Master of Science in Mechanical and Biomedical Engineering (MSMBE)

General Requirements for the MSMBE Degree:

The MSMBE program offers two interdisciplinary tracks:

1. **Applied Mechanics and Biomechanics Track** – Provides advanced training in core mechanical engineering sciences, such as solid and fluid mechanics, kinematics and dynamics, robotics, materials, and computational modeling, while integrating their application to biological and physiological systems.
2. **Biosystems and Instrumentation Track** – Focuses on engineering methods for modeling, sensing, and measuring biological systems, emphasizing bioinstrumentation, embedded and data-acquisition systems, sensing technologies, and medical device design, innovation, and applications

All students in the Master of Science in Mechanical and Biomedical Engineering (MSMBE) 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 over four semesters to complete the program. This does not include any provisional admission course requirements. Students must at least pass five of the core graduate-level required courses with an A grade. All other courses which count toward graduation must be passed with a minimum B grade. Students can enroll in Mechanical and Biomedical Engineering program courses only if they have been admitted to the program or given permission by the course instructor.

The time limit for completing the MS degree is five (5) years after a student first enrolled 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 four core (12 credits), a minimum of four engineering elective graduate level courses (12 credits), and six credits of Thesis (ENEM 799). The thesis must be supervised by a member of the faculty as the thesis advisor. The initial thesis proposal must be defended with an oral presentation and approved by the student's thesis committee, which consists of three members including the advisor. The final thesis must be submitted to the department in bound form after the oral defense, which will take place upon the completion of the thesis research. Additionally, the student is required to submit at least one journal or conference paper based on their thesis work before the defense.

Non-thesis option: The student is required to take four core courses (12 credits), a minimum of six engineering elective graduate level courses (18 credits), and complete a 3-credit research project (ENEM 696), which must be approved by the project advisor. A copy of the resulting scholarly paper (if any) must be submitted to the department. Students are encouraged to engage in scholarly activities beyond their project work.

Applicants with biochemistry or closely related background:

Applicants with a biochemistry, biology, biotechnology, or closely related academic background who seek admission to the Master of Science in Mechanical and Biomedical Engineering must have completed, at a minimum, **Physics II, Calculus II, Statics, and Differential Equations** prior to admission. These four prerequisite courses are required to ensure adequate preparation for graduate-level coursework in mechanical and biomedical engineering.

Such applicants are generally expected to pursue the **Biosystems and Instrumentation Track**, which is more closely aligned with biological systems, bioinstrumentation, sensing technologies, data acquisition, and medical device applications. Admission to the **Applied Mechanics and Biomechanics Track** may be considered only when the applicant's academic background demonstrates sufficient preparation in mechanics, biomechanics, materials, and related mechanical engineering areas.

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

MSMBE General Requirements

- A maximum of two graduate-level course units may be transferred from another institution to apply toward the MSMBE 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).
- Any coursework more than six years old at the time of the final examination will not be used to fulfill any of the MSMBE degree requirements.
- 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.
- A minimum grade point average (GPA) of 3.0 is required to remain in good standing and to graduate.
- Elective engineering courses should be primarily from one of the two tracks specified in this document. Students on each track can take 2 courses (6 credits) from the other track to satisfy graduation requirements upon approval from both the student's advisor and the graduate program director.
- Up to a maximum of 2 courses (6 credits) from other UMES departments of the physical, mathematical, biological, agricultural or similar sciences may be included to round out the student's overall program study. All courses from outside of the Engineering Master's Program must be graduate 600-level courses. Prior approval from both the student's advisor and graduate program director is required for all external courses.

- Up to maximum 6 credits of ENEM 688 Independent Study are allowed upon the student's advisor and graduate program director's approval. Independent Study needs to be structured by the faculty member with a clearly defined syllabus prior to approval.

MSMBE Degree Curriculum

Mechanical and Biomedical Engineering Program Core Courses

	Course Description	Credit Hours
ENEM 601	Linear Systems Theory	3 hrs
ENEM 602	Computational Methods in Engineering	3 hrs
ENEM 604	Fundamentals of Continuum Mechanics*	3 hrs
ENEM 661	Biomechanics*	3 hrs

Electives Courses for Applied Mechanics and Biomechanics Track

	Course Description	Credit Hours
ENEM 611	Mechatronics	3 hrs
ENEM 613	Digital Control System	3 hrs
ENEM 614	Robotics	3 hrs
ENEM 619	Micro-Electro-Mechanical-System	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 625	Advanced Heat Transfer*	3 hrs
ENEM 626	Design of Unmanned Aerial Systems*	3 hrs
ENEM 627	Applied Machine Learning and AI in Engineering*	3 hrs
ENEM 628	Interdisciplinary Design and Innovation*	3 hrs
ENEM 629	Statistical Thermodynamics*	3 hrs
ENEM 630	Materials Processing and Process Selection*	3 hrs
ENEM 716	Advanced Fluid Mechanics	3 hrs
ENEM 717	Computational Fluid Dynamics	3 hrs
ENEM 670	Selected Topics in Engineering	3 hrs
ENEM 664	Biofluid Mechanics*	3 hrs

