PhD in Mechanical Engineering

DEGREE REQUIREMENTS

1. Total credit hours
   Graduate Course Work: Typically 60 credit hours beyond B.S. and 30 credit hours (including independent study) beyond the M.S.; 60% of the Ph.D. courses (including dissertation) must be at 700 or higher level and 40% of all graduate courses must be at 600 or higher level.

   Because this program is intended to be versatile and tailored to the specific research agenda, the specific course requirements are established solely by the doctoral committee.

   Dissertation: Research hours of 36 credits

2. **PhD Candidacy**
   The preliminary examination is the candidacy or qualifying exam. Before completing four quarters at WNE University, a student must pass the qualifying examination. This exam is given to assess the student's potential to excel in PhD studies. The qualifying exam is administered by the department. This exam is comprised of two parts; a written exam based on undergraduate course work and an oral exam that has as a basis a preliminary research proposal. A student may attempt the examination no more than twice. Given that the doctoral degree committee will be guiding students through their course of study, subject material may additionally be based on foundational graduate courses that include ME 610 ME 626, ME 646, and ME 701. A PhD candidate must be registered as either full- or part-time at the time of the examination.

3. **Advisor, Advisory Committee and Plan of study**
   Before completing two (2) quarters at WNE University, a student must confirm the selection of the PhD advisor and an advisory committee. With the assistance of the advisor, the student must prepare a plan of study that must be approved by the advisory committee, department chair, and dean before the comprehensive examination is attempted. Advisory committees will consist of at least 3 departmental members (1 of which must be the PhD advisor) and at least one faculty member from outside the department.

4. **Comprehensive examination**
   The comprehensive exam should cover the specific areas of mechanical engineering, designated by the PhD advisory committee that relate to the student's area of research and study. The student may attempt this examination no more than twice. This examination will be administered by the student's advisory committee and is intended to ensure that the student has the comprehensive understanding needed to complete the dissertation research effort.

The basis for the comprehensive exam is the final written thesis proposal. The comprehensive exam will consist of an oral examination, administered by the doctoral committee. The exam will include a presentation of the final research proposal related to the thesis and plans for completing the work.

5. **Dissertation defense**

The purpose of this examination is for students to defend their PhD dissertation. Students must defend their dissertation through an oral presentation.

In the time between successful completion of the Comprehensive Examination and the final oral examination (thesis defense) the following will apply:

- The final oral exam must be requested and scheduled through the office of the Dean of the College.
- The student must be continuously registered.
- If a period of more than 5 years passes between the successful passing of the Comprehensive exam and the oral defense, the comprehensive exam must be retaken and passed before the final oral examination can be scheduled.
- The final oral exam is administered by the entire doctoral committee. It is a defense of the doctoral thesis. The final oral exam will be publicized and members of the entire academic community are invited to attend.

Students must complete this milestone within 8 years of initial enrollment into the program.

Curriculum Guideline

It is recommended that all students that enter with the M.S. complete the following four core courses:

ME PhD Program Core Curriculum Outline (Students with M.S. in ME)

Major Required (Core) Courses (Total # of courses recommended = 3+Dissertation credit hours)		
Course Number	**Course Title**	**Credit Hours**
ME 610	**Measurement Systems**	**3**
ME 646	**Applied Finite Element Analysis**	**3**
ME 701	**Seminar / Research Methods for Mechanical Engineering**	**3**
ME 798 / ME799	**Dissertation**	**36 minimum**
	Subtotal # Core Credits Required	45
Elective Course Choices by Area (Total number of courses required beyond the core = 3)		
Mechatronics and Robotics		
ME 654	Computer Control of Manufacturing	3
ME 655	Design of Mechatronics Systems	3
ME 656	Advanced Mechatronics	3
ME 787	Machine Vision	3
ME 788	Advanced Robotics	3
ME 737	Special Topics in Mechanical Engineering	3
Thermofluids and Energy		
ME 626	Applications of Advanced Fluid Mechanics	3
ME 632	Fundamentals of Flight	3
ME 635	Design of Alternative Energy Systems	3
ME 726	Design of Heat Exchangers	3
ME 752	Applied Computational Fluid Dynamics and Numerical Heat Transfer	3
ME 782	Advanced Energy Systems	3
ME 632	Fundamentals of Flight	3
ME 737	Special Topics in Mechanical Engineering	3
Vibrations and Mechanics		
ME 660	Practical Aspects of Vibrations, Noise, and Acoustics Engineering	3
ME 619	Experimental and Analytical Stress Analysis	3
ME 787	Applied Design and Analysis with Composites	3
ME 737	Special Topics in Mechanical Engineering	3
Design and Manufacturing		
ME 620	Applied Mechanical Design	3
ME 747	Advanced Manufacturing and Materials Processing	3
ME 714	Composite Design and Fabrication	3
ME 737	Special Topics in Mechanical Engineering	3

