGINEERING (ECE)

100 Level Courses

ECE 101: *Introduction to Electrical and Computer Engineering.* 3 credits.
Introduces fundamental concepts in Electrical and Computer engineering and provides insight to the various careers in each field. Both theory and practical applications of electronic components are covered through examples of real world applications. Topics are reinforced through hands-on laboratory experiments. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (((minimum score of 13 in 'Math Placement Algebra I', minimum score of 07 in 'Math Placement Algebra II' and minimum score of 07 in 'Math Placement Transcendentals') or minimum score of 65 in 'Math Placement Aleks') or (MATH 105[C], 105[XS], 113[*C], 113[XS], 115[*C], 115[XS], 123[*C] or 123[XS])).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

200 Level Courses

ECE 201: *Introduction to Signals and Systems.* 3 credits.
Provides an introduction to key concepts for the description and analysis of signals and systems with an emphasis on discrete-time signals and systems. Specific topics include sinusoidal and complex exponential signals, sampling, spectrum representation of signals via DTFT and DFT, system properties, convolution, impulse response and frequency response. The associated computer lab provides opportunities to apply concepts to physical reality. Note: Students must register for both lecture and lab. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Specialized Designation: Mason Impact.

Registration Restrictions:
Required Prerequisites: (MATH 114[C], 114[XS], 116[C] or 116[XS]) and (ECE 101[C] or 101[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 231: *Digital System Design.* 3 credits.
Covers principles of digital logic and digital system design and implementation in VHDL. Topics include number systems; Boolean algebra; analysis, design, and minimization of combinational logic circuits; analysis and design of synchronous and asynchronous finite state machines; and introduction to VHDL and behavioral modeling of combinational and sequential circuits. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((CS 112[C], 112[XS], CDS 130[XS], 130[C], CS 109[C] or 109[XS]) and (ECE 101[C], 101[XS], PHYS 261[XS] or 261[C]) and (ECE 232[*C] or 232[XS])).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 232: *Digital System Design Lab.* 1 credit.
Lab associated with ECE 231. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((CS 112[C], 112[XS], CDS 130[XS], 130[C], CS 109[C] or 109[XS]) and (ECE 101[C], 101[XS], PHYS 261[XS] or 261[C]) and (ECE 231[*C] or 231[XS])).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 240: *C Programming for Engineers.* 3 credits.
Introduction to structured programming in C with a focus on problem solving and applications for engineers. Topics include basic C syntax, data types, control flow, loops, functions, arrays, strings, pointers, structures, binary and text file processing, low-level bit programming, and C programming for embedded systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (CS 112[C], 112[XS], 109[C] or 109[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 285: *Electric Circuit Analysis I.* 3 credits.
Covers the first half of electric circuit theory and practice. Topics include DC analysis of circuits including Ohm's and Kirchhoff's laws, Thevenin and Norton equivalents, and analysis of circuits with resistors, capacitors, inductors, and operational amplifiers. Includes lab experiments to reinforce topics covered in the course. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Specialized Designation: Mason Impact.

Registration Restrictions:
Required Prerequisites: ((PHYS 260[C] or 260[XS]) and (PHYS 261[C] or 261[XS]) and (ECE 101[C] or 101[XS])) and (MATH 214[*C], U214, 214[XS] or 216[*C]) and (MATH 203[*C] or 203[XS]).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture, Recitation

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 286: *Electric Circuit Analysis II.* 3 credits.
Covers the second half of electric circuit theory and practice. Topics include AC analysis of circuits including phasors, frequency response, power analysis, and transformers. Includes a project and lab experiments to reinforce topics covered in the course. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Specialized Designation: Mason Impact.

Registration Restrictions:
Required Prerequisites: (ECE 285[C] or 285[XS]) and (MATH 214[C], U214, 214[XS] or 216[C]) and (MATH 203[C] or 203[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture, Recitation

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

300 Level Courses

ECE 301: *Digital Electronics.* 3 credits.
Introduces digital systems, circuits, and computers. Topics include binary systems and codes, digital logic gates and circuits, microelectronics and integrated circuits, coding and multiplexing, multivibrators, shift registers, counters, A/D converters, and elementary computer architecture. Notes: Not intended for those majoring in electrical or computer engineering. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: MATH 125[C], 125[XS], 114[C], 114[XS], IT 102[C], 102[XS], MATH 116[C] or 116[XS].
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 305: *Electromagnetic Theory.* 3 credits.
Static and time varying electric and magnetic fields, dielectrics, magnetization, Maxwell's Equations, and introduction to transmission lines. Course uses vector calculus and algebra of complex numbers. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (MATH 214[C], 214[XS], U214 or 216[C]) and (PHYS 260[C] or 260[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture, Recitation

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 311: *Energy Infrastructure, Market, and Management.* 3 credits.
Students will gain an understanding of the wide-ranging and vital role that energy plays within the general economy and our daily lives. The course covers a variety of topics including the organization and physical structure of the bulk electric system; energy within the transportation and industrial sectors; energy markets and regulation; and the role, challenges, and benefits associated with different forms of energy such as wind, solar, nuclear, coal, petroleum, and natural gas. The content of the course addresses a number of special topics, including risk management, resiliency, conservation, sustainability, the environment, and national security. Students will be required to form a multidisciplinary team to complete industry-oriented class projects, and given opportunities to work with industry experts. Course cannot be used as a technical elective for electrical or computer engineering majors. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Students with a class of Freshman or Sophomore may **not** enroll.

Enrollment limited to students in the College of Science, Costello College of Business or Engineering Computing colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 321: *Continuous-Time Signals and Systems.* 3 credits.
Introduction to the processing and analysis of continuous-time signals and systems in the time-domain via differential equations and in the transform-domain using Laplace and Fourier transforms. Specific topics include the frequency response of LTI systems, Bode plots, system

functions, block diagrams, filter design, and a rigorous treatment of sampling and aliasing. Includes applications to communications, circuits, control, and signal processing. Students must register for lecture, lab, and recitation. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Specialized Designation: Mason Impact.

Registration Restrictions:
Required Prerequisites: ((ECE 201[C] or 201[XS]) and (ENGR 107[C] or 107[XS]) and (MATH 203[*C] or 203[XS]) and (MATH 214[*C], U214, 214[XS], 216[XS] or 216[*C])).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture, Recitation

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 330: *Circuit Theory.* 3 credits.
This course introduces circuit analysis and design for non-ECE majors. Students develop an understanding of circuit analysis concepts such as nodal, mesh, and source transformation. Circuits with inductors, capacitors, resistors, and operational amplifiers are analyzed. Two projects are designed and built by students. A circuit simulation environment is used to simulate and analyze circuits. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (PHYS 260[C] or 260[XS]) and (PHYS 261[C] or 261[XS]) and (MATH 214[C] or 214[XS]) and (MATH 203[*C], 203[XS], ME 351[*C] or 351[XS]).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 333: *Linear Electronics I.* 3 credits.
Principles of operation and application of electron devices and linear circuits. Topics include semiconductor properties, diodes, bipolar and field effect transistors, biasing, amplifiers, frequency response, operational amplifiers, and analog design. Notes: ECE 334 is usually taken concurrently with ECE 333. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Mason Core: Mason Core (All) (http://catalog.gmu.edu/mason-core/)

Specialized Designation: Writing Intensive in Major

Registration Restrictions:
Required Prerequisites: (ECE 285[C] or 285[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture, Recitation

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 334: *Linear Electronics Lab I.* 1 credit.
Lab associated with ECE 333. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (PHYS 261[C], 261[XS] or 265[C]) and (ECE 333[*C] or 333[XS]).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 340: *Data Structures and Systems Programming in C.* 3 credits.
Covers the fundamentals of data structures and systems programming using the C programming language. Topics include pointers, linked lists, stacks, queues, trees, graphs, heaps, search and sort algorithms, and Big-O analysis, as well as Linux processes, signals, and I/O. This course includes a series of programming projects that focus on the analysis and development of large C programs. This is the second course in a two-course C programming language sequence. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((CS 211[C] or 211[XS]) and (ECE 240[C], 240[XS], CS 222[C] or 222[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 350: *Embedded Systems and Hardware Interfaces.* 3 credits.
This course introduces embedded systems design through project-based activities. The platform runs on Linux and students design their own IoT (Internet of Things) system as well as demonstrate dashboards with cloud-based data. Hardware interfaces and several types of sensors and actuators are incorporated as part of the projects. Students also

learn how to simulate and test signal-conditioning circuits, eventually integrating those as part of their projects. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((CS 222[C], 222[XS], ECE 240[C], 240[XS], CS 262[C] or 262[XS]) and (ECE 280[C], 280[XS], 285[C], 285[XS], 330[C] or 330[XS]) and ((ECE 301[C], 301[XS] or L301) or ((ECE 331[C], 331[XS], 231[C] or 231[XS]) and (ECE 332[C], 332[XS], 232[C] or 232[XS])))).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Computer Science, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 370: *Introduction to Robotics.* 3 credits.
The course will introduce general theoretical and practical use of modern robots, covering topics such as kinematics, trajectory planning, dynamics, motion control, force control, and mobile robots. Theory and practice will be tightly connected, as concepts learned in class will be put to practice on simulated and real robot platforms. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (CS 112[C], ENGR 125 or CS 109[C]) and ((MATH 203[C] or ME 351[C]) and (MATH 213[C])).
[C] Requires minimum grade of C.

