Ph.D. in Applied Computing and Engineering Curriculum (60 credits in total)

1. Concentration in Mechatronics and Control
2. Concentration in Communications and Networks

The sixty (60) credit hours of the Ph.D. in Applied Computing and Engineering are broken down into the following 4 categories:

A) Core Courses	12 Credit hours
B) Free Electives	12 Credit hours
C) Concentration Courses	24 Credit hours
D) Dissertation Hours	12 Credit hours
	---
	60 Credit hours in total

Core Courses (12 Credit hours):

Core courses include the 3 core courses (9 Credit hours) specified for the Master of Science Program in Electrical Engineering and Mechatronics plus 1 additional approved core course (3 Credits hour). That includes the following courses:

1) ENEM 601 Linear Systems Theory	3 Credit hours
2) ENEM 602 Computational Methods in Engineering	3 Credit hours
3) ENEM 603 Random Signals Analysis	3 Credit hours
4) Additional approved core course	3 Credit hours
	---
	12 Credit hours of Core Courses

Concentration Courses (24 Credit hours):

Concentration courses include 6 courses of PhD 700 level (18 Credit Hours) listed on the same concentration plus 2 Master Thesis courses (6 Credit hours). That includes the following courses:

1) 1st 700-level (or a 600-level course)	3 Credit hours
2) 2nd 700-level (or a 600-level course)	3 Credit hours
3) 3rd 700-level (or a 600-level course)	3 Credit hours
4) 4th 700-level PhD course	3 Credit hours
5) 5th 700-level PhD course	3 Credit hours
6) 6th 700-level PhD course	3 Credit hours
7) ENEM 799 Master Thesis	3 Credit hours
8) ENEM 799 Master Thesis	3 Credit hours
	---
	24 Credit hours of Concentration Courses

Note: Out of 6 PhD 700-level courses required, 2 Independent Study courses (maximum of 6 credit hours) may be allowed.

Free Electives: (12 Credit hours):

Free elective courses include 4 of either 600-level courses (listed in the Master program in Electrical and Mechatronics) or 700-level PhD courses of the program or in combined (12 Credit hour). The courses counted toward free electives are not those counted toward core or concentration courses. That includes the following courses:

1) 1st 600-level or 700-level course (different from core or concentration courses) 3 Credit hours
2) 2nd 600-level or 700-level course (different from core or concentration courses) 3 Credit hours
3) 3rd 600-level or 700-level course (different from core or concentration courses) 3 Credit hours
4) 4th 600-level or 700-level course (different from core or concentration courses) 3 Credit hours

---

12 Credit hour

Dissertation Hours: (12 Credit hours):

Dissertation hours includes a total of 12 Credit hours of dissertation research conducted under guidance of a faculty advisor along with a PhD Advising Committee. The dissertation hours may be completed in the minimum of 4 semesters. The dissertation hours may be completed as follows:

1) ENEM 899 Doctoral Dissertation Research 3 Credit hours
2) ENEM 899 Doctoral Dissertation Research 3 Credit hours
3) ENEM 899 Doctoral Dissertation Research 3 Credit hours
4) ENEM 899 Doctoral Dissertation Research 3 Credit hours

---

12 Credit hours

Note: Students are eligible to take ENEM 899 only after they have advanced to candidacy.

Note: Doctoral candidates are automatically registered by the Registrar for each fall and spring semester for six-credit blocks of ENEM899 until they graduate.

Note: Students who have not yet reached candidacy status may register for ENEM898: Pre-candidacy Research. ENEM898 does not fulfill any course requirements and is not equivalent to ENEM899 in satisfying the dissertation research credit requirement.

Candidacy:

PhD students may reach candidacy status if meeting one of the two criteria descried below:

Criterion 1: Comprehensive Qualifying Exam

With the approval of the PhD advisor, a PhD student chooses 3 graduate courses out of the courses he/she has taken for a comprehensive qualifying exam. The faculty members assigned to the selected courses provide the PhD student with comprehensive tests. The tests are scheduled on 3 different dates for each course. The entire testing is expected to conclude in one entire month. The result of the tests will be discussed with the PhD student in a meeting in attendance of the faculty examiners, and PhD advisor. If the PhD student passes all 3 tests in all 3 selected courses, he/she secures PhD candidacy. If the PhD student does not pass any of the 3 tests, the failed test is repeated until he/she passes.

