Department of Mechanical Engineering
University of Delaware

GRADUATE PROGRAM POLICY

Graduate Curriculum Committee
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1. Synopsis

Overview. The Department of Mechanical Engineering offers graduate programs leading to the degrees of MSME, which can be pursued along two tracks (thesis or non-thesis), and the Doctor of Philosophy (PhD) in Mechanical Engineering. The Department also administers the MSR Program. The graduate programs are designed to provide considerable flexibility in the selection of course work and specialization. Independent research is required for the PhD degree, as well as for both the MSME and MSR (thesis track) degrees, while the MSME and MSR non-thesis degree programs are appropriate for full-time and part-time students. For those students already enrolled in the Department's Bachelor's in Mechanical Engineering (BME) program, the Department also offers a 4+1 BME/MSME program that allows the student to complete both the BME and MSME degrees in five years of full-time study.

Admission to Program. Students are admitted into the graduate program for either a MSME or a PhD degree. The option of enrollment into the PhD program directly after the BME is available. For students with a Bachelor's degree in engineering the following minimum criteria will normally be applied:

1. A baccalaureate degree in Mechanical Engineering or in a closely related field of engineering, science or mathematics.

2. An undergraduate grade point average in engineering, science and mathematics courses of at least 3.0 on a 4.0 scale.

3. A minimum of at least three letters of strong support from former teachers or supervisors.

4. A minimum combined Quantitative and Verbal score of 308 (1200) on the Graduate Record Examination (GRE) aptitude Test. (Limited GRE waivers are possible on a case-by-case basis.)

5. A minimum score of 600 on the paper-based Test Of English as a Foreign Language (TOEFL), or at least 100 on the TOEFL iBT with a speaking score of 20, or at least 10.5 on TOEFL Essentials. This test is not required for students whose first language is English and who have received an undergraduate or graduate degree from a College or University in which English is the sole language of instruction.

Admission to the graduate program is competitive. Those who meet stated requirements are not guaranteed admission, nor are those who fail to meet all of those requirements necessarily precluded from admission if they offer other appropriate strengths. For applicants with no prior training in engineering, the same minimum criteria will apply. In addition, their records will be reviewed in relation to the intended program of study. Provisional status with specific remedial work may be a basis for acceptance of such applicants.

Advisement. A temporary academic advisor is assigned to new students when they are admitted to the Graduate Program. Students select their permanent advisor once they become familiar with the department, and are clear about their research interests. The permanent advisor will be someone whose interest matches the interest of the student insofar as possible. For students on Research Assistantships, the advisor directs their research and advises them on course selection.

2. Master of Science in Mechanical Engineering (MSME)

The MSME program may be pursued under either a thesis option, or a non-thesis option. The program requires 30 credit hours of graduate level coursework, 6 of which must be Master's Thesis credits under the Thesis Option. Coursework must be completed with a grade point average of 3.0 or higher (see Graduate Catalog for relevant details). The course requirements are designed both to provide a balanced program in Mechanical Engineering, and to allow for a degree of specialization. Students should be able to complete all degree requirements, including the thesis if chosen, in 18 to 24 months of full-time study.

Students enrolled in the MSME program are expected to financially support themselves throughout the duration of the program.

I. Course Requirements

A. Required MEEG courses (12 credits)

(a) MEEG 690 Intermediate Engineering Mathematics

(b) Three from the following list:

- MEEG 610 Intermediate Solid Mechanics
- MEEG 620 Intermediate Dynamics
- MEEG 621 Linear Systems
- MEEG 630 Intermediate Fluid Mechanics
- MEEG 640 Intermediate Heat Transfer
- MEEG 683 Orthopedic Biomechanics

Students may petition the Graduate Committee to substitute a more advanced (e.g., 800-level) course on the same topic for one of these required courses.

B. Three additional graduate mechanical engineering electives (9 credits)

Thesis-track. Under the Thesis track, 6 credits of MEEG 869 Master's Thesis must be completed toward requirement B.