Note: * indicates a new course for the MSMBE curriculum

Electives Courses for Biosystems and Instrumentation Track

	Course Description	Credit Hours
ENEM 662	Biomaterials for Engineers*	3 hrs
ENEM 663	Tissue Engineering*	3 hrs
ENEM 664	Biofluid Mechanics*	3 hrs
ENEM 665	Biomedical Devices and Systems*	3 hrs
ENEM 666	Rehabilitation Engineering and Assistive Devices*	3 hrs
ENEM 667	Medical Imaging and Analysis*	3 hrs
ENEM 668	Bioinstrumentation*	3 hrs
ENEM 627	Applied Machine Learning and AI in Engineering*	3 hrs
ENEM 630	Materials Processing and Process Selection*	3 hrs
ENEM 669	Fundamentals of Neural Engineering*	3 hrs
ENEM 628	Interdisciplinary Design and Innovation*	3 hrs
ENEM 614	Robotics	3 hrs
ENEM 619	Micro-Electro-Mechanical-System	3 hrs
ENEM 623	Finite Element Method and Application	3 hrs
ENEM 717	Computational Fluid Dynamics	3 hrs
ENEM 670	Selected Topics in Engineering	3 hrs

Engineering Research/Project Courses

	Course Description	Credit Hours
ENEM 696	Master Project	3 hrs
ENEM 799	Master Thesis	(3-6) hrs
ENEM 688	Independent Study	(1-6) hrs
ENEM 698	Graduate Seminar	(1-3) hrs

Typical Plan of Study MSMBE Degree Students			
First Year			
4 Core Courses + 2 Approved Electives			
Fall	**Credit**	**Spring**	**Credit**
ENEM 601 Linear Systems Theory	3	ENEM 604 Fundamentals of Continuum Mechanics	3
ENEM 602 Computational Methods in Engineering	3	ENEM 664 Biomechanics	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 MS 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 MS 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		

Note: *indicates the new courses introduced to the curriculum. The course descriptions of these new courses are provided below:

ENEM 604 Fundamentals of Continuum Mechanics: 3 credits. This course provides a rigorous introduction to the principles of continuum mechanics, with applications in solid and fluid mechanics. Topics include kinematics of deformation, stress tensors, balance laws, constitutive modeling, and thermodynamic principles. The course emphasizes mathematical formulations and their applications in elasticity, plasticity, and fluid dynamics. Analytical and computational methods will be used to solve engineering problems across mechanical, biomedical, and aerospace domains.

ENEM 625 Advanced Heat Transfer: 3 credits. This course covers advanced topics that include multidimensional steady-state and transient conduction problems, laminar and turbulent convection, natural convection, boiling and condensation heat transfer, radiation heat transfer, analytical methods and numerical techniques to solve complex, coupled heat transfer problems. Students are introduced to the postulatory approach used to develop the theory of thermodynamics. The postulates are stated in terms of a variational principle that allows them to be applied to composite material systems.

ENEM 626 Design of Unmanned Aerial Systems: 3 credits. This course covers the principles and methodologies for designing, analyzing, and operating unmanned aerial systems (UAS). Topics include aerodynamics, propulsion, flight dynamics, control systems, autonomy, payload integration, and mission planning. Regulatory and ethical considerations, as well as emerging applications in defense, agriculture, and environmental monitoring, are also discussed. Students will engage in hands-on projects, including computational modeling, system optimization, and experimental testing of UAS components.

ENEM 627 Applied Machine Learning and Artificial Intelligence in Engineering: 3 credits. This course provides an in-depth exploration of machine learning (ML) and artificial intelligence (AI) techniques applied to engineering problems. Topics include supervised and unsupervised learning, deep learning, optimization methods, and AI-driven modeling. Students will learn how to implement ML algorithms, analyze engineering data, and develop AI-based solutions using

Python and industry-standard tools. Case studies from mechanical, biomedical, and other engineering domains will illustrate practical applications. A hands-on approach is emphasized, including coding exercises, project-based learning, and model evaluation.

ENEM 628 Interdisciplinary Design and Innovation: 3 credits. This course introduces principles of interdisciplinary design for solving engineering challenges, focusing on system-level thinking and integration across fields; this course explores the principles and methodologies of interdisciplinary design and innovation, emphasizing collaboration across engineering disciplines to develop creative and functional solutions to complex problems. Students will engage in team-based projects that integrate mechanical, biomedical, and other engineering fields, applying design thinking, systems engineering, and user-centered design approaches. Topics include problem definition, conceptual design, prototyping, testing, and optimization. The course also examines case studies of innovative engineering solutions in healthcare, robotics, manufacturing, and emerging technologies.

ENEM 629 Statistical Thermodynamics: 3 credits. This course covers thermodynamics and introduces quantum mechanics to define the possible microscopic states of macroscopic systems. For macroscopic systems in thermodynamic equilibrium, the concept of ensemble averages is introduced, and the postulates of statistical mechanics are applied to derive their thermodynamic properties based on knowledge of their molecular behavior. The definition of entropy is examined using concepts of quantum mechanics. The thermal properties of solids, gases adsorbed on solid surfaces, electrons in solids, radiation, and ideal gases are explored.

