Master of Science in Electrical and Mechatronics Engineering

The Master of Science in Electrical and Mechatronics Engineering (MSEME) program aims to offer perspective students a graduate program with strong foundations in theory and practical to meet the needs of technical professionals with advanced learning in a specialized discipline of electrical and mechatronics engineering. The program will help students develop new technologies in the emerging fields such as robotics and automation, drone design, unmanned systems and control, mechatronics, computer networks, wireless communications, signal and image processing, and Internet of Things (IoT) for a wide range of applications including agriculture, health care, automobile, aerospace, and clean energy systems. The MSEME program offers two tracks: (1) Mechatronics and Control; and (2) Communications and Networks.

Program Educational Objectives:

Graduates with a Master's of Science in Electrical and Mechatronics Engineering will be able to:

- Demonstrate in depth knowledge of the fundamental principles, concepts, terminologies and methodologies used for design and analysis of broader mechatronics and control systems or components, as well as communications and networks systems or components.
- Demonstrate the ability to solve real-world problems in the electrical and mechatronics engineering and related field.
- Demonstrate the ability to entry research-based doctoral studies in the discipline.
- Demonstrate the ability to be in leadership positions in electrical and mechatronics engineering and related disciplines.

Students will learn interdisciplinary and cross-disciplinary methods that are broadly applicable in the emerging field of communications and networks, and mechatronics and control, etc. They will also be given specific instruction and hands-on laboratory experimental leaning experiences on how to apply these methods to a large range of problems in electrical and mechatronics engineering.

General Requirements for the MSEME Degree:

All students in the Masters of Science in Electrical and Mechatronics Engineering program will take **thirty (30)** credit hours with the Thesis option or **thirty-three (33)** credit hours with the Non-thesis option of graduate-level courses to graduate from program, not including any provisional admission course requirements, over four semesters. A minimum overall GPA of 3.0 must be maintained. Students are also required to obtain a C or better in all courses that are to count towards graduation. Students can enroll in Electrical and Mechatronics Engineering program courses only if they have been admitted to the program or given permission by course instructor.

The time limit for completing the M.S. degree is five (5) years from the first enrollment in the graduate program. This includes any Provisional Admission course requirements to be met. Any exception to the time limit must be approved by the UMES Graduate School.

Thesis option: the student is required to take three core (9 credits) and a minimum of five engineering elective (15 credits) graduate level courses, including ENEM 688 Independent Study and ENEM 698 Graduate Seminar, and six credits of Thesis (ENEM 799). The thesis must be supervised by a member of the faculty member as a thesis advisor and the initial thesis proposal must be defended with an oral presentation (see below) and approved by student's thesis committee (three members including advisor). The thesis must be submitted to the department in a bound form after the oral defense which will take place after the thesis research is completed. A student is required to submit at least one journal/conference paper from his/her thesis work before the defense.

Non-thesis option: the student is required to take three core (9 credits) and a minimum of seven engineering electives (21 credits) graduate level courses, including ENEM 688 Independent Study and ENEM 698 Graduate Seminar, and a 3-credit hour research project (ENEM 696**)** that must be approved by the project advisor. A copy of the resulting scholarly paper (if any) must be submitted to the department. A Student is advised to do scholarly activity out of his/her project work.

All M.S. students must choose either the thesis or non-thesis option. There is no course-only option.

MSEME Other Requirements

(1) Maximum of two graduate-level course units may be transferred from another institution to apply toward the MSEME degree. Transferred courses must logically fit into the student's graduate program. The student's graduate advisor decides which courses are acceptable. UMES approval of transfer credit may also be required. These two courses should not have been used in fulfillment of any other degree(s).
(2) Any coursework more than six years old at the time of the final examination will not be used to fulfill any of the MSEME degree requirements.
(3) All graduate credits must have letter grades of A, B, or C, or pass/fail grades of S (Satisfactory). No More than two graduate courses with letter grade C will be accepted.
(4) A minimum grade point average (GPA) of 3.0 is required to remain in good standing and to graduate.
(5) Elective engineering courses should be primarily from one of the two tracks specified in this document. Students in each track can take 2 courses (6 credits) from the other track to satisfy graduation requirement upon approval of both student's advisor and Director of graduate program.
(6) Up to maximum 2 courses (6 credits) from other UMES departments of the physical, mathematical, biological, agricultural or similar sciences may be included to round out

student's overall program study. All courses from outside of the Engineering Master's Program must be graduate 600-level courses. Prior approval of both student's advisor and Director of graduate program is required for all external courses.