Non-thesis track. Under the Non-Thesis track, any course listed in A(b) above, excluding those used to fulfill requirement A, can be used toward the 6 credits of requirement B. This 6 credit

requirement can also be satisfied with MEEG 868 Research or Independent Study; the latter can be earned through the Graduate Student – Industry Partnership (GSIP) program.

C. Three additional elective graduate courses (9 credits)

These must be courses in engineering, mathematics, science, another field related to the student's academic concentration. Courses must be selected with the documented approval of the department's Graduate Committee, which has the authority to decide on acceptable courses.

D. At least one semester of MEEG 600 Seminar (0 credits)

Special arrangements can be made for part-time students to fulfill this requirement.

II. Thesis Requirements

Students following the thesis-track demonstrate their ability to conduct scholarly research by compiling and defending a Thesis in front of a committee. The Thesis will have to be defended in front of a committee of at least two MEEG faculty members, chaired by the graduate advisor and including either a third full-time faculty or an external member with the prior approval of the graduate committee. The thesis is to be submitted to committee members at least two weeks in advance of the defense and shall meet the academic and professional standards set forth by the University. Upon acceptance of the thesis, the Committee recommends approval to the Department Chairperson.

III. Learning Outcomes and Assessment

A. Application of graduate-level mathematics (for both MSME tracks)

Outcome. The student will demonstrate the ability to apply graduate-level mathematics to the solution of engineering problems in at least two of the general areas of solid mechanics, fluid mechanics, dynamics and heat transfer.

Direct assessment. Student learning relative to this outcome is assessed by the student's course grades in: MEEG 610 Intermediate Solid Mechanics; MEEG 620 Intermediate Dynamics; MEEG 630 Intermediate Fluid Mechanics; MEEG 640 Intermediate Heat Transfer; and MEEG 690 Intermediate Engineering Mathematics.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goal.

B. Conduct of research (for MSME thesis track)

Outcome. The student will demonstrate the ability to conduct, present and defend graduate-level research including literature review, motivation, methodology utilized, results, unique contributions, and conclusions generated.

Direct assessment. Student learning relative to this outcome is assessed by the quality of the written Master's thesis and performance in the thesis defense.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goal.

IV. Educational Goals

The educational goals of the MSME program at the University of Delaware are to impart students with advanced analytical and technical knowledge in the core areas of mechanical engineering while also providing specialized knowledge in new and emerging areas, enabling them to lead successful careers in industry, pursue advanced degrees, and to contribute to the profession and society at large. Graduates of the MSME program will be able to:

- Demonstrate the ability to apply graduate-level mathematics to the solution of engineering problems in the general areas of mechanical engineering.
- Demonstrate the ability to conduct, present and defend graduate-level research including literature review, motivation, methodology utilized, results, unique contributions, and conclusions generated.
- Contribute to engineering knowledge, the profession, and the community through technology development, research, or service in areas relevant to mechanical engineering.
- Work effectively in multidisciplinary teams to solve complex mechanical engineering problems related to a variety of technologies shaping the future of our lives.

3. Master of Science in Robotics (MSR)

The MSR program consists of 30 credit hours of graduate level coursework, and offers a Master's thesis track or a course-based only track. The curriculum consists of a core of six (6) required courses, and four (4) electives. The latter are selected from an approved list of graduate courses and are designed to provide the opportunity for specialization in particular academic subareas such as control, estimation, optimization, or machine learning. A student pursuing the Thesis option can request to count 6 credits of Master's Thesis towards the Required Course credits (requirement A below). A justification for the substitution of thesis credits for required course credits must be provided, and the student's request should be approved by the Graduate Program Director. Students interested in our full-time campus experience are able to complete all degree requirements below, including the optional thesis, in as little as 18 to 24 months. See admission requirements and application information below.

I. Course Requirements

The MSR program requires thirty (30) credit hours of graduate level coursework, and offer a Master's Thesis or a course-based only track. Under the Master's Thesis track, six (6) of the thirty (30) total credits must be Master's Thesis credits. Coursework must be completed with a grade point average of 3.0 or higher.