Enrollment is limited to students with a major, minor, or concentration in Bioengineering, Computer Engineering, Computer Science, Cyber Security Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering, Systems Industrial Enginrng or Systems Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 390: *Engineering Design and Fabrication.* 3 credits.
Project based course where students will design projects containing analog and digital components as well as mechanical parts. Students will simulate, build, and test their projects. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (BENG 380[C], ECE 280[C], 285[C] or 285[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 391: *Professional Development for Engineers.* 1 credit.
This course builds the essential skills for students to successfully transition from college to the workplace and beyond. Topics include resume and cover letter writing, professional networking, personal branding, job/internship search, salary negotiation, identifying strengths and areas of development, career advancement and financial planning. Other topics include current trends and emerging career paths in the engineering field, graduate education, as well as an emphasis on the development and planning of a successful engineering career. Students are encouraged to register only after completion of at least 75 credits applicable to the electrical engineering or computer engineering program. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts. Equivalent to ECE 491.
Registration Restrictions:
Required Prerequisites: (COMM 100[C], 100[XS], 101[C], 101[XS], HNRS 353[C], 360[C] or 361[C]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with a class of Freshman or Sophomore may **not** enroll.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Seminar

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 395: *Electrical and Computer Engineering Internship.* 3 credits.
The objective of the course is for students to learn valuable skills related to their major through an internship. Internships provide work experience that many future employers prefer before hiring a recent engineering graduate. Internships also provide a pathway for meaningful connections to others working in the chosen field of study and associated fields, while also providing avenues for personal growth, such as the opportunity to solve real-world problems, conduct research, and improve oral and written communication skills. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 6 credits.
Registration Restrictions:
Students with a class of Freshman or Sophomore may **not** enroll.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Internship

Grading:
This course is graded on the Satisfactory/No Credit scale. (http://catalog.gmu.edu/policies/academic/grading/)

400 Level Courses

ECE 409: *Data Center Engineering.* 3 credits.
This course is an introduction to Data Center Engineering (infrastructure side design, construction, and daily operations). Emphasis is on understanding and applying design techniques and construction processes which will result in a decarbonized data center. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Enrollment limited to students with a class of Senior Plus or Senior.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering or Mechanical Engineering.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 410: *Applications of Discrete-Time Signal Processing.* 3 credits.
Introduces fundamental concepts of digital signal processing. Emphasis on the theoretical and numerical tools used for frequency domain analysis of sampled signals. Topics covered include sampling, the discrete Fourier transform, fast transform algorithms, spectral analysis, and digital filtering. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 220[C], 220[XS], 321[C] or 321[XS]) and (STAT 346[C] or 346[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 411: *Electricity Sector Engineering, Economics, and Regulation.* 3 credits.
This course presents the concepts behind electricity sector regulation from an engineering, economic, environmental, and regulatory policy perspective. The content covers the power procurement principles and practice, power system operation and ancillary services, and power market development in the US. It addresses the technical and economic challenges related to the growth of high-penetration renewable integration, transportation electrification, data center power demand, and the transition to low-carbon electricity generation. It explores the design and operation of microgrids and connected communities, and the application of cutting-edge technology in the future smart grid. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Enrollment limited to students with a class of Senior Plus or Senior.

Students with the terminated from CEC major attribute may **not** enroll.

Enrollment limited to students in the College of Science, Costello College of Business or Engineering Computing colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 412: *Renewable Energy Lab.* 1 credit.
This hands-on laboratory course offers a comprehensive exploration of renewable energy technologies, their integration, and practical applications across various contexts. Engaging in a series of experiments encompassing a broad range of topics related to renewable energy, distribution systems, power monitoring, and sustainability, students will develop a holistic comprehension of renewable energy technologies and their real-world implementation Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Recommended Corequisite: ECE 415

Registration Restrictions:
Required Prerequisites: ECE 286[C], 330[C] or PHYS 306[C].
[C] Requires minimum grade of C.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Physics.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 414: *Grid Digitization and Automation.* 3 credits.
This course provides an overview of power grid digitization and covers IEC 61850 based substation automation systems from the real-world application perspective. Topics include: substation equipment, functions, interfaces and communication technology; IEC 61850 scope, protocol and configuration technology; IEC 61850 modeling approach, process bus, substation model; overview of synchrophasors; Substation Configuration Language; application software and cyber security considerations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((CS 112[C], 112[XS], 109[C], 109[XS], CDS 130[C], 130[XS] or ENGR 125T) and (ECE 286[C], 286[XS], 330[C] or 330[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Systems Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:

This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 415: *Power System Analysis.* 3 credits.
Introduces the concepts of power system analysis commonly encountered in the study and practice of electric power engineering. Emphasis is on topics of modern power system modeling, operation and protection, power flow studies, economic dispatch, symmetrical and asymmetrical fault calculations, and system protection. Students will use interactive power system simulation tools to complete homework assignments and a comprehensive term project. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 286[C], 286[XS], 330[C], 330[XS], PHYS 306[C] or 306[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Physics.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 416: *Electric Machinery and Modern Applications.* 3 credits.
The course examines the principles, construction, characteristics, operation, and applications of electric machines. Topics covered include electromechanical energy conversion, synchronous machines, induction machines, direct current machines, linear generators, and their applications in modern power grids, renewable energy harvesting, electric vehicles, and flywheel energy storage systems. Computer simulation tools will be used throughout the course to demonstrate the behavior of machines and systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 286[C], 286[XS], 330[XS], 330[C], 305[C] or 305[XS]) or (PHYS 306[C] or 306[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Physics.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 417: *Smart Grid and Cyber Security.* 3 credits.
The course covers smart grid and system security of integrated cyber and physical power systems. Other topics include power system operation and control, smart grid technology, cyber-physical power system security, vulnerability of the integrated system, intrusion detection, mitigation and defense, and system restoration. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 311[C] or 311[XS]) or ((PHYS 260[C] or 260[XS]) and (PHYS 261[C] or 261[XS]))).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment limited to students with a class of Senior Plus or Senior.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Cyber Security Engineering, Electrical and Computer Engr, Electrical Engineering, Energy Transition Management or Mechanical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 418: *Power System Protection and Control.* 3 credits.
The course addresses the main topics and trends relating to power system protection. It covers the advanced knowledge and principles needed for designing and setting modern power grid protection systems. Topics include review of power system faults; overview of transducers and protective equipment; in-depth guidelines for relay application and settings calculation; protection design of power lines, transformers, buses, generators, reactors and capacitors; improved protection with Wide Area Measurements (WAMs); protection considerations for renewable resources. The knowledge is reinforced with real-world examples and class projects. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 415[C] or 415[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Physics.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 419: *Power Electronics for Modern Power Systems.* 3 credits.
This course covers the principle, design, control and application of power electronics in the modern power systems. Topics include: modeling and design of power electronics circuits including rectifiers, converters and inverters; analysis and design of magnetic components and filters; application of power electronics in grid interface of renewable energy resources, electric machine control systems, aircrafts, HVDC and FACTS; computer simulation of power electronics and motor drives; and practical issues in power electronic devices. Offered by Electrical & Comp.

Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 333[C] or 333[XS]) and (ECE 334[C] or 334[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 420: *Smart Grid Lab.* 1 credit.
This laboratory provides students with software and hardware hands-on experience of smart grid protection, communication, control, operation and cyber security. The experiments are conducted through power system commercial and open source software, hardware, Real-Time Digital Simulator (RTDS) and Hardware-in-the-Loop (HIL) Testing. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Recommended Corequisite: ECE 415

Registration Restrictions:
Required Prerequisites: (ECE 286[C], 330[C] or PHYS 306[C]).
[C] Requires minimum grade of C.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Physics.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 421: *Classical Systems and Control Theory.* 3 credits.
Introduces analysis and synthesis of feedback systems, including functional description of linear and nonlinear systems, block diagrams and signal flow graphs; state-pace representation of dynamical systems, frequency response methods, Root Locus, Nyquist, and other stability criteria; performance indices and error criteria; and applications to mechanical and electromechanical control systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts. Equivalent to SYST 421.
Registration Restrictions:
Required Prerequisites: (ECE 220[C], 220[XS], 321[C] or 321[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 424: *Modern Control Systems Design.* 3 credits.
Introduces state-space modeling, analysis, and control of feedback systems using time-domain methods rather than frequency-domain methods, and the connections between the two. In particular the course will emphasize the connections between physical real-world systems and mathematical control problems. Specific topics include modeling and realization theory, stability analysis and control of linear systems, controllability and observability, introductions to digital control, linear optimal control, and nonlinear control. Students will demonstrate their obtained knowledge through the design of a complete control system including choices of sensors/actuators in addition to the controller. The course will include extensive use of Matlab and Simulink. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ECE 421[C], 421[XS], ME 432[C] or 432[XS].
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Bioengineering, Computer Engineering, Electrical and Computer Engr, Electrical Engineering, Mechanical Engineering or Systems Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 425: *Secure RF Communications.* 3 credits.
Reviews current systems of Radio Frequency (RF) communications and related cyber security issues. This course focuses on security issues in wireless networks, such as cellular networks, wireless LANs, Bluetooth, NFC, RFID, mobile security, anti-jamming communication, and physical layer security. The course will first present an overview of wireless networks, then focus on attacks and discuss proposed solutions and their limitations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts. Equivalent to CYSE 425.
Registration Restrictions:
Required Prerequisites: ((CS 222[C], 222[XS], ECE 240[C], 240[XS], CS 262[C] or 262[XS]) and (ECE 465[C], 465[XS], CYSE 230[C], 230[XS], CS 455[C] or 455[XS]) and (MATH 125[C], 125[XS], ECE 231[C] or 231[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Computer Science, Cyber Security Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 427: *Introduction to Machine Learning and Artificial Intelligence in Engineering.* 3 credits.
This is an introductory course in machine learning (ML) and artificial intelligence (AI) that is intended for students who are interested in learning about ML and AI presented from an engineering perspective. The course will introduce the student to many of the current state-of-the-art machine learning algorithms and the use of AI in modern applications without going deep into the mathematics. The topics that will be covered include classification, regression, reinforcement learning, and key results from statistical learning theory. Applications include image classification, face recognition, object detection, natural language processing, speech recognition, and computer vision. The course introduces the student to the important software libraries, including ScikitLearn, Tensorflow, NLTK, and OpenCV. Knowledge of Python is required. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (STAT 346[C], 346[XS], 344[C] or 344[XS]) and (MATH 203[C], 203[XS], ME 351[C] or 351[XS]) and (CS 112[C], 112[XS], SYST 130[C] or 130[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 429: *Modern Control Systems Lab.* 1 credit.
Laboratory experiments for topics in control systems analysis, design, and implementation. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 421[C], 421[XS], ME 432[C] or 432[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical Engineering or Mechanical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 430: *Principles of Semiconductor Devices.* 3 credits.
Introduces solid-state physics and its application to semiconductors and semiconductor devices. Topics include band theory, doping, p-n junctions, diffusion theory, low-frequency circuits, devices including bipolar transistor, MOSFET, CMOS, and photo transistors. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: PHYS 260[C] and (MATH 214[C], U214, 214[XS] or 216[C]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Students with a class of Freshman, Junior or Sophomore may **not** enroll.