	Subtotal # Elective Credits Recommended	9

Curriculum Summary	
Total number of courses recommended for the degree	6[††]
Total credit hours recommended for the degree	54

Prerequisite, Concentration, Dissertation or Other Requirements: *Students must take a minimum of 36 credit hours of research….of any combination of ME 798/799 (Dissertation) and submission of Dissertation required. Additional examinations include Preliminary Examination (qualifying), Comprehensive Examination (covering major area of study), Dissertation Approval Examination (oral examination on dissertation research proposal), and Dissertation Defense (oral).*

[††] Excludes number of Dissertation courses needed to meet 36 credit hour minimum requirement.

All students who enter the program and do not have a Master of Science (M.S.) degree in Engineering, or a closely related field, will need to complete the following courses:

Course Number	**Course Title**	**Credit Hours**
ME 610	**Measurement Systems**	**3**
ME 626	**Applications of Advanced Fluid Mechanics**	**3**
ME 646	**Applied Finite Element Analysis**	**3**
ME 656	**Advanced Mechatronics**	**3**
ME 747	**Advanced Manufacturing and Materials Processing**	**3**
ME 701	**Seminar / Research Methods for Mechanical Engineering**	**3**
ME 798 / ME799	**Dissertation**	**36 minimum**
	Subtotal # Core Credits Required	54

Students may complete their remaining course requirements by taking any additional Mechanical Engineering courses or other graduate courses (600 – 700 level) offered by the College of Engineering in consultation with their major advisor. Please see appendix A.

COURSE DESCRIPTIONS

ME 610 - Measurement Systems (3 cr.)
Prerequisite: ME 320, ME 435, or equivalent.
This graduate course is offered to mechanical engineering majors and is designed to familiarize students with electronic instrumentation and mechanical measurement techniques. Students will be able to make accurate and meaningful measurements of mechanical and thermal quantities such as strain, force, displacement, torque, pressure, velocity, acceleration, flow, volume flow rate, and temperature. Signal conditioning and data collection and reduction techniques are presented and the use of PC based data acquisition and control systems for automated data collection are emphasized. Case studies of practical significance or related to innovative sensor design and implementation are discussed and demonstrated. Each student will conduct an independent design project related to an area of mechanical testing or measurement and submit a final written report. The method of assessing students includes examinations, the project report, and a final exam.

ME 619 - Experimental and Analytical Stress Analysis (3 cr.)
Prerequisite: ME 208, MATH 350, ME 435, or equivalent.
This advanced course builds on the material presented in Mechanics of Materials course and develops the student's ability to apply the principles of advanced mechanics of materials to problem solving while applying common experimental techniques for solution verification. The analytic studies will allow students to determine shear centers of composite sections; determine stresses and deflections of curved beams and beams on elastic foundations; determine deflection and slope in beams using Castigliano's theorem; determine stresses in thick-walled cylinders; and determine stresses in initially curved and eccentrically loaded columns. The experimental studies include the basic theory and installation techniques of electric resistance strain gauges, photoelastic coatings, and applications of load and deflection measuring techniques. Applications of these techniques in the verification of analytical solutions is emphasized throughout the course. A project involving the use of analytical and experimental verification methods is required. Methods of assessing students include homework assignments, laboratory reports, quizzes, a midterm, and a comprehensive final exam.

ME 620 - Applied Mechanical Design (3 cr.)
Prerequisite: ME 425 or equivalent or permission of instructor.
This graduate level course is offered to engineering graduate students who have taken an undergraduate course in machine design. The course is conducted entirely off campus using the Internet and conference calling as the primary modes of delivery. The course is designed to build on concepts introduced in a senior level undergraduate machine design course and utilizes a series of design projects which apply the design theory presented in class. Topics include theories of static and fatigue failure; statistical techniques used to predict component reliability; extension, compression, and torsion spring design for static and fatigue loading; roller contact bearings and lubrication; clutches and brakes; and flexible drive systems. Design of complex components and assemblies, and the development of engineering product

specifications is introduced, and the impacts of social, economic, and material constraints on the design process are also considered. The methods of assessing students include a midterm and a final examination, and a number of machine design projects. A substantial final design project will be required by all students. Students will use advanced design principles to design and build a scale model which will be tested for performance. Testing of the model will be captured using avi files which will be submitted via Kodiak.