A. Required Courses (18 credits)

The following six (6) courses are required[1] for the degree:

1. CISC 621 Algorithm Design and Analysis
2. MEEG 621 Linear Systems
3. MEEG 671 Introduction to Robotics
4. MEEG 678 Introduction to Autonomous Driving
5. CISC 642 Introduction to Computer Vision
6. MAST 632 Environmental Field Robotics

[1] A student pursuing the thesis option can request to count 6 credits of 869 Master's Thesis.

B. Elective courses (12 credits)

Students can choose four (4) from the following pre-approved graduate electives.

- MEEG 620 Intermediate Dynamics
- CISC 681 Artificial Intelligence
- MEEG 677 Introduction to State Estimation
- CISC 684 Introduction to Machine Learning
- MEEG 698 Stochastic Optimal Control
- MEEG 894 Linear Feedback Control Design
- MEEG 877 Sensing and Estimation in Robotics
- MEEG 895 Game Theory and Mechanism Design
- MEEG 829 Applied Nonlinear Control
- MEEG 890 Nonlinear Programming

The list above is expected to grow as the program expands, with the approval of the program's Executive Committee. Still, the courses in this list give a student the opportunity to any of five academic specializations:

Control: MEEG 621 (Linear Systems); MEEG 698 (Stochastic Optimal Control) or MEEG 894 (Linear Feedback Control Design); MEEG 829 (Applied Nonlinear Control)

Estimation: MEEG 621 (Linear Systems); MEEG 677 (Introduction to State Estimation); MEEG 877 (Sensing and Estimation in Robotics)

Artificial Intelligence: CISC 621 (Algorithms); CISC 684 (Machine Learning); CISC 642 (Computer Vision)

Design: MEEG 620 (Dynamics); MEEG 671 (Intro to Robotics); MAST 632 (Environmental Field Robotics)

Optimization: CISC 621 (Algorithms); MEEG 895 (Game Theory and Mechanism Design); MEEG 890 (Nonlinear Programming)

Graduate-level independent study and internship can substitute for up to six (6) graduate elective credits along a non-thesis degree track. To facilitate academic assessment, all independent study courses receiving credit toward MSR degree requirements (including those available through the Graduate Student – Industry Partnership (GSIP) program) should lead to a tangible deliverable, including but not limited to a technical report, a research poster, or a prototype. This option is provided to the student under the following course:

MEEG 664 Internship

Component: Independent Study

Off or on campus practical learning experience under the supervision of a faculty member (or Graduate Program Director) requiring two written reports: 1) a plan of work outlining the background of the project and the learning objectives for the internship, and 2) a scholarly paper outlining the objectives of the internship, what was accomplished for each objective and recommendations for future work.

Repeatable for Credit: Y

Allowed Units: 1-6

Multiple Term Enrollment: N

Grading Basis: Student Option

Restrictions: Requires permission of Graduate Program Director and related faculty member

II. Thesis Requirements

For those students following the MSR Thesis-Track, the thesis requirements are very similar to those for MSME, namely: At the completion of the thesis research, candidates for the MSR thesis-track degree must defend their thesis orally in front of a committee of at least three members, two of which being full-time faculty members and one serving as the committee chair, and a third full-time faculty or an external member, with the prior approval of the program's Executive Committee. The thesis is to be submitted to committee members at least two weeks in advance of the defense and shall meet the academic and professional standards set forth by the University. Upon acceptance of the thesis, the committee recommends approval to the Mechanical Engineering Department Chairperson.

III. Learning Outcomes and Assessment

Graduates of this program will be able to demonstrate different technical skills depending on their specialization through elective course selection. These skills may cover different aspects of design, analysis, simulation, and control of robotic systems. Yet all graduates should be able to demonstrate competency relative to the following three program learning outcomes.

A. Ability to derive mathematical models of robotic systems

Outcome. Ability to derive mathematical models of typical robotic systems, analyze their dynamic behavior, and design standard controllers.

Direct assessment. Student learning relative to this outcome is assessed by the students course grades in: MEEG 621 Linear Systems; MEEG 671 Introduction to Robotics; MEEG 620 Intermediate Dynamics; MEEG 698 Stochastic Optimal Control; MEEG 894 Linear Feedback Control Design; MEEG 829 Applied Nonlinear Control.