(7) Up to maximum 3 credits of ENEM 688 Independent Study are allowed upon student's advisor and Director of graduate program's approval. Independent Study needs to be structured by the faculty member with a clearly defined syllabus for the prior approval.

(8) No more than one credit of ENEM 698 Graduate Seminar may be included. Combined total number of credits of ENEE 698 Graduate Seminar and ENEE 688 Independent Study may not exceed three.

MSEME Degree Curriculum

Electrical and Mechatronics Engineering Program Core Courses

	Course Description	Credit Hours
ENEM 601	Linear Systems Theory	3 hrs
ENEM 602	Computational Methods in Engineering	3 hrs
ENEM 603	Random Signals Analysis	3 hrs

Electives Courses for Mechatronics and Control Track

	Course Description	Credit Hours
ENEM 611	Mechatronics	3 hrs
ENEM 612	Microelectronics Devices and Circuits	3 hrs
ENEM 613	Digital Control System	3 hrs
ENEM 614	Robotics	3 hrs
ENEM 615	Nonlinear Systems Analysis and Control	3 hrs
ENEM 616	Embedded Systems Design	3 hrs
ENEM 617	Autonomous Systems	3 hrs
ENEM 618	Mechatronic System Design, Integration, and Test	3 hrs
ENEM 619	Micro-Electro-Mechanical Systems	3 hrs
ENEM 620	Mechanical Vibrations	3 hrs
ENEM 621	Structural Design	3 hrs
ENEM 622	Advanced Dynamics	3 hrs
ENEM 623	Finite Element Method and Applications	3 hrs
ENEM 624	Aerodynamics for Unmanned Aerial Systems	3 hrs
ENEM 670	Selected Topics in Engineering	3 hrs
ENEM 698	Graduate Seminar	(1-3) hrs
ENEM 688	Independent Study	(1-3) hrs

Electives Courses for Communications and Networks Track

	Course Description	Credit Hours
ENEM 641	Detection and Estimation Theory	3 hrs
ENEM 642	Digital Signal Processing	3 hrs
ENEM 643	Principles of Digital Communications	3 hrs
ENEM 644	Wireless Communications	3 hrs
ENEM 645	Principles of Communications Networks	3 hrs
ENEM 646	Wireless Networks	3 hrs
ENEM 647	Advanced Topics in Computers Networks	3 hrs
ENEM 648	Coding and Applications	3 hrs
ENEM 649	Design and Optimization of Networks	3 hrs
ENEM 650	Digital Integrated Circuit Design	3 hrs
ENEM 651	RF Integrated Circuit Design	3 hrs
ENEM 652	Introduction to Machine Learning	3 hrs
ENEM 653	Computer Vision and Image Processing	3 hrs
ENEM 670	Selected Topics in Engineering	3 hrs
ENEM 698	Graduate Seminar	(1-3) hrs
ENEM 688	Independent Study	(1-3) hrs

Engineering Research/Project Courses

	Course Description	Credit Hours
ENEM 696	Master Project	3 hrs
ENEM 799	Master Thesis	(3-6) hrs

Typical Plan of Study M.S.E.M.E. Degree Students			
First Year			
3 Core Courses + 3 Approved Electives			
Fall	**Credit**	**Spring**	**Credit**
ENEM 601 Linear Systems Theory	3	ENEM 603 Random Signals Analysis	3
ENEM 602 Computational Methods in Engineering	3	ENEM 6XX Approved Elective	3
ENEM 6XX Approved Elective	3	ENEM 6XX Approved Elective	3
Second Year			
Fall	**Credit**	**Spring**	**Credit**
THESIS OPTION *(30 credit hours)*: 2 Electives + 6 Hrs for M.S. Thesis			
ENEM 6XX Approved Elective	3	ENEM 799 Master Thesis	3
ENEM 6XX Approved Elective	3		
ENEM 799 Master Thesis	3		
PROJECT OPTION *(33 credit hours)*: 3 Electives + 3 Hrs for M.S. Nonthesis			
ENEM 6XX Approved Elective	3	ENEM 6XX Approved Elective	3
ENEM 6XX Approved Elective	3	ENEM 696 Master Project	3
ENEM 6XX Approved Elective	3		

ELECTRICAL & MECHATRONICS ENGINEERING COURSE DESCRIPTIONS

ENEM 601 Linear Systems Theory: 3 credits. Methods of linear system analysis, in both time and frequency domains for continuous and discrete systems, as well as the analysis and design of systems control. This course will introduce time-domain systems dynamic control fundamentals and their design issues for electrical engineering applications. Emphasis will be on linear, time-invariant, multi-input multioutput continuous time systems. Topics include open and closed-loop state-space representations, analytical solutions, computer simulations, stability, controllability, observability, and controller/observer design.