ME 626 - Applications of Advanced Fluid Mechanics (3 cr.)
Prerequisite: ME 303, ME 316, and graduate standing.
This course covers a practical, hands on approach to applying complex fluid dynamic principles to solving real life problems, and to the development of new and novel products. Classical theory from Kuchemann, Prandtl, Schlichting, and Shapiro are used to introduce fluid concepts, fluid flow, vorticity, boundary layers, vortex motion, lift forces, and acoustic waves. These concepts are combined using potential flow, control volume analyses, and conservation principles to solve real life engineering problems. Discussions and engineering problem solving sessions will be an integral part of the classroom learning experience. Applications discussed will include throwing a curve ball, using wing surfaces as a means to gain mechanical advantage, using ejectors as thrust augmenters, and using toroidal vortices as self-propelling fluid carriers. Case studies will include a Sikorsky UAV, Stage III Technologies ALMEC exhaust noise suppressor, and FloDesign's RAP nozzle. The methods of assessing students include homework, quizzes, examinations, classroom discussions, a design project, and a final exam.

ME 632 - Fundamentals of Flight (3 cr.)
Prerequisite: ME 426, ME 447, or permission of instructor.
This course is an introduction to the fundamentals of flight, with a more advanced focus on engineering aspects of flight. Topics include basic aerodynamics of sub-sonic, trans-sonic and super-sonic flight, airfoil and wing design, airplane performance at various flight attitudes and conditions, and aircraft stability and control. Aerodynamic concepts discussed in the classroom are confirmed by conducting several laboratory experiments in a sub-sonic wind tunnel. A flight simulator is also used to demonstrate basic fundamentals of flight. The methods of assessing students include homework, quizzes, examinations, classroom discussions, laboratory experiments, a team-based aerodynamic design project, and a final exam.

ME 635 - Design of Alternative Energy Systems (3 cr.)
Prerequisite: ME 417 or both ME 303 and graduate standing.
This course is an introduction to the theory and design of solar, water, wind, and geothermal power generation systems. Students will become familiar with flat-plate collector performance, practical considerations for flat-plate collectors, estimation of residential heating and cooling loads, and thermal design methods. A project involving the design of an energy independent home is assigned. The methods of assessing students include homework, quizzes, a midterm exam, design project report, and a final exam.

ME 640 - Materials Selection for Engineering Design and Manufacturing (3 cr.)
Prerequisite: ME 309 or equivalent or permission of instructor.
The course will develop a systemic approach for the development of a new idea or product and facilitate the continuous improvement processes for products currently on the market. The approach is based on evaluating open-ended design problems with respect to the interrelationship between material, shape, function, and processes used to produce a variety of products. In the course, the general characteristics of a wide variety of materials including metals, ceramics, polymers, and composites, will be explored using the materials selection process. Case studies and team projects will focus on materials selection decisions with multiple constraints and based on the factors involved in materials processing and information from several databases. The methods of assessing students include homework, quizzes, and design project reports.

ME 646 - Applied Finite Element Analysis (3 cr.)
Prerequisite: Baccalaureate degree in mechanical, civil or aeronautical engineering or permission of the instructor.
This graduate course is intended to assist engineers in understanding and applying the concept of the finite element modeling and analysis (FEA). Students may use commercially available FEA packages to perform linear and non-linear static, transient and steady thermal analyses but the course will be taught using ANSYS with some NX support. The finite element uses of beam theory, natural frequencies, and heat transfer will be investigated. Practical application of the FEA results are emphasized. Civil Engineering students will be given the opportunity to study structural composites like reinforced concrete or soils in class. Case studies of practical significance and innovative modeling techniques are discussed and demonstrated. Each student will conduct a comprehensive, independent, finite element analyses on a topic related to a mechanical or civil engineering design and submit a final written report. The method of assessing student progress includes in-class examinations, homework, participation, and the final project/exam/report.

ME 654 - Computer Control of Manufacturing (3 cr.)
Prerequisite: Graduate standing.
This is an introduction to NC systems. Topics include point-to-point positioning control and continuous path contouring control, interpolation methods, actuating devices and sensors, digital computer interfaces (A to D, D to A, D to D), position and velocity feedback control loops, and programmable logic controllers. The methods of assessing students include homework, quizzes, a midterm exam, design project report, and a final exam.