Criterion 2: Journal Paper Publication

If the PhD student publishes 1 journal article in collaboration with his/her PhD advisor on the topics related to his/her on-going research activities while attending UMES and being admitted to the PhD program, he/she secures candidacy.

PhD Advising Committee:

Upon reaching candidacy status, a PhD candidate requires to form a PhD Advisory Committee consistent with the School of Graduate Studies policies. The committee is composed of 5 faculty members. The PhD Advisor chairs the committee.

Dissertation Proposal:

A PhD candidate requires to present a Dissertation Proposal to the PhD Advisory Committee after the dissertation research is defined and formed for further studies. If the PhD Advisory Committee approves the candidate's Dissertation Proposal, the candidate is allowed to continue the research toward completion. Otherwise, the Dissertation Proposal is repeated after the committee's feedback is implemented.

Dissertation Defense:

Upon completion of dissertation research, and with the PhD Advisor approval, a PhD Candidate defends the dissertation in an oral form in the presence of the PhD Advisory Committee. The Dissertation Defense is not allowed unless Dissertation Proposal was completed successfully. The write-up of the dissertation research must be in a complete form so the candidate is allowed to defend. If the PhD Advisory Committee passes the candidate's Dissertation Defense, the candidate meets the Dissertation Hours requirements. If the candidate does not pass, the defense is repeated after the PhD Advisory Committee's feedback is implemented.

600 level courses (including core and elective courses) are identical to the curriculum of the Master of Science in Electrical and Mechatronics Engineering. (see the link below: MSEME curriculum)

700 level courses are listed below:

Elective Courses for Mechatronics and Control Track (700 Level)

ENEM 711	Continuum Mechanics	3 hrs
ENEM 712	Elasticity	3 hrs
ENEM 713	Mechanics of Composite Structures	3 hrs
ENEM 714	Design of Autonomous Aerial Systems	3 hrs
ENEM 715	Nano-mechanics	3 hrs
ENEM 716	Advanced Fluid Mechanics	3 hrs
ENEM 717	Computational Fluid Dynamics	3 hrs
ENEM 718	Advanced Vibrations	3 hrs
ENEM 719	Optimal Control	3 hrs
ENEM 720	Adaptive Control	3 hrs

Elective Courses for Communications and Networks Track (700 Level)

ENEM 741	Probability and Random Processes	3 hrs
ENEM 742	Stochastic Processes	3 hrs

ENEM 743	Information Theory	3 hrs
ENEM 744	Adaptive Signal Processing	3 hrs
ENEM 745	Channel Coding Theory	3 hrs
ENEM 746	Stochastic Control	3 hrs
ENEM 747	Optimization Methods in Signal Processing and Machine Learning	3 hrs
ENEM 748	Introduction to Microwave Circuit	3 hrs
ENEM 749	Introduction to Numerical Electromagnetics	3 hrs
ENEM 770	Selected Topics in Engineering	3 hrs

Dissertation Research Credits

ENEM 898	Pre-Candidacy Research	1-8 hrs
ENEM 899	Doctoral Dissertation Research	1-8 hrs

ENEM 711 Continuum Mechanics: 3 credits. The general theory of continuous medium governs both solid and fluid mechanics. Kinematics of large deformation, stress, and strain tensors, conservation laws including conservation of mass, energy, linear and angular momentum, constitutive equations, and material models for elasticity, viscoelasticity, and plasticity.

ENEM 712 Elasticity: 3 credits. Fundamentals of solid mechanics and deformation, stress-strain and equilibrium and compatibility equations, generalized Hook's law, boundary conditions. Plane strain, generalized plane stress, and planar elasticity. Airy stress function, torsion and bending, St. Venant principle, introduction to thermoelasticity, and numerical methods.