ENEM 602 Computational Methods in Engineering: 3 credits. Fundamentals of linear algebra and basic operations of vectors and matrices; error analysis; solution of a system of linear equations; iterative solution of nonlinear equations; numerical integration; numerical solution of differential equations; introduction to Matlab software; programming and applications relating to the computational functions in Matlab.

ENEM 603 Random Signals Analysis: 3 credits. Foundations for the engineering analysis of random signals and stochastic processes: Review of probability theory, Introduction to stochastic processes, Continuous time and discrete time processes, Mean functions, correlation functions, covariance functions, noise, Strict- and wide-sense stationarity, ergodicity, Gaussian processes, power spectral densities, mean square estimation, Markov processes, estimation of random variables and model parameters.

ENEM 611 Mechatronics: 3 credits. Physical and mathematical modeling of mechanical, electrical, electromechanical, thermal, fluid, and multidisciplinary physical systems; sensors and electronics for measurements of system; embedded/external feedback control using conventional and intelligent control algorithms; computer aided engineering tools for mechatronic system design and analysis; practical applications using mechatronic devices.

ENEM 612 Microelectronic Devices and Circuits: 3 credits. Introduces Modeling of microelectronic devices, and basic microelectronic circuit analysis and design. The topics covered include modeling of microelectronic devices, basic microelectronic circuit analysis and design, physical electronics of semiconductor junction and MOS devices, relation of electrical behavior to internal physical processes, development of circuit models, and understanding the uses and limitations of various models.

ENEM 613 Digital Control Systems: 3 credits. Theoretical foundation needed to implement the microprocessor in control applications. Effects of sampling, data conversion, quantization, finite word length and time delays on system response and stability are examined. Pole-placement and

observer/estimator techniques. Actual construction of a microcomputer-based controller culminates the course

ENEM 614 Robotics: 3 credits. Introduction to industrial manipulator systems; Kinematic and dynamic models of robotic arms; homogeneous transformations; forward and inverse kinematics; motion control through coordinate transformations; robotic vision and sensors.

ENEM 615 Nonlinear Systems Analysis and Control: 3 credits. Introduction to Nonlinear Phenomena: Multiple Equilibria, Limit Cycles, Complex Dynamics, Bifurcations Second Order Nonlinear Systems: Phase Plane Techniques, Limit Cycles - Poincare-Bendixson Theory, Index Theory, Input-output analysis and stability: Small Gain Theorem, Passivity, Describing Functions Lyapunov Stability Theory: Basic stability and instability theorems, LaSalle's theorem, Indirect method of Lyapunov Linearization by State Feedback: Input-Output and Full State Linearization, Zero Dynamics, Inversion, Tracking, Stabilization.

ENEM 616 Embedded Systems Design: 3 credits. Topics covered include automotive embedded system requirements, verification during design, sneak circuit analysis, worst-case circuit analysis, design considering component tolerances and non-ideal behavior, thermal analysis, EMC analysis, FMEA analysis, grounding rules for circuits, six sigma, fault tolerance, risk analysis, reliability issues, trade-offs in design, delays in automotive networks, and software-in-the-loop and hardware-in-the-loop tests.

ENEM 617 Autonomous Systems: 3 credits. Present applications and future roles of autonomous manned and unmanned systems. The course introduces theoretical and practical backgrounds for components and integration of autonomous vehicle systems. Topics include mobility dynamics and control, sensors and perception, cognition and decision, action and commands, computer communications and integration. Case studies include lane following, obstacle avoidance, leader following, waypoint navigation and guidance.

ENEM 618 Mechatronic System Design, Integration, and Test: 3 credits. This course addresses in detail the systems engineer’s responsibilities and activities during the conceptual, design and integration and test and evaluation phases of a system development program. Systems engineering tools commonly employed at these stages of a program are presented along with selected problems that illustrate both the applicability and limitations of commonly employed tools and procedures. The course steps through conceptual design beginning with analysis of needs and objectives and proceeding to the exploration of alternative concepts and the selection of a concept that best meets goals of performance, timeliness, and affordability. Topics include definition of operational scenarios, functional analysis, risk assessment, system tradeoffs, measures of effectiveness, and requirements formulation.

ENEM 619 Micro-Electro-Mechanical Systems: 3 credits. A comprehensive overview of MEMS technique and MEMS control. Topics include MEMS fabrication processes, MEMS sensors and actuators, Dynamic modeling of MEMS, control, signal processing, and electronics for MEMS, and case studies of MEMS devices.