B. Ability to simulate robotic behavior

Outcome. Ability to simulate robotic behavior in industry-standard software environments —e.g., Robot Operating System (ROS), Webots, etc.

Direct assessment. Student learning relative to this outcome is assessed by the student's course grades in: MEEG 678 Introduction to Autonomous Driving; MEEG 671 Introduction to Robotics; CISC 642 Introduction to Computer Vision.

C. Familiarity with robotic systems deployment

Outcome. Familiarity with robotic deployment in real-world environments.

Direct assessment. Student learning relative to this outcome is assessed by the student's course grades in MAST 632 Environmental Field Robotics.

IV. Educational Goals

The objective of the graduate MSR program at the University of Delaware is to produce graduates with a strong foundation in the science of robotics and autonomous systems, enabling them to lead

successful careers, to pursue advanced degrees, and to contribute to the profession and the society at large, by advancing the quality of life and work through robotic technologies. Graduates of the MSR program will be able to:

- Design, develop and control robotic and autonomous systems found in application areas such as manufacturing, transportation, aerospace, defense, and healthcare.
- Apply fundamental knowledge of dynamics, perception, machine learning, decision and control in semi-autonomous and fully autonomous systems found in a variety of applications shaping the future of life and work.
- Contribute to engineering knowledge, the profession, and the community through original research, technology development, and service in robotics and autonomous systems.
- Work effectively on multidisciplinary teams to solve complex engineering problems related to control systems, perception, autonomy and robotic technologies.

4. Bachelor's/Master's in Mechanical Engineering 4+1 (BME/MSME)

The $4+1$ BME/MSME degree program is offered to highly-qualified undergraduate students already enrolled in the BME degree program. This program allows the student to earn both the BME and the MSME degree in 5 years of full-time study in Mechanical Engineering at the University of Delaware. Students should apply in the spring of their junior year.

I. Course Requirements

The MSME portion of this degree follows the course requirements of the non-thesis track of the MSME degree. The differences of the $4+1$ degree, compared to the non-thesis track MSME degree, are the following:

- Students first complete all the required credits for the BME.
- Students take two 600-level technical electives as part of the requirements for the BME degree. These courses are to be chosen from the course requirements for the MSME degree and will also count towards their $4+1$ degree requirements.
- Students complete an additional 24 credits of coursework to meet the course requirements for the MSME degree
- Students must achieve a 3.0 Grade Point Average (GPA) (a B average) in their graduate work to earn the $4+1$ degree.

II. Learning Outcomes and Assessment

A. Application of graduate-level mathematics

Outcome. The student will demonstrate the ability to apply graduate-level mathematics to the solution of engineering problems in at least two of the general areas of solid mechanics, fluid mechanics, dynamics and heat transfer.

Direct assessment. Student learning relative to this outcome is assessed by the student's course grades in: MEEG 610 Intermediate Solid Mechanics; MEEG 620 Intermediate Dynamics; MEEG 630 Intermediate Fluid Mechanics; MEEG 640 Intermediate Heat Transfer; and MEEG 690 Intermediate Engineering Mathematics.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goal.

III. Educational Goals

The educational goals of the MSME program at the University of Delaware are to impart students with advanced analytical and technical knowledge in the core areas of mechanical engineering while also providing specialized knowledge in new and emerging areas, enabling them to lead successful careers in industry, pursue advanced degrees, and to contribute to the profession and society at large. Graduates of the MSME program will be able to:

- Demonstrate the ability to apply graduate-level mathematics to the solution of engineering problems in the general areas of mechanical engineering.
- Demonstrate the ability to conduct, present and defend graduate-level research including literature review, motivation, methodology utilized, results, unique contributions, and conclusions generated.
- Contribute to engineering knowledge, the profession, and the community through technology development, research, or service in areas relevant to mechanical engineering.
- Work effectively in multidisciplinary teams to solve complex mechanical engineering problems related to a variety of technologies shaping the future of our lives.