ME 655 - Design of Mechatronic Systems (3 cr.)
Prerequisite: Graduate standing.
This graduate/undergraduate is intended to provide students with skills needed to design, model, validate, and control complete PC or PLC-based mechatronic systems, constructed with modern intelligent sensors, signal conditioners, pneumatic and hydraulic actuators, servo or stepper motors, PLC or embedded microcontrollers, and intelligent PID channels. Visual Basic is used for control and analysis of PC based mechatronic systems. Formerly ME 555.

ME 656 - Advanced Mechatronics (3 cr.)
Prerequisite: Graduate standing or permission.
This course studies Mechatronics at an advanced theoretical and practical level. Balance between theory/analysis and hardware implementation is emphasized; physical understanding is stressed through various case-studies. Topics covered include: mechatronics system design, modeling and analysis of dynamic systems, system identification techniques, vision-based measurement and inspection systems, analog and digital sensors and their interface to actuators and controllers, and real-time programming far control. Advanced motion control topics such as master/slave drives, electronic gearing and electronic CAM, adaptive tuning of PID controllers are discussed and demonstrated.

ME 660 - Practical Aspects of Vibrations, Noise, and Acoustics Engineering (3 cr.)
Prerequisite: Baccalaureate degree in mechanical engineering or permission of instructor.
In today's competitive environment every product designed by an engineer is subject to dynamic loads in sometimes harsh conditions. The product is likely to be more successful when vibration and noise performance of the design is optimized. This course provides a hands-on introduction to vibrations and noise engineering. The fundamental concepts of vibrations, noise, and acoustics are introduced. The characteristics of typical sensors and actuators used in dynamic testing, such as accelerometers, force transducers, strain gauges, microphones, mechanical shakers, and impact hammers, are reviewed. Using these sensors in combination with modern data acquisition systems (LabView), students will learn to build experimental testing setups to measure the vibration and noise performance of typical engineering devices. Examples of practical applications are measurement of jet noise, measurement of vibration levels of devices, e.g. a ski, experimental modal analysis of structures, e.g., a golf club, and performing a noise control study of a machine. Several case studies encompassing contemporary design problems from industry are used in the classroom to enhance the learning process. The method of assessing students includes classroom participation, homework and laboratory assignments, examinations, and a final exam.

ME 685 - Mechanical Engineering Project (3 cr.)
Prerequisite: EMGT 605 or EMGT 648 and 12 credit hours minimum in the program.
Students must select a project faculty advisor and obtain topic approval prior to registration for this course. This is an independent engineering project under the supervision of a project faculty advisor. The design process is emphasized. Progress reports and a final written report are required. An oral presentation and defense of the project is made before a faculty committee.

ME 690 - Special Topics in Mechanical Engineering (3 cr.)
Cross-Listed as: ME 691
This is a study of an advanced topic in engineering of special interest to mechanical engineering majors.

ME 698 - Thesis Research (3 cr.)
Cross-Listed as: ME 699
This is a research course open to mechanical engineering graduate students who have completed requirements for admission to candidacy for the master's degree. Prior to registration, written permission to enroll must be obtained from the student's advisor.

ME 699 - Thesis Research (3 cr.)
Cross-Listed as: ME 698
This is a research course open to mechanical engineering graduate students who have completed requirements for admission to candidacy for the master's degree. Prior to registration, written permission to enroll must be obtained from the student's advisor

ME 701 - Seminar/Research Methods for Mechanical Engineering (3 cr.)
Prerequisite: Enrollment as ME Ph.D. Student.
This course provides tools and techniques employed to be used in Mechanical Engineering research. Topics covered include: program/faculty overview, literature review methods and tools, hierarchy of research questions, research ethics, and visual display of quantitative information.

ME 714 - Composite Materials Design and Manufacturing (3 cr.)
Prerequisites: ME 208 & ME 309 or equivalent
Composite applications have grown exponentially in the last decade due to manufacturing and materials advances. This course will serve as an introduction to composite materials selection and architecture dictating mechanical and thermomechanical behavior. This course is intended to introduce continuous fiber reinforced composites having polymer, ceramic and carbon matrices. The focus will be on applications that include aerospace, energy, automotive, medical, research, manufacturing and marine.