ENEM 630 Materials Processing and Process Selection: 3 credits. This course provides an in-depth exploration of materials processing techniques and their impact on mechanical properties and performance. Students will study traditional and advanced manufacturing processes, including casting, forming, machining, welding, and additive manufacturing. Emphasis is placed on process selection based on material properties, economic considerations, and environmental factors. Through case studies, students will develop a systematic approach to evaluating and optimizing materials processing methods for various engineering applications.

ENEM 661 Biomechanics: 3 credits. This course explores the mechanical principles governing biological systems, with applications in human movement, tissue mechanics, and biomedical engineering. Topics include statics and dynamics of biological structures, stress-strain behavior of biological tissues, joint and muscle mechanics, fluid dynamics in the circulatory system, and applications in medical device design. Students will analyze biomechanical systems using mathematical modeling, computational simulations, and experimental techniques. Case studies from orthopedics, rehabilitation, and sports biomechanics will be discussed.

ENEM 662 Biomaterials for Engineers: 3 credits. This course explores the selection, design, and application of biomaterials in medical and engineering contexts. Topics include the properties

and performance of metallic, ceramic, polymeric, and composite biomaterials; biocompatibility and biodegradation; surface modification techniques; and regulatory considerations for biomedical applications. Case studies in implantable devices, drug delivery systems, and tissue scaffolds will be examined. Laboratory demonstrations and computational modeling may be incorporated.

ENEM 663 Tissue Engineering: 3 credits. This course provides an overview of the principles and applications of tissue engineering, integrating biology, materials science, and engineering. Topics include scaffold fabrication, cell-material interactions, bioreactors, and regenerative medicine strategies. Students will examine case studies in engineered tissues, including skin, cartilage, bone, and organ regeneration. Ethical considerations and regulatory challenges in clinical translation will also be discussed. Hands-on activities may include biomaterial characterization and computational modeling of tissue growth.

ENEM 664 Biofluid Mechanics: 3 credits. This course examines the principles of fluid mechanics as applied to biological systems, with an emphasis on cardiovascular, respiratory, and microfluidic applications. Topics include blood flow in arteries, hemodynamics, pulmonary airflow, non-Newtonian fluid behavior, and microfluidics in lab-on-a-chip devices. Analytical and computational methods will be used to model biofluid transport processes. Applications in medical diagnostics and therapeutic devices will be explored.

ENEM 665 Biomedical Devices and Systems: 3 credits. This course introduces the design, development, and evaluation of biomedical devices and systems. Topics include medical sensors, implantable devices, prosthetics, biosignal processing, and regulatory pathways for medical technologies. Students will analyze real-world case studies and engage in hands-on projects related to device prototyping and performance assessment. Emphasis is placed on safety, reliability, and clinical integration of biomedical devices.

ENEM 666 Rehabilitation Engineering and Assistive Devices: 3 credits. This course explores engineering solutions for individuals with disabilities, focusing on assistive devices and rehabilitation technologies. Topics include prosthetics and orthotics, mobility aids, neural interfaces, wearable sensors, and smart rehabilitation systems. Students will learn about human biomechanics, assistive technology design, and clinical considerations for rehabilitation engineering. Case studies and hands-on projects will enhance practical understanding.

ENEM 667 Medical Imaging and Analysis: 3 credits. This course covers the principles, techniques, and computational analysis of medical imaging systems. Topics include X-ray, CT, MRI, ultrasound, and nuclear imaging, along with image processing methods such as segmentation, registration, and feature extraction. Applications in disease diagnosis, treatment planning, and AI-driven medical image analysis will be discussed. Students will gain experience with imaging software and programming for medical data analysis.

ENEM 668 Bioinstrumentation: 3 credits. This course focuses on the design, development, and application of biomedical instruments for physiological measurement and monitoring. Topics include biosensors, signal acquisition, amplification, filtering, and data analysis. Emphasis is placed on instrumentation for electrocardiography (ECG), electromyography (EMG), electroencephalography (EEG), and wearable health monitoring. Hands-on experience with sensor interfacing, circuit design, and data processing is included.

ENEM 669 Fundamentals of Neural Engineering: 3 credits. This course introduces the principles and applications of neural engineering, focusing on the interface between the nervous system and engineered systems. Topics include neural signal generation and processing, brain-machine interfaces, neuroprosthetics, computational neuroscience, and neuromodulation techniques. Students will explore technologies such as deep brain stimulation, EEG-based systems, and neurorehabilitation devices. Emphasis is placed on both theoretical foundations and practical applications in medical and research settings. Hands-on activities may include neural signal analysis and modeling.

Note: In addition to the newly proposed courses described above, several core and elective courses are shared with existing graduate programs in the Department of Engineering, including the **MS in Electrical and Mechatronics Engineering** (https://wwwcp.umes.edu/engineering/wp-content/uploads/sites/116/2023/04/MS-Course-Description-April-25-updated-2-2023.pdf) and the Ph.D. in Applied Computing and Engineering.

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 688 Independent Study: [3-6 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 mechanical and biomedical 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**).