5. Bachelor's in Mechanical Engineering/Master's in Robotics 4+1 (BME/MSR)

The $4+1$ BME/MSR degree program is offered to highly-qualified undergraduate students already enrolled in the BME degree program. This program allows the student to earn both the BME and the MSR degree in 5 years of full-time study in Mechanical Engineering at the University of Delaware. Students should apply in the spring of their junior year.

I. Course Requirements

The MSR portion of this degree follows the course requirements of the non-thesis track of the MSR degree. The differences of the $4+1$ degree, compared to the non-thesis track MSR degree, are the following:

- Students first complete all the required credits for the BME.
- Students take two 600-level technical electives as part of the requirements for the BME degree. These courses are to be chosen from the course requirements for the MSR degree and will also count towards their $4+1$ degree requirements.
- Students complete an additional 24 credits of coursework to meet the course requirements for the MSR degree
- Students must achieve a 3.0 GPA (a B average) in their graduate work to earn the $4+1$ degree.

II. Learning Outcomes and Assessment

Graduates of this program will be able to demonstrate different technical skills depending on their specialization through elective course selection. These skills may cover different aspects of design, analysis, simulation, and control of robotic systems. Yet all graduates should be able to demonstrate competency relative to the following three program learning outcomes.

A. Ability to derive mathematical models of robotic systems

Outcome. Ability to derive mathematical models of typical robotic systems, analyze their dynamic behavior, and design standard controllers.

Direct assessment. Student learning relative to this outcome is assessed by the students course grades in: MEEG 621 Linear Systems; MEEG 671 Introduction to Robotics; MEEG 620 Intermediate Dynamics; MEEG 698 Stochastic Optimal Control; MEEG 894 Linear Feedback Control Design; MEEG 829 Applied Nonlinear Control.

B. Ability to simulate robotic behavior

Outcome. Ability to simulate robotic behavior in industry-standard software environments —e.g., ROS, Webots, etc.

Direct assessment. Student learning relative to this outcome is assessed by the student's course grades in: MEEG 678 Introduction to Autonomous Driving; MEEG 671 Introduction to Robotics; CISC 642 Introduction to Computer Vision.

C. Familiarity with robotic systems deployment

Outcome. Familiarity with robotic deployment in real-world environments.

Direct assessment. Student learning relative to this outcome is assessed by the student's course grades in MAST 632 Environmental Field Robotics.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goals.

III. Educational Goals

The objective of the graduate MSR program at the University of Delaware is to produce graduates with a strong foundation in the science of robotics and autonomous systems, enabling them to lead successful careers, to pursue advanced degrees, and to contribute to the profession and the society at large, by advancing the quality of life and work through robotic technologies. Graduates of the MSR program will be able to:

- Design, develop and control robotic and autonomous systems found in application areas such as manufacturing, transportation, aerospace, defense, and healthcare.

- Apply fundamental knowledge of dynamics, perception, machine learning, decision and control in semi-autonomous and fully autonomous systems found in a variety of applications shaping the future of life and work.
- Contribute to engineering knowledge, the profession, and the community through original research, technology development, and service in robotics and autonomous systems.
- Work effectively on multidisciplinary teams to solve complex engineering problems related to control systems, perception, autonomy and robotic technologies.

6. PhD in Mechanical Engineering

The PhD program in Mechanical Engineering consists of 33 credits of graduate level coursework plus 9 credits of Doctoral Dissertation. The PhD program is designed to allow for considerable flexibility in course selection and specialization of study. Course work must be completed with a cumulative grade point average of 3.0 or higher (see Graduate Catalog for relevant details). In addition, the student must pass the Qualifying Examination, Candidacy Examination and fulfill the teaching requirement prior to completing the dissertation requirements. The PhD should be obtainable in four years of full-time study after entering the program. There is no foreign language requirement for the PhD.