ENEM 713 Mechanics of Composite Structures: 3 credits. Current and potential applications of composite materials, fibers, matrices, manufacturing methods for composites, anisotropic elasticity, micromechanics for determining mechanical properties of composite materials, classical lamination theory, failure and strength analysis of composite materials, mathematical modeling, and other advanced topics related to mechanics of composite materials.

ENEM 714 Design of Autonomous Aerial Systems: 3 credits. Introduction to unmanned aerial vehicles, unmanned aircraft design; conceptual unmanned aerial vehicles design based on concepts drawn from weight estimation, aerodynamics, aircraft structure, stability and control, propulsion, navigation, guidance, communication, and design of control system; design for efficiency, design for performance, design for stability; flight dynamics equations are emphasized for design purposes; introduction to ground, wind tunnel, and flight testing.

ENEM 715 Nano-mechanics: 3 credits. Topics in computational nanomechanics, which involves the study of materials properties and structures down to a nanometer; classical molecular dynamics, lattice mechanics, Methods of thermodynamics and statistical mechanics, multiple-scale modeling, bridging scale and numerical applications, the material design.

ENEM 716 Advanced Fluid Mechanics: 3 credits. Advanced topics in fluid mechanics include Navier-stokes equations and their exact solutions for classic cases, approximate solutions of Navier-Stokes equations, inviscid flow, irrotational flow, potential flow, and applications; boundary layer theory, introduction to compressible flow, introduction to turbulent flow.

ENEM 717 Computational Fluid Dynamics: 3 credits. Physical and mathematical foundations of computational fluid mechanics with emphasis on applications. Classification of partial differential equations and solution techniques, Finite Difference Formulations, Solution methods for model equations, the Euler, and the Navier-Stokes equations. The finite volume formulation of the equations, Truncation errors, stability, conservation, monotonicity, mesh generation. Computer coding and commercial software projects are included.

ENEM 718 Advanced Vibrations: 3 credits. Free and forced vibrations of multi-degree-of-freedom systems, modal analysis, Hamilton Principle and Energy Method to analyze free and forced vibrations of continuous systems such as axial bars, beams, shafts, etc with different

boundary conditions; different numerical methods and in particular finite difference methods to analyze discretized multi-degree-of-freedom systems.

ENEM 719 Optimal Control: 3 credits. Principles of optimal control theory for dynamics systems, constrained and unconstrained optimization problems, vibrational calculus, dynamic programming, Pontryagin's maximum principle, Hamilton-Jacobi-Bellman equation. Interactive numerical techniques for finding optimal trajectories.

ENEM 720 Adaptive Control: 3 credits. Introduction to control of systems with undetermined or time-varying parameters. Theory and application of self-tuning and model reference adaptive control for continuous and discrete-time deterministic systems. Model-based methods for estimation and control, stability of nonlinear systems, adaptation laws, and design and application of adaptive control systems.

ENEM 741 Probability and Random Process: 3 credits. Discrete-time and the continuous-time cases. Basic concepts of random variables, random vectors, stochastic processes, and random fields. Common random processes including the white noise, Gaussian processes, Markov processes, Poisson processes, and Markov random fields. Moment analysis (including Karhunen-Loeve transform), the frequency-domain description, and linear systems applied to stochastic processes. Elements of estimation theory and optimal filtering including Wiener and Kalman filtering. Advanced topics in modern statistical signal processing such as linear prediction, linear models and spectrum estimation are discussed

ENEE 742 Stochastic Process: 3 credits. Correlations and spectra. Quadratic mean calculus, including stochastic integrals and representations, wide-sense stationary processes (filtering, white noise, sampling, time averages, moving averages, autoregression). Renewal and regenerative processes, Markov chains, random walk and run, branching processes, Markov jump processes, uniformization, reversibility and queuing applications

ENEM 743 Information Theory: 3 credits. Introduction to information theory. Information measures: entropy, mutual information, relative entropy and differential entropy. These topics are connected to practical problems in communications, compression, and inference, including lossless data compression, Huffman coding, asymptotic equipartition property, channel capacity, Gaussian channels, rate distortion theory, and Fisher information.