ENEM 620 Mechanical Vibrations: 3 credits. Linear free and forced response of one and multiple degree of freedom systems. Equations of motion of discrete systems. Free vibration eigenvalues and eigenvectors. Applications to engineering systems including vibration isolation, rotating imbalance, vibration absorbers and balancing of rotating machinery, and energy harvesting.

ENEM 621 Structural Design: 3 credits. Introduction to elasticity, stress, strain, material properties, stress function, failure criteria, fracture, fatigue, elasticity solution to bending, advanced torsion, buckling of columns, energy methods, plates and shells, plastic deformation.

ENEM 622 Advanced Dynamics: 3 credits. This graduate level course deals with the study of mechanical systems undergoing change of state described by the motions of their part under the influence of surrounding factors. The primary objective of this course is to equip students with analytical tools needed to conduct accurate and realistic dynamic analysis, and it is recommended for students pursuing an interest in system dynamics, mechanics, robotics, controls, and other relevant areas of mechanical and aerospace systems. The fundamental concepts of Newtonian mechanics and Hamilton's principle from the viewpoint of Variational approach will be taught in this class. Students will also learn the analytical applications of Euler's and Lagrange's equations of motion to model rigid body system dynamical properties.

ENEM 623 Finite Element Method and Applications: 3 credits. This course covers the introduction to finite element method and applications such as unmanned and mechatronics systems; relations between stresses, strains, displacements, temperature and material properties; discretization and meshing; force vector, displacement vector, stiffness matrix, assembly process, solution techniques; truss elements, beam elements; triangular and quadrilateral elements; iso-parametric formulation; plane stress and plane strain applications; penalty and Lagrangian methods; software applications and simulations.

ENEM 624 Aerodynamics for Unmanned Aerial Systems: 3 credit. This course covers the introduction to aerodynamics fundamental concepts such as lift, drag, moment, pressure distribution, boundary layers for design and testing of unmanned aerial systems (UAS) with fixed or rotatory wings; potential theory of bodies; airfoil theory and applications; finite wing theory and applications; introduction to Navier-Stokes equations; laminar boundary layers; turbulent boundary layers; instability and turbulence/separation; introduction to airfoil design; computational fluid dynamics (CFD) technique.

ENEM 641 Estimation and Detection Theory: 3 credits. Decision theory: Binary hypothesis testing, M-ary testing, Bayes, Neyman-Pearson, Min-Max. Performance. Probability of error, ROC. Estimation theory: linear and nonlinear estimation, parameter estimation. Bayes, MAP, maximum likelihood, Cramér-Rao bounds. Bias, efficiency, consistency. Asymptotic properties of estimators. Orthogonal decomposition of random processes and harmonic representation. Waveform detection and estimation. Wiener filtering and Kalman-Bucy filtering. Elements of identification. Recursive algorithms. Spectral estimation. The level of this course is suitable for research students in communications, control, signal processing, and related areas

ENEM 642 Digital Signal Processing: 3 credits. Introduction to digital signal processing; discrete-time description of signals; z-transform; digital filter structures; infinite and finite impulse response filter design techniques. Advanced topics include design of quadrature mirror filter banks and discrete wavelet transforms.

ENEM 643 Principles of Digital Communications: 3 credits. This course focuses on the fundamental principles behind reliable digital data transmission over noisy and band-limited channels. Signaling schemes, channel models, and receiver structures widely used in practical systems are developed and analyzed. The communication techniques covered in the course are applications of digital signal processing, detection, estimation, and information theories. The covered topics include: modern communications; probabilistic viewpoint; vector representation of signal; signal spaces; vector channels; additive white Gaussian noise; optimum receivers; maximum-likelihood detection; error probabilities; memoryless modulation methods; intersymbol interference (ISI); Nyquist signaling; equalization; complex baseband models; noncoherent detection; source coding; error control coding.

ENEM 644 Wireless Communications: 3 credits. Introduction to wireless communication principles and systems. Wireless channel models, TDMA, FDMA, spread spectrum, CDMA, equalization, detection, estimation, coding, security, quality assessment of service and personal communications. Modern generation wireless standards are also discussed.

ENEM 645 Principals of Communications Networks: 3 credits. This course covers advanced subjects in computer networks. Topics will include Internet architecture and core protocols for congestion control, forwarding, naming, and routing; approaches to achieve reliability, scalability, and security; and design of hyperscale cloud networks, data centers, wireless networks, content delivery, enterprise networks, quality of service, and network security. Material will range from the classics to the latest results, and from analytical foundations to systems design and real-world deployment.