I. Course Requirements

A. Five MEEG courses at 600 or higher level (15 credits)

One of these courses must be the following

- MEEG 690 Intermediate Engineering Mathematics

At least two of the remaining four courses must be from the following list

- MEEG 610 Intermediate Solid Mechanics
- MEEG 620 Intermediate Dynamics
- MEEG 630 Intermediate Fluid Mechanics
- MEEG 640 Intermediate Heat Transfer
- MEEG 683 Orthopedic Biomechanics
- MEEG 621 Linear Systems

B. Five additional graduate electives (15 credits)

These five electives can be in engineering, science or mathematics with at least three (9 credits) being at the 800 level.

C. At least one additional graduate course in mathematics (3 credits)

MEEG 690 cannot be used to satisfy this requirement. Unless the course is offered by the Department of Mathematical Sciences, electives intended to satisfy this requirement should typically require approval of the Graduate Committee.

D. MEEG 600 Seminar (0 credits)

At least three semesters of demonstrated attendance of the Department's Seminar Series (MEEG 600 Seminar) are required. Special arrangements can be made for part-time students to fulfill this requirement.

E. Credit Waiver for a relevant Master's degree (up to 12 credits)

In recognition of graduate degree experience, up to a maximum of 12 credits out of the 33 required credits can be waived for a student who is entering the PhD Program with a previously awarded Master's degree in Mechanical Engineering or a relevant field. The relevance of a Master's degree is determined by the Graduate Curriculum Committee (GCC) and the student's advisor after the student enrolls in the PhD program. To consider a Master's degree relevant, evidence must be provided regarding graduate coursework and/or research experience that is sufficiently similar to the Master's degree requirements at UD. In the case where 12 credits are waived, requirements A, B and C would be appropriately reduced, provided that at least 9 out of the remaining 21 credits are in Mechanical Engineering, with the remainder in engineering, mathematics, or science. In case the Master's degree is deemed not sufficiently similar to a Master's degree in Mechanical Engineering, the GCC and the student's advisor will, based on the prior graduate coursework evidence provided, determine the number of credits to be waived, and the appropriate reduction in requirements A, B and C . All students are responsible for organizing their course plan in consultation with their thesis advisor such that they are well prepared for the PhD qualifying examination, and that they fully undertake the coursework needed for their research.

F. MEEG 969 Doctoral Dissertation (9 credits)

In order to proceed to MEEG 969 students must complete all course requirements and have candidacy. An individual course can be used to meet more than one of the requirements provided the total number of credits is at least 33. MEEG 868 cannot be used toward these requirements.

Students will submit their list of completed courses, including any approved requests for credit waivers, to the Dissertation Committee at the time of their candidacy exam (see below). Upon approval, it will enter into the candidate's file. Deviations from the proposed plan must be approved by the Dissertation Committee. A copy of the course plan must be sent to the University Office of Graduate Studies.

II. Dissertation Requirements

A dissertation is required which demonstrates the student's ability to conduct independent research. A Dissertation Committee is selected by the advisor and approved by the Department Chairperson. This committee will also serve as the student's Candidacy Examination Committee. At least three Mechanical Engineering Department faculty members and at least one external faculty member (from another department or institution) will serve on the Dissertation Committee. The Committee will be chaired by the research advisor, who must be a regular full-time member of the Department of Mechanical Engineering Faculty. During the course of the research, the student will periodically review progress with the Committee.

The student must orally present the dissertation before the Dissertation Committee at an open defense. The student shall supply final draft copies of the dissertation to members of the Committee at least two weeks before the oral defense. The dissertation must meet the academic and professional standards set forth by the University.

III. Qualifying Examination

The objectives of the ME PhD qualifying exam are to (i) ensure that PhD students can think openly, creatively, and independently and at an advanced level about a topical area in mechanical engineering, (ii) ensure that PhD students can communicate effectively (including their ability to organize and express their thoughts), (iii) ensure that PhD students can handle questions raised in technical discussions and other professional interactions, and (iv) allow the ME faculty to collectively assess the aptitude of a PhD student in the early stages of the program. The qualifying exam will consist of two parts:

(a) **Course-based part:** The objective of this part is to evaluate the student's problem-solving ability within the structured work environment of courses from the core MEEG subjects. The course-based part of the exam will be assessed based on the grades received in three courses

from the list of core courses in Requirement A; one of these courses must be MEEG 690 and the other two are selected by the student. The student must maintain an average GPA of 3.0 in these three courses to be allowed to participate in the oral exam. If this requirement is not met, the student must consult with their advisor. If both the student and the advisor agree, they can appeal the GCC for an exception to be made so that the student can participate in the oral part of the qualifying exam. If the appeal is turned down, the student is not eligible to continue in the PhD program, but may apply to change his/her matriculation to the MSME or the MSR program. In this case, either the thesis or the non-thesis track can be selected.