ENEM 744 Adaptive Signal Processing: 3 credits. Theory and application of adaptive algorithms like LMS and RLS in addition to non-linear extensions like generalized linear models, and Fokker-Planck theory for discrete time measurements of a continuous time state.

ENEM 745 Channel Coding Theory and Applications: 3 credits. The theory and application of channel coding for reliable communication. Basic results from information and coding theory (e.g., error exponents). Study of families of good codes, collectively referred to as turbo-like codes. Space-time code for multi-antenna wireless fading channels. Channel coding with transmitter side information, coding in the presence of feedback, connections between communications and control, coding for multi-user channels, recent capacity achieving codes such as polar codes, etc.

ENEM 746 Stochastic Control: 3 credits. Analysis and optimization of controlled stochastic systems. Models: linear and nonlinear stochastic controlled systems, controlled Markov chains. Optimization of systems described by Markov processes; dynamic programming under perfect and imperfect information, finite and infinite horizons. System identification: off-line, recursive. Stochastic adaptive control: Markov chains, self-tuning regulators, bandit problems.

ENEM 747 Optimization Methods in Signal Processing and Machine Learning: 3 credits. Optimization methods that are suitable for large-scale problems arising in data science and machine learning applications. Optimization algorithms are explored for solving convex/nonconvex, and smooth/nonsmooth problems appearing in signal processing and machine learning. The efficacy of these methods, which include (sub)gradient methods, proximal methods, Nesterov's accelerated methods, ADMM, quasi-Newton, trust-region, cubic regularization methods, and (some of) their stochastic variants are studied. Constraint optimization over Riemannian manifold is also included.

ENEM 748 Introduction to Microwave Circuit: 3 credits. Transmission-line theory, microstrip and coplanar lines, S-parameters, signal-flow graphs, matching networks, directional couplers, low-pass and band-pass filters, diode detectors. Design, fabrication and measurements (1-10GHz) of microwave-integrated circuits using CAD tools and network analyzers.

ENEM 749 Introduction to Numerical Electromagnetics: 3 credits. Introduction to numerical methods in electromagnetics including finite difference, finite element and integral equation methods for static, harmonic and time dependent fields; use of commercial software for analysis and design purposes; applications to open and shielded transmission lines, antennas, cavity resonances and scattering.

ENEM 770 Special Topics in Engineering: 3 credits. Topics of current interest selected by the faculty.

ENEM 780 Doctoral Independent Study I: 3 credits. A PhD-level independent study is conducted with a faculty member on a relevant topic. The course must be structured by the faculty member with a clearly defined syllabus for the PhD student. The study may involve relevant research, experimental efforts, simulations, design, data analysis and development. The course requires the prior approval of the student's advisor and graduate program director.

ENEM 781 Doctoral Independent Study II: 3 credits. A second-PhD level independent study is conducted with a faculty member on a relevant topic. The course must be structured by the faculty member with a clearly defined syllabus for the PhD student. The study may involve relevant research, experimental efforts, simulations, design, data analysis and development. The course requires the prior approval of the student's advisor and graduate program director.

ENEM 898 Pre-Candidacy Research: **1-8 credits**. Provide training in education for senior PhD students who contemplate an academic career, and give them the opportunity to gain some teaching experience. Emphasis is on issues that are of special importance in electrical and mechatronics engineering education. Students who have not yet reached candidacy may register for ENEM898: Pre-candidacy Research. ENEM898 does not fulfill any course requirements and is not equivalent to ENEM899 in satisfying the dissertation research credit requirement.

ENEM 899 Doctoral Dissertation Research: **1-8 credits**. Students are eligible to take ENEM 899 only after they have advanced to candidacy. Doctoral candidates are automatically registered by the Registrar for each fall and spring semester until they graduate for six-credit blocks of ENEM899. This course is related to research under faculty supervision in an area of specialization leads to the preparation and submission of a Dissertation in partial fulfillment of the graduation requirements. Note: Students who have not yet reached candidacy may register for ENEM898: Pre-candidacy Research. ENEM898 does not fulfill any course requirements and is not equivalent to ENEM899 in satisfying the dissertation research credit requirement.