ENEM 646 Wireless Networks: 3 credits. Fundamental concepts of wireless networks: network architecture for personal communications systems, wireless LANs, radio, tactical and other wireless networks, and design and analysis of protocols, and wireless network programming.

ENEM 647 Advanced Topics in Computer Networks: 3 credits. Introduction to security principles and practices of computer and network systems. Topics include basic computer security concepts, common attacking techniques, common security policies, basic cryptographic tools, authentication, access control, network intrusion detection, software security, operating system security, network security, firewalls, network management, email and web security, legal and ethical issues in computer security.

ENEM 648 Coding Theory and Applications: 3 credits. The theory and practice of error control coding with emphasis on linear, cyclic, convolutional, and parallel concatenated codes (Hamming codes, Repetition codes, polynomial codes, Reed Solomon Codes). Turbo codes, Viterbi decoding and applications.

ENEM 649 Design and Optimization of Networks: 3 credits. A comprehensive introduction to network flows with an integrative view of theory, algorithms, and applications. It covers shortest path, maximum flow, and minimum cost flow problems, including a description of new and novel polynomial-time algorithms. It also covers topics from basic network design to protection and restoration design, to multi-layer network design while taking into account routing and flow requirement as applicable in different network architecture, protocol and technologies.

ENEM 650 Digital Integrated Circuit Design: 3 credits. Introduction to the design process of VLSI CMOS circuits. This course also covers all the major steps of the design process, including logic, circuit, and layout design. A variety of computer-aided tools are discussed and used to provide VLSI design experience that includes design of basic VLSI CMOS functional blocks, and verification of the design, testing, and debugging procedures.

ENEM 651 RF Integrated Circuit Design: 3 credits. Introduction to the design and analysis of radio frequency integrated circuits (RFICs) for communications. Topics include an overview of RF and wireless technology, fundamental concepts in RF design such as nonlinearity, sensitivity, and dynamic range. Matching and impedance transformation networks, and S-parameters. Transceiver architectures (Heterodyne, Direct Conversion, etc.), modulation and up-conversion concepts. A detailed examination of each of the blocks in the transceiver architectures discussed: Low Noise Amplifiers, Mixers, Oscillators, Frequency Synthesizers, and Power Amplifiers.

ENEM 652 Introduction to Machine Learning: 3 credits. An introduction to theoretical foundations, algorithms, methodologies, and applications for machine learning and provides a foundation for advanced study in topics shared by machine learning, statistical inference, and

signal processing. Topics may include supervised methods for regression and classification (linear models, trees, neural networks, ensemble methods, instance-based methods); generative and discriminative probabilistic models; Bayesian parametric learning; density estimation and clustering; Bayesian networks; time series.

ENEM 653 Computer Vision and Image Processing: 3 credits. An introduction to computer vision, including fundamentals of image formation, camera imaging geometry, feature detection and matching, stereo, motion estimation and tracking, image classification, scene understanding, and deep learning with neural networks. We will develop basic methods for applications that include finding known models in images, depth recovery from stereo, camera calibration, image stabilization, automated alignment, tracking, boundary detection, and recognition.

ENEM 670 Selected Topics in Engineering: 3 credits. This course covers selected topics on special or current topics and issues relating to electrical engineering, mechatronics, control, communications, and networks etc. for master's students in engineering and other areas.

ENEM 688 Independent Study: [1-3 credits]. An independent study conducted with a faculty member on a relevant topic. The course needs to be structured by the faculty member with a clearly defined syllabus for the Master's student. The course needs prior approval of the student's advisor and graduate program director.

ENEM 698 Graduate Seminar: [1-3 credits]. Every semester regular seminars are held in electrical and mechatronics engineering and in the areas of specialization offered by the department. They may be taken, by arrangement with the student's advisor, for repeated credit. Prerequisite: Permission of Instructor.

ENEM 696 Master's Project: 3 credits. The student will conduct advanced research of interest to the student and the instructor. A written proposal, which outlines the nature of the project, must be submitted for approval. This course is only available to Non-thesis option students. The student is required to complete a scholarly paper. Prerequisite: Master standing and Consent of advisor. (**Satisfactory or Unsatisfactory**)

ENEM 799 Master's Thesis: credits var. (3-6). Master of Science thesis research will be conducted under the supervision of the thesis committee chairperson leading to the completion of the Master's thesis. Six credits in two semesters; Three credits for each semester. This course is only available to Thesis option students. Prerequisite: Master standing and Consent of advisor. (**Satisfactory or Unsatisfactory**).