(b) **Oral part:** The objective of this part is to assess the research aptitude of a doctoral student in the early stages of the program. The oral part will be offered in early June and will include:

  (i) A short report with a concise description of an advanced problem in the student's area of research.

  (ii) A short oral presentation based on the above report before a faculty committee of at least three faculty members, including the student's research advisor and two other faculty members, not advising the student, appointed by the department chair.

  (iii) A period of discussion following the student's presentation. Part of the discussion will revolve around foundational aspects of the problem presented and of the corresponding research area; a list of fundamental topics per research area will be established by the faculty and provided to the students ahead of the exam. Part of the discussion that follows the oral presentation will also address future steps on how to approach the solution of the presented problem to examine the student's ability to creatively think about the problem.

In assessing a student's performance on the qualifying examination, the faculty will collectively consider the following factors:

(a) grades of the courses selected in the course-based part

(b) performance of the student in the oral part

(c) advisor's opinion, who will comment on criteria related to the student's overall performance, including work ethics, research aptitude, creativity, productivity.

The outcomes of the qualifying exam will be (i) outright passing, (ii) conditional passing, or (iii) outright failing. If the student is given a conditional passing, the faculty will specify the parameters for taking and passing the second chance exam. These decisions will be made in a faculty meeting held as soon as possible following the completion of the oral exams. There will be

no third chance given. A student who ultimately fails the Qualifying Examination is not eligible to continue in the PhD program, but may apply to change his/her matriculation to the MSME or the MSR program. In this case, either the thesis or the non-thesis track can be selected.

IV. Candidacy Examination

The PhD Candidacy Examination must be taken within one and a half years of successful completion of the Qualifying Examination and at least one year prior to the dissertation defense. The student will prepare a comprehensive, written research proposal and defend it orally before the Candidacy Examination Committee (the composition of which is specified in §II). The Candidacy Examination is intended to test the student's ability to synthesize knowledge in the formulation of an independent research proposal. Performance is judged by the Candidacy Examination Committee, and any additional requirements they wish to impose must be satisfied before the student is admitted to candidacy. Additional requirements could include, but are not limited to: taking additional coursework, modifying the written research proposal, and defending the revised proposal before the Candidacy Examination Committee. Satisfactory completion of any additional requirements must be approved by the student's Candidacy Examination Committee.

V. Embedded MSME

Doctoral students can earn an MSME while pursuing their doctoral degree. Students who enter the PhD Program are not automatically enrolled in the MSME program. To add the MSME degree, students must complete at least 33 credits of coursework, as required for the PhD degree, and submit an MS checkout form approved and signed by the student's PhD Dissertation Committee to the GCC no sooner than the beginning of the semester following the completion of the candidacy requirement. Then, the GCC will complete a Change of Classification Form and an Application for an Advanced Degree Form and submit them to the Graduate College. The embedded MSME degree is awarded to recognize the student's significant progress towards her/his PhD. Thus, in addition to the successful completion of the PhD coursework and candidacy examination, significant research contributions (typically in the form of journal and/or conference publications) will be taken into account when a PhD candidate applies for the MSME degree.