Enrollment is limited to students with a major, minor, or concentration in Bioengineering, Computer Engineering, Electrical and Computer Engr, Electrical Engineering or Mechanical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 431: *Digital Circuit Design.* 3 credits.
Analysis and design of CMOS digital integrated circuits. Topics include: MOSFET transistor design equations for “hand” analysis and models for computer (SPICE) simulations; static and dynamic characteristics of inverters; fabrication, mask layout, and simulation; static and dynamic CMOS, pass transistor and transmission gate integrated circuit styles; combinational and sequential integrated circuits; semiconductor memory cell types and memory cell arrays. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 331[C], 331[XS], 231[C] or 231[XS]) and (ECE 333[C] or 333[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 433: *Linear Electronics II.* 3 credits.
Second course in linear electronics. Covers differential amplifiers, feedback circuits, power amplifiers, feedback amplifier frequency response, analog integrated circuits, operational amplifier systems, oscillators, wide band and microwave amplifiers, and computer-aided design. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 286[C] or 286[XS]) and (ECE 333[C] or 333[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 434: *Linear Electronics II Laboratory.* 1 credit.
Second lab course in linear electronics involving analysis and design of topics listed in ECE 433. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 334[C] or 334[XS]) and (ECE 433[*C] or 433[XS]).
[*] May be taken concurrently.
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 436: *Printed Circuit Board Design Lab.* 1 credit.
Introduces fundamental concepts of Printed Circuit Board (PCB) design and fabrication. Selected topics include design workflow, schematics, symbols, footprints, rules checking, dimensioning, component selection, customization and layout optimization. Software tools are used to design and create multi-layer PCBs based on through-hole as well as surface mount technology. Students learn how to select and solder electrical and mechanical components onto their manufactured boards. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 232[C], 232[XS], 332[C] or 332[XS]) and (ECE 334[C] or 334[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 445: *Computer Organization.* 3 credits.
General overview of operating a digital computer. Topics include computer arithmetic, arithmetic unit, hardwired and microprogrammed control, memory, register-to-register, input-output operations, and behavioral modeling of computer organization using VHDL. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 331[C], 331[XS], 231[C] or 231[XS]) and (ECE 332[C], 332[XS], 232[C] or 232[XS]) and (CS 262[C], 262[XS], ECE 240[C], 240[XS], CS 222[C] or 222[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 446: *Device Driver Development.* 3 credits.
Addresses device driver and kernel level software programming and development. The C programming language and program trouble shooting are reviewed. Basics of device driver software, Character driver operations and data structures, concurrency and race conditions, kernel timers, memory allocation, communications with hardware, interrupt handling, kernel data types, memory mapping and Direct Memory Access concepts are explored. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ECE 445[C], 445[XS], CS 465[C] or 465[XS].
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Computer Science, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 447: *Microcontrollers.* 4 credits.
Explores designing with microcontrollers and microcontroller interfacing. Topics include the role of microcontrollers compared with microprocessors, microcontroller architecture and organization, interfacing with sensors and input/output devices, embedded system programming using C, and assembly language and design tools. Students perform laboratory exercises devoted to constructing systems including a microcontroller and ancillary hardware. Notes: This course is highly recommended for ECE 492/493 students interested in using microcontroller technology in their senior design projects. It should be taken before ECE 493. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Recommended Prerequisite: ECE 350

Registration Restrictions:
Required Prerequisites: (ECE 445[C], 445[XS], CS 465[C] or 465[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering, Computer Science, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 448: *FPGA Design with VHDL.* 4 credits.
Practical introduction to modeling of digital systems with VHDL for logic synthesis. Overview of design flow and tools for FPGAs. Discusses verification of digital systems using testbenches, prototyping boards and modern testing equipment, and illustrates VHDL-based design methodology with multiple examples from communications, control, DSP, and cryptography. Laboratory experiments create link between simulation and actual hardware implementation based on FPGA boards. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 445[C] or 445[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 450: *Mobile Robots.* 3 credits.
Introduces mobile robotic systems. Topics include overview of power systems, motors, behavior-based programming, sensors, and sensor integration. Design projects conceived, developed, implemented, and presented. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ECE 350[C] or 350[XS].
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 455: *GPU Architecture and Programming.* 3 credits.
This course introduces the major architectural building blocks of contemporary Graphics Processing Units (GPUs). Lectures cover the GPU massive parallelism concept and techniques for developing optimum-performance programs targeting GPU platforms. The course introduces the widely-used Compute-Unified Device Architecture (CUDA) GPU programming language and covers methodologies for using CUDA to implement parallel sorting, reduction, numeric iterations, and fundamental graphics operations, such as ray tracing, in a manner that progressively increases the sophistication and performance of the developed programs. Students implement hands-on laboratory exercises on a high-performance UNIX cluster. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 445[C], 445[XS], CS 465[C] or 465[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Computer Science, Electrical and Computer Engr or Electrical Engineering.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 460: *Communication and Information Theory.* 3 credits.
Introduction to analog and digital communications. Topics include review of important concepts from signals and systems theory and probability theory; Gaussian processes and power spectral density; digital transmission through additive white Gaussian channels; sampling and pulse code modulation; analog signal transmission and reception using amplitude, frequency and phase modulation; and effects of noise on analog communication systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 220[C], 220[XS], 321[C] or 321[XS]) and (STAT 346[C] or 346[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 461: *Communication Engineering Laboratory.* 1 credit.
Lab experiments in analog and digital communication areas covered in ECE 460. Offered by Electrical & Comp. Engineering (http://

catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (ECE 334[C] or 334[XS]) and (ECE 460[C] or 460[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 462: *Data and Computer Communications.* 3 credits.
Introduces modern data communications and computer networks. Topics include point-to-point communication links and transmission of digital information, modems, and codecs; packet switching, multiplexing, and concentrator design; multiaccess and broadcasting; local area and wide area networks; architectures and protocols for computer networks; OSI reference model and seven layers; physical interfaces and protocols; and data link control layer and network layer. Provides examples of data networks. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (STAT 344[C], 344[XS], 346[C] or 346[XS]) and (ECE 220[C], 220[XS], 321[C] or 321[XS]) and (ECE 231[C], 231[XS], 331[C], 331[XS], 301[C], L301 or 301[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 463: *Digital Communications Systems.* 3 credits.
Introduces digital transmission systems. Topics include quantization, digital coding of analog waveforms, PCM, DPCM, DM, baseband transmission, digital modulation schemes, ASK, FSK, PSK, MSK, QAM, pulse shaping, intersymbol interference, partial response, voice-band and wideband modems, digital cable systems, regenerative repeaters, clock recovery and jitter, multipath fading, digital radio design, optimal receiver design, MAP receiver, and probability of error. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ECE 460[C] or 460[XS].
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 465: *Computer Networking Protocols.* 3 credits.
Introduces computer networking protocols and concepts, emphasizing Internet and Internet Protocol Suite. Covers computer networking protocols at application, transport, and network layers, including multimedia networking protocols, and network security and management. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: (STAT 346[C], 346[XS], 344[C] or 344[XS]) and (CS 222[C], 222[XS], ECE 240[C], 240[XS], CS 211[C] or 211[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering or Systems Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 467: *Computer Networking Laboratory.* 1 credit.
Hands#on experience designing and configuring Internet and computer networks in both physical and virtual environments. Students are exposed to real world computer networking technologies, concepts, and scenarios including the basics of packet forwarding, dynamic routing protocols, network virtualization, and packet capture and dissection tools. The coursework will allow students to work with open#source network simulation and configuration environment. Recommended to be taken after completion of 75 credits applicable to the program. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Recommended Corequisite: ECE 465

Registration Restrictions:
Students with a class of Freshman or Sophomore may **not** enroll.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Laboratory

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 470: *Introduction to Humanoid Robotics.* 3 credits.
Covers basic robot architecture with a focus on humanoid robotics. Topics include mechanical design philosophies, electrical design philosophies, and controller design of high DOF systems. Simulation of various parts and functionalities of humanoids culminates in a term project , which includes hardware demonstrations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((CS 112[C], 112[XS], 109[C] or 112[XS]) and (ECE 280[C], 280[XS], 285[C], 285[XS], BENG 380[C] or 380[XS]) and ((ECE 301[C], 301[XS] or L301) or (ECE 331[C] and 332[C]) or (ECE 231[C] and 232[C]))).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 476: *Cryptography Fundamentals.* 3 credits.
Covers basic concepts of cryptology, types of cryptosystems, security services, and key management. Gradually introduces mathematical background required for understanding cryptography. Discusses modern secret-key stream and block ciphers, modes of operation, public key cryptosystems (RSA, elliptic curve, and post-quantum cryptography), hash functions, message authentication codes, and digital signature schemes. Covers key cracking machines, side-channel attacks, and fault attacks. Discusses popular cryptographic modules, such as True Random Number Generators and Physical Unclonable Functions, used for key generation and device authentication. Introduces educational and public domain software implementing modern cryptographic algorithms. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts. Equivalent to CYSE 476.
Registration Restrictions:
Required Prerequisites: (ECE 301[C], 301[XS], 231[C], 231[XS], 331[C] or 331[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering, Computer Science, Cyber Security Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 480: *Small Spacecraft Engineering.* 3 credits.
Comprehensive study of small spacecraft design, operations, satellite bus, communications, computing hardware, radiation-hardened software, sensors, power, testing, orbit, space environment, and other topics needed for successful engineering of a spacecraft and its ground station. Review of CubeSat technology, hardware, software, missions, and applications. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ((ECE 285[C], 285[XS], 330[C] or 330[XS]) and (CS 112[C], 112[XS], 109[C], 109[XS] or ENGR 125T[C])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment limited to students with a class of Senior Plus or Senior.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr, Electrical Engineering or Mechanical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 488: *Nanoelectronics Fundamentals.* 3 credits.
This course introduces fundamental theories of materials science and device physics for nanoelectronics. Specific topics include the quantum transport of electrons, phonons, and spin in nanoscale materials, emerging device concepts and new approaches for high-speed and low-energy electronics, and structure-property relations of low-dimensional nanomaterials. State-of-the-art nanofabrication technologies are also taught to provide students with useful insights into how modern nanoelectronic devices are fabricated. Students complete projects that focus on device fabrication in a cleanroom environment Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisite: ECE 333[C].
[C] Requires minimum grade of C.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 491: *Engineering Seminar.* 1 credit.
Engineering ethics, professionalism, role of engineer in society, current topics, and employment opportunities. Students are encouraged to register only after completion of at least 75 credits applicable to the electrical engineering or computer engineering program. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts. Equivalent to ECE 391.
Registration Restrictions:
Required Prerequisites: (COMM 100[C], 100[XS], 101[C], 101[XS], HNRS 353[C] or 360[C]).
[C] Requires minimum grade of C.

[XS] Requires minimum grade of XS.

Students with a class of Freshman or Sophomore may **not** enroll.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Seminar

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 492: *Senior Advanced Design Project I.* 1 credit.
Conception of senior design project and determination of feasibility of proposed project. Work includes developing preliminary design and implementation plan. Students planning to use microcontroller technology in their projects should enroll in ECE 447 before taking ECE 493. Note: Registration is allowed only after completion of at least 90 credits applicable to the electrical engineering or computer engineering program. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Mason Core: Mason Core (All), Mason Apex (http://catalog.gmu.edu/mason-core/)

Specialized Designation: Mason Impact.

Registration Restrictions:
Required Prerequisites: (((COMM 100[C], 100[XS], 101[C] or 101[XS]) and (ENGH 302[C], 302[XS] or ENGL 302[C])) or (HNRS 353[C], 360[C] or 361[C]) and (ECE 201[C] or 201[XS]) and (ECE 286[C] or 286[XS]) and (ECE 350[C] or 350[XS])).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 493: *RS: Senior Advanced Design Project II.* 2 credits.
Implementation of project for which preliminary work was done in ECE 492. Project includes designing and constructing hardware, writing required software, conducting experiments or studies, and testing complete system. Requires oral and written reports during project and at completion. Notes: Students planning to use microcontroller technology in their projects should enroll in ECE 447 before taking ECE 493. If meeting time conflicts with other courses, come directly to the ECE department for registration. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Mason Core: Mason Core (All), Mason Apex (http://catalog.gmu.edu/mason-core/)

Specialized Designation: Research/Scholarship Intensive

Registration Restrictions:
Required Prerequisites: (ECE 492[C] or 492[XS]).
[C] Requires minimum grade of C.
[XS] Requires minimum grade of XS.