As the demand for high-performance materials with superior properties and performance, flexibility and resilience grows, a new design paradigm from the molecular scale upwards has revolutionized our ability to create novel materials. This course covers the science, technology (fabrication technologies) and state-of-the-art in atomistic, molecular and multiscale design on composites material’s performance.

ME 726 - Design of Heat Exchangers (3 cr.)
Prerequisite: ME 303, ME 316, ME 417.
This course will be offered in fall 2019 and in the Department of Mechanical Engineering with an intend to teach principles of heat exchanger design. The course focuses on principles of heat transfer and fluid mechanics (pressure drop) in design of heat exchangers. Different heat exchanger types along with analysis of heat exchangers will be discussed in this course. In particular, the effectiveness of heat exchangers based on the number of transfer units (NTU) method will be discussed. Although the emphasize will be on heat exchangers with separation of hot and cold fluids by a stationary wall, evaporative heat exchangers which involve direct

contact between a liquid and a gas will be studied as well. In addition to heat exchanger, heat pipes and vapor chambers will be reviewed.

ME 747 - Advanced Manufacturing and Materials Processing (3 cr.)
Prerequisite: ME 322 or equivalent, and graduate standing.
This course introduces the fundamental principles and recent developments in the fast-growing field of advanced manufacturing, which includes additive manufacturing, microfabrication, fiber manufacturing, laser materials processing, smart manufacturing and nanomanufacturing. Emphasis will be laid on the underlying physics and limitations of existing technologies leading to methodologies for new process and product innovations. Laboratory experience will complement the lectures with the demonstration of in-house manufacturing of glass coated metal microwires with applications in electronics, energy and biomedical industries. Each student will submit a design project proposal utilizing the microwires and knowledge learned in this course to address an unmet societal need. The methods of assessing students include homework assignments, quizzes, and the final project proposal.

ME 752 - Applied Computational Fluid Dynamics and Numerical Heat Transfer (3 cr.)
Prerequisite: ME 304, ME 316, and graduate standing.
This course teaches the students the basics of developing and applying computational methods for solving problems of fluid flow and heat transfer. It covers both fundamental theory and application of the techniques to develop practical fluid flow software. In addition, you will be also using one of the commercial fluid flow software to solve industrially relevant flow problems. This course adopted a project-based approach. The students will develop and use projects to learn and apply CFD. Each project can take two to three weeks depending on complexity. The objective of the course is to expose students to fundamentals of computational fluid dynamics and heat transfer, to make students confident of developing as well as using software for computational fluid dynamics, to make students familiar with simulation of complex fluid flows with complex boundary shapes and boundary conditions.

ME 782 - Advanced Energy Systems (3 cr.)
Prerequisite: Graduate standing.
This course covers modern energy systems with a focus on electrochemical energy conversion and storage devices including fuel cells, li-po batteries, and flow batteries among others. The course will include relevant units on thermodynamics, charge & mass transport, fluid mechanics, and electrochemistry. Students will engage in classroom lectures as well lab modules that include cell design & assembly, as well as cell performance testing. Students are expected to have undergraduate experience in Calc 1-3, Linear Algebra, and Differential Equations. Grading is based on attendance, HW sets, and a project.

ME 784 - Applied Design and Analysis with Composites (3 cr.)
This applied graduate course is intended to assist engineers in understanding how to design and analyze structures made of composites. Students are exposed to comprehensive efforts of MILK-HNDBK17, the basics of laminated media, matrix algebra, a variety of composites

including those for civil engineering applications, and a majority of the class emphasizes spreadsheets, Ashby Charts, and ANSYS to design and analyze structures. Students may use other commercially available FEA packages to perform linear and non-linear static, and steady thermal analyses but the course will emphasize ANSYS. Practical sources of information are provided and application of the FEA results are emphasized. Civil Engineering students will be given the opportunity to study large structures and reinforced concrete as an orthotropic material and on a meso-mechanical basis. Case studies of practical significance and innovative modeling techniques are discussed and demonstrated. The method of assessing student progress includes in-class examinations and finite element results.

ME 798 - PhD Thesis Research (3 cr.)
Cross-Listed as: ME 699
This is a research course open to mechanical engineering graduate students who have completed requirements for admission to candidacy for the master's degree. Prior to registration, written permission to enroll must be obtained from the student's advisor.

ME 799 - PhD Thesis Research (3 cr.)
Cross-Listed as: ME 798
This is a research course open to mechanical engineering graduate students who have completed requirements for admission to candidacy for the master's degree. Prior to registration, written permission to enroll must be obtained from the student's advisor.