VI. Embedded MSR

Doctoral students can earn an MSR while pursuing their PhD in Mechanical Engineering. Students who enter the PhD program are not automatically enrolled in the MSR program. To add the MSR degree, students must complete at least 33 credits of coursework, as required for the PhD degree, while also meeting the following coursework requirements for the Embedded MSR program:

(i) 6 MSR core courses[2] (total: 18 credits)

(ii) 4 approved MSR technical elective courses[3] (total: 12 credits)

The embedded MSR degree is awarded to recognize the student's significant progress towards her/his PhD. Thus, in addition to the successful completion of the PhD coursework and candidacy examination, significant research contributions (typically in the form of journal and/or conference publications) will be taken into account when a PhD candidate applies for the MSR degree. Students should submit an MSR checkout form approved and signed by the student's PhD Dissertation Committee to the MSR Graduate Program Director no sooner than the beginning of the semester following the completion of the candidacy requirement. Then, the MSR Graduate Program Director (GPD) will complete a Change of Classification Form and an Application for an Advanced Degree Form and submit them to the Graduate College. Credits in Embedded MSR degree, cannot be counted toward the Embedded MSME Degree.

VII. Teaching Requirement

The ability to communicate effectively is an essential skill for all PhD graduates. Therefore, all PhD students are required to fulfill a teaching requirement, which consists of serving as a Teaching Assistant (TA) for one or two semesters, depending on the assignment. Students are expected to continue to be actively involved in their research while serving as a TA.

International graduate students are required to take International Teaching Assistant (ITA) training through the University's English Language Institute (ELI) prior to their first semester. Training and assessment are part of the University's requirements for the proficiency of international TAs. A final decision on how to resolve any deficiency is made by the Graduate Curriculum Chair in consultation with the student's thesis advisor and the Department Chair.

Teaching Assistant positions are assigned by the GCC Chair in advance for the upcoming semester.

[2]Updated list: https://me.udel.edu/academics/graduate/msr/.

[3]Updated list: https://me.udel.edu/academics/graduate/msr/. Note that the list of MSR technical electives is growing, and students can request other graduate level classes to count as MSR technical electives.

Students are encouraged to submit their preferences for specific TA positions early to facilitate the process. Although every effort is made to satisfy these requests, students should recognize that this might not be possible in all cases. In addition, the educational needs of the Department may require the GCC Chair to ask students to fill specific TA positions.

VIII. Learning Outcomes and Assessment

A. Application of graduate-level mathematics

Outcome. The student will demonstrate the ability to apply graduate-level mathematics to the solution of engineering problems in at least two of the general areas of solid mechanics, fluid mechanics, dynamics and heat transfer.

Direct assessment. Student learning relative to this outcome is assessed by the student's performance on the written PhD Qualifying exam.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goal.

B. Conduct of research

Outcome. The student will demonstrate the ability to conduct, present and defend graduate-level research including literature review, motivation, methodology utilized, results, unique contributions, and conclusions generated.

Direct assessment. Student learning relative to this outcome is assessed by the quality of the written dissertation and performance in the dissertation defense.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goal.

C. Planning of graduate-level research

Outcome. The student will demonstrate the ability to propose and present relevant graduate-level research including the description of importance of a problem, a literature review of potential topics where unique contributions can be made and anticipated methodology.

Direct assessment. Student learning related to this outcome is assessed by performance on the Candidacy Examination.

Indirect assessment. A current and updated employment listing will serve as indirect evidence of student attainment of the learning goal.

IX. Educational Goals

The principal objectives of the PhD program in Mechanical Engineering at the University of Delaware are to provide students with a rigorous, multidisciplinary, and research-intensive education and training which will equip them to solve the most compelling scientific and technical challenges of our age. Graduates from the program will be well positioned to pursue careers in industry, academia, and the government. More specifically, graduates of the PhD program in Mechanical Engineering will be able to:

- Demonstrate the ability to apply advanced graduate-level mathematics to the solution of engineering problems in the general areas of solid mechanics, fluid mechanics, dynamics, and heat transfer.
- Demonstrate the ability to conduct and publish fundamental research in the areas of biomechanical engineering, clean energy and environment, composites and advanced materials, nanotechnology, and robotics and control.
- Mentor undergraduate and graduate students in education and research.
- Contribute to scientific knowledge, the profession, and the community through original research, technology development, or service in areas relevant to mechanical engineering.
- Lead multidisciplinary teams to solve complex mechanical engineering problems related to a variety of technologies shaping the future of our lives.