Enrollment is limited to students with a major in Computer Engineering or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 498: *Independent Study in Electrical and Computer Engineering.* 1-3 credits.
Directed self-study of special topics of current interest in ECE. Topic must be arranged with an instructor and approved by department chair before registering. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the term for a maximum 3 credits.
Specialized Designation: Topic Varies

Registration Restrictions:
Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Independent Study

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 499: *Special Topics in Electrical and Computer Engineering.* 0-4 credits.
Topics of special interest to undergraduates. Notes: May be repeated if topics substantially different. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the term for a maximum 11 credits.
Specialized Designation: Topic Varies

Registration Restrictions:
Students with a class of Freshman or Sophomore may **not** enroll.

Enrollment is limited to students with a major, minor, or concentration in Computer Engineering, Electrical and Computer Engr or Electrical Engineering.

Students with the terminated from CEC major attribute may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Undergraduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

500 Level Courses

ECE 500: *Special Topics.* 0-4 credits.
Select contemporary topics in Engineering and Computing. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 6 credits.
Specialized Designation: Topic Varies

Registration Restrictions:

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Special scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 505: *Hardware Security.* 3 credits.
Covers security and trust in hardware, in relation to both ASIC and FPGA technologies. Topics include ASIC and FPGA manufacturing supply chain, threats and security challenges such as IP piracy, overproduction, counterfeiting, trojan insertion, reverse engineering, etc. Discusses various attacks against hardware, including physical, invasive, destructive, logical, and side channel attacks. Spans various hardware defense solutions including metering, locking, obfuscation, watermarking, access control, Trojan testing, IP core isolation, and the theory and practice of physical unclonable functions. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ((ECE 301 or ECE 231) and (CS 211 or CS 222 or ECE 240)) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 507: *Seminar in Emerging Technologies.* 3 credits.
Study of emerging technologies, how they are identified, how they evolve, actions which may encourage or stifle their growth, government influences, societal influences, examples of success and failure, and some lessons to be learned which are unique to government information technology. Topics covered will include a general introduction to emerging technologies, with emphasis on IT, discussion of difficulty in letting go of legacy systems, the DOD Global Information Grid, Cyberwarfare, Complex Adaptive Systems, and Federal Government support of Research and Development. Cannot be used in the PhD IT program. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 508: *Internet of Things.* 3 credits.
Introduces the principles, technologies, challenges, and required expertise needed for building the Internet of Things (IoT) solutions. It provides a big picture of what is involved in IoT. Topics covered in this course include analog and digital sensing, interfacing sensors with microcontrollers, digital communication protocols, microcontroller choices and capabilities, gateways, fog computing, networking, cloud computing, need and challenges for cryptography and compression, security issues, and low power/energy challenges. The listed topics are covered only to the extent required to understand the challenges and to the point that the role of a given topic in IoT solutions is comprehended. While briefly covering the technologies involved at the various hierarchal levels of IoT solutions, the course introduces other courses at GMU where students could build further expertise in the topics of interest. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 350 or ((ECE 301 or ECE 231) and (CS 222 or ECE 240)) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 511: *Computer Architecture.* 3 credits.
Introduces the concepts of a processor microarchitecture, from a pipelined processing unit, through a superscalar, to a multicore multithreaded computing system. Topics include instruction set architecture, single cycle processor, MIPS pipeline processor, precise state, parallel processing, superscalars, memory and cache organization, branch prediction, multicore processors, memory consistency, multi- and many-core cache coherence, and heterogeneous computing. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 445 or CS 465 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:

This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 512: *Computer Architecture Security.* 3 credits.
This course focuses on recent advances in computer systems security, including both attacks and countermeasures. An emphasis will be placed on attacks that exploit hardware vulnerabilities and hardware and software protection from these attacks. Specific topics include memory corruption attacks, control flow attacks, return-oriented programming attacks and their variations, side-channel attacks, covert channels, trusted computing systems and secure architectures, malware detection techniques, oblivious memory, and operating system security. The course will also overview recent industry developments, including Intel's SGX, MPX and CET, ARM's TrustZone and AMD's SME and SEV technologies. Students are expected to read recent research papers in the area, present them in class, and participate in discussions. Students are also expected to complete a semester-long research project and take a final exam. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 445 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 513: *Applied Electromagnetic Theory.* 3 credits.
Maxwell's Equations, electromagnetic wave propagation, wave guides, transmission lines, radiation, and antennas. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 305 or equivalent.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 514: *Grid Digitization and Automation.* 3 credits.
This course provides an overview of power grid digitization and covers IEC 61850 based substation automation systems from the real-world application perspective. Topics include substation equipment, functions, interfaces, and communication technology; IEC 61850 scope, protocol and configuration technology; IEC 61850 modeling approach, process bus, substation model; overview of synchrophasors; Substation Configuration Language; application software and cyber security considerations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 415 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 516: *Mobile Systems and Applications.* 3 credits.
A comprehensive study of modern mobile devices, with the special focus on smartphones and wearable devices. Topics include mobile operating systems, mobile device components, application development, human-computer interaction, data management, network systems, mobile intelligence, and mobile security. Lectures are enhanced and illustrated with several take-home, hands-on labs. A group-based, open-topic project involves specifying, developing, and presenting a medium complexity application using the Android operating system. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: CS 211 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 517: *Cyber Infrastructure of the Smart Grid.* 3 credits.
This course combines cybersecurity controls with the power system elements needed to meet federal, state, local, and territorial requirements for the resiliency of the smart grid. Beyond the methodologies and approaches for managing a power system with its many diverse components, this course establishes the key linkages to the control framework requirements needed for sustained operation and rapid restoration after maintenance, outage, or other operational transition of major power system sources and loads. The course will progress in an iterative approach from the high-level framework controls to the hands-on building of protection, testing, and monitoring elements for cyber defense, resiliency, and continuity of operation. The course content can be directly applied by students in municipal or larger power companies. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.

Recommended Prerequisite: ECE 415 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 518: *Power System Protection and Control.* 3 credits.
The course addresses the main topics and trends relating to power system protection. It covers the advanced knowledge and principles needed for designing and setting modern power grid protection systems. Topics include a review of power system faults; overview of transducers and protective equipment; in-depth guidelines for relay application and settings calculation; protection design of power lines, transformers, buses, generators, reactors, and capacitors; improved protection with Wide Area Measurements (WAMs); protection considerations for renewable resources. The instruction is reinforced with real-world examples and class projects. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 415 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 519: *Power Electronics for Modern Power Systems.* 3 credits.
This course covers the principle, design, control, and application of power electronics in modern power systems. Topics include modeling and design of power electronics circuits, such as rectifiers, converters, and inverters; analysis and design of magnetic components and filters; application of power electronics in grid interface of renewable energy resources, electric machine control systems, aircrafts, HVDC and FACTS; computer simulation of power electronics and motor drives; and practical issues in power electronic devices. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 333 and ECE 334) or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 521: *Linear Systems and Control.* 3 credits.
Introduces linear systems theory and design of linear feedback control systems. Reviews linear algebra, state variables, state-space description of dynamic systems, analysis of continuous-time and discrete-time linear systems, controllability and observability of linear systems, and stability theory. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Corequisite: ECE 421 or ME 432

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 527: *Learning From Data.* 3 credits.
This is an introductory course in machine learning and pattern recognition that covers basic theory, algorithms, and applications. Machine learning is the science of getting computers to act without being explicitly programmed. This course balances theory and practice, and covers the mathematical as well as the heuristic aspects. It provides a broad introduction to machine learning and pattern recognition. Topics include: (i) supervised learning (parametric/non-parametric algorithms, support vector machines, kernels, neural networks). (ii) Unsupervised learning (clustering, dimensionality reduction, recommender systems, autoencoders). (iii) Learning theory (bias/variance tradeoffs, VC theory, generalization). (iv) Ensemble methods (boosting and bagging, random forests). (v) Deep learning (deep belief networks, convolutional neural networks, deep autoencoders). The course will draw from numerous case studies and applications. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit. Equivalent to DAEN 527.
Recommended Prerequisite: (MATH 203 and STAT 346) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:

This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 528: *Introduction to Random Processes in Electrical and Computer Engineering.* 3 credits.
Probability and random processes are fundamental to communications, control, signal processing, and computer networks. Provides basic theory and important applications. Topics include probability concepts and axioms; stationarity and ergodicity; random variables and their functions; vectors; expectation and variance; conditional expectation; moment-generating and characteristic functions; random processes such as white noise and Gaussian; autocorrelation and power spectral density; linear filtering of random processes, and basic ideas of estimation and detection. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 321 and STAT 346, or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture, Recitation

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 530: *Sensor Engineering.* 3 credits.
Presents the fundamentals of sensor characteristics and transfer functions, sensor circuits and interfacing, sensor noise, and protection methods. Studies of different methods used in sensing position, motion, acceleration, force, humidity, temperature, chemicals, etc. are developed, followed by an analysis of specific sensor designs. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 531: *Introduction to Wireless Communications and Networks.* 3 credits.
Presents the basics of modern wireless communications and wireless networking at the first-year graduate level. Topics include wireless signal design, channel characterization, receiver structure, multiple access technologies, cellular concepts, capacity enlargement, mobility management, and wireless/wireless interworking. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 460 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 532: *Secure Wireless Communications and Networks.* 3 credits.
Introduces the security mechanisms and protocols for thwarting attacks on wireless networks, including wireless LANs, cellular networks, Bluetooth, RFID, and NFC. Reviews cryptography primitives, including symmetric/asymmetric cryptography, block/stream cipher, digital signature, and cryptographic hash functions. Examines physical layer security mechanisms including anti- jamming, low probability of detection/interception (LPD/LPI) communication, and physical layer authentication. Includes semester-long hands-on project on securing wireless communications and networks. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ((CS 222 or ECE 240) and ECE 462) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 535: *Digital Signal Processing.* 3 credits.
Representation analysis and design of digital signals and systems. Covers sampling and quantization, z-transform and discrete Fourier transform, digital filter realizations, design techniques for recursive and non-recursive filters, fast Fourier transform algorithms, and spectral analysis. Additional topics may include adaptive filtering, homomorphic digital signal processing, digital interpolation and decimation. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-

schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 460 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 537: *Image Processing and Computer Vision.* 3 credits.
This is an introductory course in image processing and computer vision and is open to anyone with a background in discrete-time signal processing and linear algebra, a basic understanding of probability, and familiarity with Python. It covers the basics of image formation, image capture, the processing and manipulation of images, image enhancement and restoration, image segmentation, object detection and recognition, and object tracking. Other topics may include image compression, video processing, stereo vision, and image stitching. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (CS 112 (Python), ECE 201, MATH 203, and STAT 346) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 538: *Medical Imaging.* 3 credits.
Provides an introduction to the physical, mathematical and engineering foundations of modem medical imaging systems, medical image processing and analysis methods. In addition, this course introduces engineering students to clinical applications of medical imaging. The emphasis is on diagnostic ultrasound and magnetic resonance imaging methods, although several other modalities are covered. The course also provides an overview of recent developments and future trends in the field of medical imaging, discusses some of the challenges and controversies, and involves hands-on experience applying the methods learned in class to real-world problems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit. Equivalent to BENG 538.
Recommended Prerequisite: ECE 321 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 539: *Neural Engineering.* 3 credits.
Provides an overview of topics in Neural Engineering. Topics covered range from sensory and motor prosthetic devices, stimulation of biological tissue, bioelectrodes and characterization techniques, brain-machine interfaces, and engineered devices to ameliorate neurodisorders. Prior knowledge in electrical or computer engineering disciplines required. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 542: *Computer Network Architectures and Protocols.* 3 credits.
Introduction to architectures and protocols of computer networks and concept of packet switching. Topics include ISO standard layer model, physical interfaces and protocols, data link control, multiaccess techniques, packet switching, routing and flow control, network topology, data communication subsystems, error control coding, local area network, satellite packet broadcasting, packet radio, interconnection of packet-switching networks, network security and privacy, and various examples of computer networks. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: STAT 346 or equivalent.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 545: *Digital System Design with VHDL.* 3 credits.
Introduction to the design of complex digital systems using hardware description languages. Emphasizes the design methodology based on the partitioning of a digital system into a datapath and control unit. Introduces a clear sequence of steps leading from specification to synthesizable, register transfer level (RTL), and fully verified HDL code. Covers VHDL for digital circuit design, including dataflow, structural, and behavioral coding styles. Introduces and illustrates the concepts of VHDL simulation, verification, synthesis, mapping, placing, routing, timing analysis and performance optimization. Requires semester long project devoted to the design of a complex digital system using VHDL as a hardware description language and FPGA as an implementation platform. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 231 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 550: *System Engineering Design.* 3 credits.
System engineering design methods are studied and practiced, including object-oriented and structured analysis based techniques. Design Description languages such as UML, SysML, IDEF0 and IDEF1x are introduced and used in carrying out complete system designs. Teams make presentations of their designs. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit. Equivalent to SYST 520.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 552: *Big Data Technologies.* 3 credits.
Covers the principles of the Big Data ecosystem architecture and in-depth understating of selected Big Data technologies that are an important part of such a scalable ecosystem. Important topics covered in this course include Hadoop distributed file system (HDFS), along with the system requirements that drove the need for such distributed file system, MapReduce - a new computing paradigm that enables processing of massive amount of data stored in HDFS, new open-source analytical engines that rely on parallel and in-memory computations to improve the analytical processing time of the massive amount of data, concepts and rigors of machine learning and their implementation using Big Data technologies, functional programming, NoSQL technologies, and integration. The course also covers the implementation and instantiation of a cloud-based Big Data ecosystem that allows illustrating concepts introduced in this class. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: CS 112 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 554: *Machine Learning for Embedded Systems.* 3 credits.
This course introduces the methodologies and approaches for accommodating neural networks into resource-constrained edge computing. It focuses on the embedded systems and introduces techniques for developing energy/time efficient machine learning (ML) algorithms and models suitable for them. Topics covered include commonly used ML algorithms, ML model compression techniques, hardware-aware ML, and hardware and neural architecture co-design. The course also provides a comprehensive team-based research and development experience through projects and presentations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 445 or CS 465 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 555: *GPU Architecture and Programming.* 3 credits.
This course introduces Graphics Processing Unit (GPU) architectural building blocks such as global, constant, texture, scratchpad, and cache memory. Lectures center around the GPU massive parallelism concept and techniques in building optimum-performance programs in GPU platforms by comparing CPU and GPU platforms. Although the course primarily utilizes the widely used Compute-Unified Device Architecture (CUDA) GPU programming language, it also introduces the Open-CL language to compare and contrast syntactic and performance differences. Lectures teach methodologies in using CUDA to implement parallel sorting, reduction, numeric iterations, and fundamental graphics operations, such as ray tracing in a manner that progressively increases in sophistication and performance. The course incorporates class-wide literature reviews and discussion sessions to study key publications that introduce and detail GPU architecture and programming. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 445 or CS 465 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 556: *Neuromorphic Computing.* 3 credits.
This course offers an interdisciplinary perspective on neuromorphic computing across the full stack of computing. It examines fundamentals and learning of artificial neural networks (ANNs), discusses operational principles and learning in spiking neural networks (SNNs), and reviews their implementations in hardware. It presents several state-of-the-art learning algorithms such as converting ANN to SNN, spike timing dependent plasticity, evolutionary approaches, and reservoir computing. Hardware-aware neural architecture search and Bayesian optimization approaches are also covered to co-optimize algorithm-hardware in this full-stack computing framework. This course involves projects focusing on applications of neuromorphic computing in computational neuroscience, control and robotics, smart healthcare, and smart city design. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: MATH 203 and STAT 346, or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 565: *Introduction to Optical Electronics.* 3 credits.
Introduces optoelectronic devices for generation, detection, and modulation of light. Topics include electro-optic modulators, gas, solid state and semiconductor lasers, photodetectors, and detector arrays. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 305 and 333.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 567: *Optical Fiber Communications.* 3 credits.
Studies components and integration of fiber-optic transmission systems. Topics include optical fibers, signal degradation, optical sources, power launching and coupling, photodetectors, receiver circuits, link analysis, and optical measurements. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 462 or TCOM 500 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 570: *Quantum Computing System Design.* 3 credits.
Quantum computing is an emerging and promising technology that can be used to solve complex problems that are beyond the capability of classical computing. This course is a self-contained introduction aimed at students who might have never been previously exposed to quantum theory. The course focuses on end-to-end quantum system integration, including quantum algorithm design for an application, function synthesis into a quantum circuit, and compiling the circuit to

quantum devices. The topics cover essential mathematical fundamentals for quantum computing, quantum logic gates, quantum machine learning, quantum circuit optimization, quantum noise, and quantum error mitigation. The course also provides a comprehensive team-based research and development experience through projects and presentations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Corequisite: PHYS 534

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 575: *AI Design and Deployment Risks.* 3 credits.
This course will explore the fundamental issues that underpin risk inherent in systems that utilize AI. Students will learn how to measure these risks, assess the impacts and harms that could results from AI, and formulate plans for managing risks including testing, maintenance, governance and legal interventions. Topics will include AI robustness, generalizability, validity, reliability, safety, and security and students will develop risk assessment plans for a domain of their choice. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Corequisite: (CS 480 or 580) or (ECE 427, 527 or 554)

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 576: *AI: Ethics, Policy, and Society.* 3 credits.
Artificial intelligence (AI) technologies are rapidly expanding across multiple domains, leading to significant debate about its ethical and societal impacts. Still a matter of debate is what appropriate legal and governance structures should be created to ensure the ethical design, development, deployment, and use of AI. Further complicating the debate is the question of which parties and stakeholders should contribute to creating AI governance structures and mechanisms. The course will explore pressing issues in ethics and policy, including transparency, privacy and surveillance, misinformation and disinformation, fairness, algorithmic bias (from both underlying data and modeling choices), justice, equity, trust, and labor practices and supply chains. These topics will be grounded in specific use cases often drawn from cutting edge topics in the news. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 577: *Emerging AI & Robotics Tech Seminar.* 1 credit.
This seminar focuses on student-led critical analyses of emerging AI issues in the news across all domains. Speakers from industry and government will also participate. May be repeated within the certificate, BS degree, MS degree, and PhD degree for a maximum 2, 3, 3, and 6 credits respectively. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 6 credits.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Seminar

Grading:
This course is graded on the Satisfactory/No Credit scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 580: *Small Spacecraft Engineering.* 3 credits.
Comprehensive study of small spacecraft design, operations, bus, communications, computing hardware, software, sensors, power, attitude control, testing, and other topics needed for successful engineering of a spacecraft and its ground station. Review of ultra-small CubeSats, their hardware, software, and missions. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science or Engineering Computing colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 584: *Semiconductor Device Fundamentals.* 3 credits.
Studies principals of operation of semiconductor devices based on solid state physics. Topics include band theory of solids, intrinsic and extrinsic semiconductor properties, pn junction diode, bipolar junction transistor, Schottky diode, metal insulator semiconductor junctions, field-effect transistors, and hetero-structures. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.

Recommended Prerequisite: ECE 333 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 585: *Human Robot Interaction.* 3 credits.
Introduction to the theory, principles, and methods used to model, design and test automated, autonomous or robotic systems that require or support human interaction. Focus areas include understanding the theory and mechanics of both human and robot perception and cognition, the design of interaction architectures such as teleoperation and human supervisory control, and how to conduct principled tests and experiments of human-robot systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 586: *Digital Integrated Circuits.* 3 credits.
Studies design and analysis of digital integrated circuits, emphasizing CMOS technology. Reviews MOSFET operation and SPICE modeling. Covers analysis and design of basic inverter circuits, structure and operation of combinational and sequential logic gates, dynamic logic circuits, chip I/O circuits, and brief introduction to VLSI methodologies. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 231 and ECE 333) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 587: *Design of Analog Integrated Circuits.* 3 credits.
Studies design methodologies of CMOS-based analog integrated circuits. Topics include differential amplifiers, current sources, output stages, operational amplifiers, comparators, frequency response, noise, and computer-aided design. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 333 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 588: *Nanoelectronics Fundamentals.* 3 credits.
This course introduces fundamental theories of materials science and device physics for nanoelectronics. Specific topics include the quantum transport of electrons, phonons, and spin in nanoscale materials, emerging device concepts and new approaches for high-speed and low-energy electronics, and structure-property relations of low-dimensional nanomaterials. State-of-the-art nanofabrication technologies are also taught to provide students with useful insights into how modern nanoelectronic devices are fabricated. The projects include device fabrication in a cleanroom environment and advanced technical presentation in both written and oral formats. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 333 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 590: *Selected Topics in Engineering.* 3 credits.
Selected topics from recent developments, and applications in various engineering disciplines. Designed to help professional engineering community keep abreast of current developments. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/

engineering-computing/engineering/electrical-computer/). May be repeated within the term for a maximum 15 credits.
Specialized Designation: Topic Varies

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

600 Level Courses

ECE 605: *Microgrid Design and Control.* 3 credits.
The course addresses the main topics and trends relating to microgrid systems. It covers the advanced knowledge and principles of a microgrid from modeling, design, and completion to operation. Topics include leading-edge technologies and tools for microgrid design; studies and requirements associated with the control and operation of the microgrid; architectural considerations and various control strategies for the operation of microgrid systems; renewable energy solutions integrations and solutions. The knowledge is reinforced with real-world case studies and class projects. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 518 and ECE 519) or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 606: *Advanced Data Analytics in Smart Grid.* 3 credits.
The power grid is transforming from a centralized, passive, fossil-fuel dominated and sparsely-sensed system into a distributed, active, 100% renewable, and ubiquitously-sensed system. The transformation imposes tremendous challenges on power system design, operation, and management. The emerging multi-scale data from synchrophasors, smart meters, weather, and electricity markets, along with data analytics and machine learning tools, offer state-of-the-art solutions to tackle the grid transformation challenges. This course covers data analytics and machine learning in various smart grid applications, including modeling, operation, protection, stability, forecasting, and management. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 518 and ECE 527) or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 611: *Advanced Computer Architecture.* 3 credits.
Qualitatively and quantitatively examines power, performance and security trade-offs in architecting computing systems. Explores three major components of modern general-purpose architectures: processors, memories, and networks. Enables students to understand how these components can be integrated to build complex multicore, manycore, and multithreaded architectures. Covers the architectural trade-offs in IoT, embedded, and high-performance processors. Topics include processor and system architecture in single core, multicore, multithreaded and heterogeneous architectures; memory architecture, network topology, routing, and flow control. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 511 or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 612: *Real-Time Embedded Systems.* 3 credits.
Study of real-time operating systems and device drivers for embedded computers. Emphasizes microprocessor systems and associated input device sampling strategies, including interrupt driven and polled I/O. Covers basic input/output operations, analog to digital conversion methods, I/O programming techniques and process, and communication control methodologies. Involves design project. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 511 or permission of instructor.

Registration Restrictions:

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 615: *Software/Hardware Codesign.* 3 credits.
Introduces software/hardware codesign for modern all-programmable system on chip platforms. Covers profiling, design partitioning, interfacing, debugging using integrated logic analyzers, and optimizing performance and resource utilization. Demonstrates the development of hardware accelerators using existing intellectual property cores and establishing efficient communication between software and hardware parts of complex embedded systems. Introduces high-level synthesis for improved efficiency of the development process. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 511 and 545, or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 616: *Advanced Mobile Systems and Applications.* 3 credits.
Advanced study of mobile systems and applications, with the focus on system architecture, computing paradigms, and optimization methods. Most lectures are dedicated to case studies based on the most influential research publications and best-known industry products. Special topics include the most cutting-edge applications, such as virtual and augmented reality, machine learning, and cloud computing. For each topic, the design concepts are presented from the perspective of the application performance and system design considerations. Lectures are enhanced with the comprehensive literature review and a group-based, semester-long project. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 516 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 617: *Distributed and Federated Learning.* 3 credits.
As compute resources inside of end devices, such as mobile phones, are becoming increasingly powerful, deep learning is moving from centralized data centers to clouds and end devices. Emerging techniques such as centralized distributed learning and emerging decentralized federated learning open up brand new computing paradigms to artificial intelligence. This course is designed to focus on distributed and federated learning techniques with an expected research-oriented depth and sufficient implementation practice. The course lectures cover cutting-edge algorithms and system implementations. They are enhanced with a comprehensive literature review and a group-based, semester-long project. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 527 or ECE 554 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 618: *Hardware Accelerators for Machine Learning.* 3 credits.
This course covers the hardware design principles to deploy different machine learning algorithms. The emphasis is on understanding the fundamentals of machine learning and hardware architectures and determine plausible methods to bridge them. Topics include precision scaling, approximate computing, in-memory computing, architectural modifications, GPUs, and vector architectures, as well as recent EDA tools for AI such as Xilinx AI Vitis, Xilinx HLS, Tensorflow Lite, and Caffee. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ((ECE 511 or CS 465) and (ECE 527 or ECE 554 or CS 580 or CS 688)) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 619: *Nonlinear Systems and Control.* 3 credits.
Includes motivating examples; analysis techniques include basic fixed-point theory, implicit function theorem, and dependence of trajectories on initial data and parameters. Also covers computational simulation techniques; stability theory including Lyapunov's direct method; nonlinear control systems of input-output and absolute stability; strong positive

real transfer functions; feedback linearization of nonlinear systems; nonlinear canonical forms; nonlinear decoupling; sliding control; and applications to adaptive control, neural networks, and robotics. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 620: *Optimal Control Theory.* 3 credits.
Detailed treatment of optimal control theory and its applications. Topics include system dynamics and performance criteria, calculus of variations and Pontryagin's minimum principle, computational methods in optimal control, and applications of optimal control. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521 or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 621: *Systems Identification.* 3 credits.
Foundations of parameter estimation using the least squares method. Identification of static and discrete dynamic system models. Batch and recursive (online) approaches. Model order estimation. Persistent excitation requirements. The effect of noise on model accuracy. Nonlinear estimation methods: generalized least squares and maximum likelihood. Applications in control, diagnostics, and economy. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521 and 528 or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 622: *Kalman Filtering with Applications.* 3 credits.
Detailed treatment of Kalman Filtering Theory and its applications, including some aspects of stochastic control theory. Topics include state-space models with random inputs, optimum state estimation, filtering, prediction and smoothing of random signals with noisy measurements, all within the framework of Kalman filtering. Additional topics are nonlinear filtering problems, computational methods, and various applications such as global positioning system, tracking, system control, and others. Stochastic control problems include linear-quadratic-Gaussian problem and minimum-variance control. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521 and 528, or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 623: *Distributed Control and Optimization.* 3 credits.
This course introduces the state-of-the-art design of distributed algorithms, which provide efficient and scalable tools for multi-agent systems to perform complex tasks such as cooperative control, optimization, and machine learning. To this end, the course will familiarize students with fundamental concepts and tools in dynamics and control (differential equations), matrix theory (spectrum), graph theory (topology and connectivity), and game theory (Nash equilibrium). Building on these topics, applications to be covered include multi-robot formation control (by distributed gradient flow), sensor network information fusion (by distributed averaging), resilient multi-agent decision-making (by resilient consensus), multi-robot task allocation (by distributed auction), large-scale network reconstruction (by distributed data-driven identification), and learning-based distributed coordination (by learning differentiable games). Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521

Registration Restrictions:

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 625: *Autonomous Control for Robotic Systems.* 3 credits.
The field of robotics is currently enjoying tremendous scientific, practical, and popular success. This course will introduce the fundamental disciplines of modern robotics, which include mechanics, control, and computing. These components are integrated into the analysis, design, and control of mobile robots to serve engineering or scientific needs. Students will learn: (1) how to use mathematical methods to model mobile robots and manipulators and to plan their motion; (2) how to process sensor information to form a perception of the environment; and (3) how to implement algorithms through computer systems to achieve autonomy. The specific topics covered in this course include foundations (affine transformations and Jacobian matrices), Kinematics (forward and inverse kinematics), Perception (range, sonar and image sensors) and Reactive Behaviors (linear and nonlinear feedback control). Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 627: *Adaptive Control.* 3 credits.
Topics include identification algorithms, model reference adaptive control, self-tuning regulators, convergence, stability, robustness, averaging theory, singular perturbation, and intelligent learning schemes. Students are required to study literature and complete a course project. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 521 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 628: *Random Processes in Electrical and Computer Engineering.* 3 credits.
This course focuses on Markov processes in discrete and continuous time, on renewal theory, and on Markov renewal theory. Quoting from E. Cinlar, "The theory of Markovian processes comprises the largest and most important chapter in the theory of stochastic processes. This importance is further enhanced by the many applications it has found in both the physical, biological, and social sciences and in engineering and in commerce." Non-ECE students are welcome. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 629: *Wireless Networks.* 3 credits.
The course covers the foundation and design of wireless communication networks. It includes radio channel characterization, transmission techniques for mobile radio, state-of-the-art performance evaluation of channel, resource assignment and network infrastructure, and mobility, handoff, interference, and capacity modeling applicable to wireless cellular and local networks. Additional topics covered include system architecture, control traffic loading, resource optimization, multiaccess protocols, admission policy and call control, as well as spectrum sharing technique and coexistence, and multilayer network configurations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 531 or ECE 542 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 630: *Principles of Digital Communications.* 3 credits.
Introduces design principles for optimum receivers for digital communication systems operating in additive white Gaussian noise environments. Topics include signal space concepts, baseband equivalent signals, matched filter and correlation receiver, bandwidth efficient signaling, message sequences and principles of error correction coding, and performance bounds of communications. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-

schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 631: *Software-Defined Radio.* 3 credits.
Design and implementation of the essential building blocks of a software-defined radio, including sampling, pulse shaping, modulation/demodulation, synchronization, equalization, and coding. Focus is on software implementation and integration of the building blocks in a software-defined radio platform. Other topics include software-defined radio architectures, application development on software radio platforms, and hardware acceleration for software-defined radio. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 531 or ECE 535 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 632: *Digital Communications.* 3 credits.
To reduce digital communication systems to practice, impairments induced during transmission must be mitigated. This course addresses the problems that must be addressed when implementing digital communication systems, including synchronization in time, frequency, and phase, and channel equalization. Additionally, modern techniques for achieving high power and bandwidth-efficiency, including multi-carrier modulation (OFDM), multi-channel systems (MIMO), and adaptive modulation, are discussed. Examples are drawn from current generation cellular, satellite, and terrestrial communication systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 630 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 633: *Error Control Coding.* 3 credits.
Introduction to error control coding techniques, which enable the detection and correction of errors that arise in the transmission and storage of digital data. Provides the necessary background in discrete mathematics, algebra, and number theory. Topics include classical linear block codes, convolutional codes, and modern sparse-graph codes; hardware and software implementation of encoders and decoders; and applications of error control coding to modern and emerging technologies, such as contemporary and proposed wireless networking standards, quantum communications, quantum computing, post-quantum cryptography, physically unclonable functions, and secure distributed storage media. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 511 or ECE 542 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 634: *Detection and Estimation Theory.* 3 credits.
This course covers the fundamentals of linear estimation and provides an introduction to parameter estimation. We begin with deterministic least squares and proceed to the development of the Wiener and Kalman filters. The main theme is estimation from the innovation process (Gram-Schmidt) using the orthogonality principle. We also discuss more modern subspace-based estimation approaches such as the multistage Wiener filter. In parameter estimation we introduce the maximum-likelihood approach and its implementation through the expectation-maximization algorithm. We demonstrate the workings of the EM algorithm in state space parameter estimation. This course is recommended for students interested in communication theory, control theory, and signal processing. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or equivalent

Registration Restrictions:

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 635: *Adaptive Signal Processing.* 3 credits.
Introduces adaptive systems and adaptive signal processing. Topics include correlation functions and matrices; performance functions; search of minimum; steepest descent and Newton algorithms; least mean squares algorithm; noise perturbed search and misadjustment; sequential regression algorithm and convergence issues; recursive least squares algorithm and forgetting factor; frequency domain algorithms; adaptive equalization; pseudorandom binary sequences and system identification; adaptive interference cancellation; and adaptive beam forming and arrays. Simulates adaptive algorithms. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 636: *Advanced Digital Signal Processing.* 3 credits.
Theory and practice of advanced digital signal processing techniques. Topics may include efficient high-speed algorithms for convolution, correlation, orthogonal transforms, multirate processing of digital signals, multiresolution time-frequency and time-scale analysis of one- and two-dimensional signals, and multitaper spectral estimation. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 and ECE 535

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 637: *Array Processing.* 3 credits.
Fundamentals of signal processing for sensor arrays, including conventional and adaptive beamformers, space-time random processes, beam pattern design, deterministic null-steering, sparse arrays, and robust algorithms. Applications include sonar, radar, and communications systems. Special emphasis on transferring intuition from discrete-time signal processing to narrowband array processing for uniform linear arrays. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 and ECE 535

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 639: *Satellite Communications.* 3 credits.
Comprehensive study of satellite communication systems. Topics include link budget and quality of service considerations, basics of information transmission, digital modulation and demodulation, channel coding and coded modulation, multiple access, networking services for voice, broadcasting and Internet access over satellites, payload and reliability issues, and technological applications. Understanding of satellite system architectures, propagation link characteristics, key communication techniques, power and bandwidth requirements, and various satellite communications systems and applications. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or ECE 542 or ECE 580

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 640: *Small Satellite Development.* 3 credits.
Advanced topics in satellite development life cycle, mission planning, operational considerations, structure, bus architecture, and subsystems such as power, communications, on-board computing hardware and software. In-depth study of lessons learned from CubeSat development, testing, and operations in space, as well as recommendations for the development practice, mission assurance, and required legal and technical compliances. Development executed through group design meetings, take-home designs/assignments, and/or in-house fabrication and testing. Offered by Electrical & Comp. Engineering (http://

catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 580 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 641: *Robot System Integration.* 3 credits.
Building complex systems such as robots requires knowledge and expertise across many different fields, as well as the ability to integrate them. The aim of this course is for the students to gain hands-on experience in building a robot system by integrating different components of the system. The lectures will cover fundamental topics in robotics including microcontroller, circuits, mechanical systems, modeling, perception and control. Towards the end of the course, the lectures will focus on topics focused on system integration. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisites: ME 631[B-], ECE 521[B-], CS 580[B-] and CYSE 550[B-].
[B-] Requires minimum grade of B-.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 642: *Design and Analysis of Computer Networks.* 3 credits.
The course covers the foundations of computer communication networks and introduces principles upon which the Internet and other computer networks are designed. It discusses the performance, analytical, and design aspects of packet-switched and forwarding networks, routing, and path computation algorithms. The course starts with a treatment of a single node (e.g., a router or a switch) as a queueing system such as state-dependent queues and imbedded Markov chains. It continues with the modeling of virtual channels through a network of queues. Additional topics covered include admission control algorithms modeling, performance evaluation of local and wide-area computer networks (e.g., LANs, IP/Internet, MPLS Traffic Engineering), and analysis of random-access techniques. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 643: *Network Switching and Routing.* 3 credits.
Fundamentals of switching and routing with application to communications networks, both wireline and wireless. Topics include concepts of space and time for switching and forwarding of data, scalability and performance, label swapping, algorithms for routing and path computation, constrained route optimization, traffic theory, control and signaling, and traffic engineering. The course also covers the concepts and issues underlying the design and implementation of the contemporary switched networks. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 542 or equivalent.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 645: *Computer Arithmetic.* 3 credits.
Covers computer arithmetic as applied to the design of general-purpose microprocessors and application-specific integrated circuits for cryptography, coding, and digital signal processing. Focuses on efficient implementations of all basic arithmetic operations in three major domains: integers, real numbers, and elements of Galois Fields GF(2n). Illustrates tradeoffs among various hardware algorithms and architectures depending on primary optimization criteria, such as speed, area, and power consumption. Demonstrates the use of software implementations as a source of test vectors for verification of hardware implementations and for evaluating hardware versus software speed-up. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 545 or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 646: *Applied Cryptography.* 3 credits.
Topics include need for security services in computer networks and digital devices, basic concepts of cryptology, modern symmetric ciphers, public key cryptography (RSA, elliptic curve cryptosystems, post-quantum cryptography), data integrity and authentication, digital signature schemes, key exchange and key management, standard protocols for secure mail, the web and electronic payments, security aspects of mobile communications, efficient software and hardware implementations of cryptographic primitives, attacks against implementations and relevant defenses, requirements for implementation and validation of cryptographic modules, and security engineering with cryptography. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 542 or CS 555 or CYSE 610 or INFS 612 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 647: *Post-Quantum Cryptography.* 3 credits.
A broad introduction to post-quantum cryptography (PQC), understood as a class of public-key cryptographic schemes capable of being implemented using traditional software and hardware but resistant to all known attacks using both quantum and classical computers. Topics include major types of public-key schemes, such as public key encryption, key encapsulation mechanisms (KEMs), and digital signatures. The course covers the mathematical background and basic underlying operations, such as polynomial multiplication, hash and eXtendable Output Functions, operations on matrices, and Gaussian elimination. Examples of schemes belonging to the following five PQC families are discussed: lattice-based, hash-based, code-based, multivariate, and isogeny-based. The focus is on the visual representation of algorithms and data structures and the efficient and secure implementations in software and hardware. The use of PQC schemes in major security protocols is explored. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 476, CYSE 476, CS 487, IT 466, CYSE 550, CS 587, ECE 646, ISA 656 or AIT 682) or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 648: *Digital Signal Processing Hardware Architectures.* 3 credits.
Addresses topics that include high-level DSP optimizations, such as pipelining, unfolding, and parallel processing; common DSP structures such as FFTs, filters, direct digital frequency synthesizers, and correlators; modeling of DSP algorithms in MATLAB and conversion of MATLAB models into fixed-point VHDL blocks; platform implementation issues: hardware vs. software, FPGA vs. ASIC, power, area, throughput, and applications of DSP hardware. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 535 and ECE 545 or equivalents or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 651: *Advanced Learning From Data.* 3 credits.
Review of machine learning basics to motivate deep learning networks. Examines various deep learning network architectures and models in detail, including deep forward networks, convolutional networks, recurrent networks, and autoencoders. Discusses the training and implementation of deep models, such as hyper-parameter tuning, regularization, and optimization. Introduction of deep reinforcement learning. Involves course projects with a focus on the survey of applications, research problems, and new advances. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 527 or DAEN 527 or CS 688) and (MATH 203 and STAT 346 and CS 112) or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 653: *Machine Learning Security and Privacy.* 3 credits.
Covers advanced topics in security and privacy of machine learning techniques, including differential privacy, data collection, adversarial machine learning, model watermarking, and formal verification. Students are expected to complete projects on technical topics related to the scope of the course. They will also get hands-on experience with frameworks such as TensorFlow and Tensorflow Lite. The course will emphasize research skills, such as analyzing research papers, giving technical presentations, and writing summaries and reviews. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 527 or ECE 554 or CS 688 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 655: *Advanced GPU Programming and Deep Learning.* 3 credits.
This course expands on the GPU architecture and programming concepts introduced in ECE 555 by detailing advanced architectural components, such as Tensor Processing Units (TPUs), and their role in accelerating Deep Learning (DL) applications. Lectures study example DL applications, such as object recognition, and how the GPU instruction sets, e.g., Parallel Thread Execution (PTX), are improved to accelerate DL by utilizing TPUs, load/store controllers, fetch, decode, and execute cycles, cache utilization, and emerging data types such as half-precision floating-point. Literature review sessions and lectures facilitate a rigorous study of the data flow in and out of the GPU to determine optimal ways to provide hardware acceleration for data-intensive deep learning using GPUs. Concepts such as Multi-GPU execution and virtual addressing are also introduced for further performance improvements and code modularization. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 555 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 657: *Probabilistic Machine Learning.* 3 credits.
Machine learning relies on probabilistic models to train computers to perform intelligently certain tasks such as natural language processing, image recognition, robot navigation, and resource allocation in communication networks. This course covers powerful probabilistic methodologies that have proven useful in machine learning. Both supervised learning and unsupervised learning will be discussed. We begin with basic statistical inference based on Bayesian decision theory and then discuss probabilistic models and inference methods for machine learning. These include hidden Markov models, graphical models, Bayesian networks, regression, kernels, Markov Chain Monte Carlo, and particle filters. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or OR 542 or STAT 544 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 660: *Space Systems Engineering.* 3 credits.
Overview of the scientific and engineering foundations of spacecraft systems and interaction among satellite subsystems. Topics include fundamentals on astrodynamics, power, communications, command and data handling, thermal management, attitude control, mechanical configuration, structures and launch systems. In addition to traditional instruction, a number of case studies and a team design project provide further breadth and exposure. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit. Equivalent to SYST 682.
Recommended Prerequisite: ECE 580 or SYST 520

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 664: *Information Theory.* 3 credits.
Information theory is the mathematical theory of communications. It was developed in 1948 by Claude E. Shannon. Information Theory sets bounds on achievable performance and communication rates of any communication system. The basic theory is summarized in a set of source and channel coding theorems, which are expressed in terms of information measures such as entropy, channel capacity and rate-distortion. In this course we introduce these fundamental concepts, we present and prove basic coding theorems, and provide some practical insight on implementation of these theorems. Non-ECE students are welcome. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 528 or equivalent

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 670: *Principles of Command, Control, Communications, Computing, and Intelligence (C4I).* 3 credits.
Provides broad introduction to fundamental principles of command, control, communication, computing, and intelligence (C4I). Applies principles, techniques to wide range of civilian and military situations. Discusses modeling, simulation of combat operations; studies sensing, fusion, and situation assessment processes. Derives optimal decision-making rules. Discusses concepts of C4I architectures and tools to evaluate and design systems such as queuing theory. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit. Equivalent to SYST 680.
Recommended Prerequisite: ECE 528 or SYST 611 or OR 542, or equivalent.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 674: *Systems Architecture Design.* 3 credits.
Advanced system integration and evaluation techniques are presented. Testing and analysis of design solutions using simulation and executable views are introduced using modern systems engineering tools. Model-based systems engineering is employed to integrate design and analysis artifacts. Modern architecture frameworks are used for developing practical design solutions. Examples from current practice are discussed. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit. Equivalent to SYST 621.
Recommended Prerequisite: ECE 550.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 681: *VLSI Design for ASICs.* 3 credits.
Introduces VLSI design of application-specific integrated circuits (ASICs) from front-end to back-end using HDL and modern design automation software. Covers simulation, synthesis of digital circuits using standard cells, static timing analysis, formal verification, power analysis, test generation/fault simulation, and physical design including floor planning, placement, routing, and design rule checking. Addresses deep submicron CMOS scaling issues and other advanced topics. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 545.

Recommended Corequisite: ECE 586, or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 682: *VLSI Test Concepts.* 3 credits.
Broad introduction to basic concepts, techniques, and tools of modern VLSI testing. Fundamentals of defect modeling, fault simulation, design for testability, built-in self-test techniques, and failure analysis. Test economics, physical defects and fault modeling, automated test pattern generation, fault simulation, design for test, built-in self test, memory test, PLD test, mixed-signal test, Iddq test, boundary scan and related standards, test synthesis, diagnosis and failure analysis, automated test equipment, embedded core test. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 586

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Laboratory, Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 684: *MOS Device Electronics.* 3 credits.
Study of Metal Oxide Semiconductor (MOS)-based device theory, characteristics, models, and limitations. Topics include MOS capacitor, MOSFETs, CMOS, charge coupled devices, scaling, hot carrier effects, latchup, radiation effects, and isolation techniques. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 584 or permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 685: *Nanoelectronics.* 3 credits.
Emphasizes the fundamental concepts and principles that govern the operation of nano-electronic devices (100 nm down to 1 nm.). Addresses basic device building blocks such as quantum dot (QD), single electron tunneling transistor (SETT), carbon nanotube (CNT), nanowire, etc. Considers the design and analysis of a variety of nano-devices ("quantum" or "mesoscopic" devices) and examine some notable applications. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 584

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 686: *Sensor Device Technology.* 3 credits.
Design and integration of essential sensor devices and arrays for intelligent wearable electronics and human-computer interactions. Study of the relevant electronics and semiconductor device principles, as well as various types of sensors, including optical, thermal, RF, electromechanical, chemical, inertia, and acceleration sensors. The focus is on the physical principles, device development, and advanced electronic characteristics of a variety of sensors. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 530 or ECE 584 or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 687: *Radio Frequency Electronics.* 3 credits.
This course addresses the design of electronic building blocks for radio frequency (RF) microelectronic circuits. Topics include trade-offs in RF design, transceiver architectures, low-noise amplifiers, mixers, oscillators, frequency-synthesizers, phase-locked loops, and power amplifiers. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: (ECE 584 and ECE 587) or permission of instructor

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 691: *CubeSat Design.* 1.5 credit.
First phase of a project course focused on design and early prototyping. Design and implementation of a project related to CubeSats, satellite communication ground and space systems, satellite bus modules, embedded hardware and software. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science or Engineering Computing colleges.

Schedule Type: Laboratory

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 692: *CubeSat Engineering.* 1.5 credit.
Second phase of a project course dedicated to project implementation and testing. Design and implementation of a project related to CubeSats, satellite communication ground and space systems, satellite bus modules, embedded hardware and software. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). Limited to two attempts.
Registration Restrictions:
Required Prerequisite: ECE 691[B-].
[B-] Requires minimum grade of B-.

Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science or Engineering Computing colleges.

Schedule Type: Laboratory

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 698: *Independent Reading and Research.* 1-3 credits.
Independent study under the supervision of a faculty member, resulting in an acceptable technical report. Notes: Requires written report. May be taken no more than twice for graduate credit. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 3 credits.
Recommended Prerequisite: At least two core courses and permission of instructor.

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Research

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 699: *Advanced Topics in Electrical and Computer Engineering.* 1-6 credits.
Advanced topics of current interest in electrical and computer engineering. Topics chosen so they do not duplicate other courses in department. Active participation encouraged in form of writing and presenting papers in research areas. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the term.
Specialized Designation: Topic Varies

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy, Graduate, Junior Plus, Non-Degree or Senior Plus.

Enrollment is limited to Graduate, Non-Degree or Undergraduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

700 Level Courses

ECE 701: *Research Experience in Electrical and Computer Engineering.* 3 credits.
Readings and research for early stage ECE PhD students under the direction of a faculty member. Research findings must be delivered in a professionally prepared document and an oral presentation in formats consistent with the Research Qualifying Exam. Offered by Electrical and Computer Engineering. May be taken only once. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy or Graduate.

Enrollment is limited to students with a major in Electrical and Computer Engr.

Enrollment limited to students in a Doctor of Philosophy degree.

Schedule Type: Research

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 732: *Mobile Communication Systems.* 3 credits.
Topics include modeling of mobile communication channel, signal set and receiver design for mobile communication channel, access and mobility control, mobile network architectures, connection to fixed network, and signaling protocols for mobile communication systems. Examples of mobile communication systems are presented, including pan-European GSM, North American D-AMPS, and personal communication systems. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.

Recommended Prerequisite: ECE 542 and 630.

Registration Restrictions:
Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 746: *Advanced Applied Cryptography.* 3 credits.
Discusses complex cryptographic algorithms and their implementations in software and hardware. Provides mathematical background necessary to understand, implement, and break modern cryptoalgorithms. Covers implementations of cryptosystems using smart cards, network processors, and other platforms. Discusses side channel attacks against implementations of cryptography, including timing attacks, power analysis, fault analysis, cache attacks, etc. Introduces advanced topics, such as random and pseudorandom number generators, secret sharing, zero-knowledge, and quantum cryptography. Requires a semester-long project devoted to implementation of selected algorithms or protocols in software or hardware, and/or comparative analysis of various algorithms, protocols, or implementations. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 646 or permission of instructor.

Registration Restrictions:
Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Lecture

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 747: *Cryptographic Engineering.* 3 credits.
Discusses efficient implementations of cryptographic algorithms and protocols in hardware and software, ranging from high-performance to low-power, as well as resistance to side-channel and fault attacks. Covers code breaking algorithms and practical implementations of side-channel attacks. Introduces research techniques. Requires semester-long project devoted to study of a cryptographic engineering problem, including a comprehensive literature review, problem definition, and research plan. Notes: Course will be partially lecture style, partially seminar. Students will give hour long, in depth presentations on their research topics. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May not be repeated for credit.
Recommended Prerequisite: ECE 646 or permission of instructor.

Registration Restrictions:
Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Seminar

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 795: *Engineering Seminar.* 0 credits.
Fulfills seminar requirement for MS in electrical and computer engineering programs. Invited speakers, faculty, and ECE graduate students lecture on current topics and research. Notes: Students must enroll in ECE 795 the final semester they file to graduate. Once the department verifies that the seminar requirement has been met, a grade of S (satisfactory) will be submitted. Students who have not met the seminar requirement in their final semester must continue to register for ECE 795 in subsequent semesters until the requirement is met. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree.
Registration Restrictions:
Enrollment is limited to Graduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Seminar

Grading:
This course is graded on the Graduate Special scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 797: *Scholarly Paper.* 0 credits.
Student must develop a rigorous, technical report (called Scholarly Paper) on a topic of current interest in Electrical and Computer Engineering and make an oral presentation of this report. Students fulfill this requirement through and individual project in a 600-level or above ECE graduate course. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree.
Recommended Prerequisite: Completed 18 credit hours of graduate work.

Registration Restrictions:
Enrollment is limited to Graduate level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Research

Grading:
This course is graded on the Graduate Special scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 798: *Research Project.* 1-6 credits.
Student must complete a one-semester long research project on an ECE technical topic under the guidance of a faculty advisor, and write a research report that will be presented as a departmental seminar. Notes: No more than a combined total of 3 credits may be taken towards

satisfying the master's degree, although students may register for more credits. Students may not count both ECE 799 and ECE 798 for master's degree. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 6 credits.
Recommended Prerequisite: Completed 18 credit hours of graduate work.

Registration Restrictions:
Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Thesis

Grading:
This course is graded on the Satisfactory/No Credit scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 799: *Master's Thesis.* 1-6 credits.
Research project chosen and completed under guidance of graduate faculty member that results in technical report and oral defense acceptable to thesis committee of three faculty members. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree.
Recommended Prerequisite: 9 graduate credits, and permission of instructor.

Registration Restrictions:
Enrollment is limited to Graduate or Non-Degree level students.

Students in a Non-Degree Undergraduate degree may **not** enroll.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Thesis

Grading:
This course is graded on the Satisfactory/No Credit scale. (http://catalog.gmu.edu/policies/academic/grading/)

800 Level Courses

ECE 896: *Directed Reading and Research.* 1-6 credits.
Reading and research on a specific topic under the direction of a faculty member resulting in an acceptable technical report. Offered by Electrical and Computer Engineering. May be repeated within the degree for a maximum of 21 credits. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 21 credits.
Specialized Designation: Topic Varies

Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy or Graduate.

Enrollment is limited to students with a major in Electrical and Computer Engr.

Enrollment limited to students in a Doctor of Philosophy degree.

Schedule Type: Research

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 899: *Research Topics in ECE.* 3 credits.
Studies advanced research areas in Electrical and Computer Engineering within a course format. Students will develop specialized research skills, which will also involve the presentation of their own work, developed individually and within groups. This course may be repeated for credit if the research areas differ. Notes: This will be an irregularly scheduled course intended for advanced master's students who want to pursue a specific topic to more depth than a typical course offers at the master's level. It will prepare students to undertake their individual research topics when they move on to pursue a Ph.D. program, or enter a research environment in their chosen professional careers. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree for a maximum 9 credits.
Specialized Designation: Topic Varies

Recommended Prerequisite: Completion of at least one 600 or 700 level course in the Research Topic area; and permission of instructor.

Registration Restrictions:
Enrollment is limited to Graduate level students.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Research

Grading:
This course is graded on the Graduate Regular scale. (http://catalog.gmu.edu/policies/academic/grading/)

900 Level Courses

ECE 998: *Doctoral Dissertation Proposal.* 1-12 credits.
Work on research proposal that forms basis for doctoral dissertation. Notes: No more than 24 credits of ECE 998 and 999 may be applied to doctoral degree requirements. Offered by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree.
Registration Restrictions:
Enrollment is limited to Graduate level students.

Enrollment limited to students in the College of Science, Engineering Computing or Schar School of Policy and Gov colleges.

Schedule Type: Dissertation

Grading:
This course is graded on the Satisfactory/No Credit scale. (http://catalog.gmu.edu/policies/academic/grading/)

ECE 999: *Doctoral Dissertation.* 1-12 credits.
Formal record of commitment to doctoral dissertation research under direction of ECE faculty member. Notes: Students must complete minimum 12 credits of doctoral proposal (ECE 998) and doctoral dissertation research (ECE 999) Maximum of 24 credits of ECE 998 and 999 may be applied to degree. Students who choose to take less than 24 credits of ECE 998 and 999 may earn remaining credits from approved course work. Students cannot enroll in ECE 999 before research proposal accepted and approved by dissertation committee. Offered

by Electrical & Comp. Engineering (http://catalog.gmu.edu/colleges-schools/engineering-computing/engineering/electrical-computer/). May be repeated within the degree.
Registration Restrictions:
Enrollment limited to students with a class of Advanced to Candidacy.

Enrollment is limited to Graduate level students.

Enrollment limited to students in the Engineering Computing college.

Schedule Type: Dissertation

Grading:
This course is graded on the Satisfactory/No Credit scale. (http://catalog.gmu.edu/policies/academic/grading/)