

The Chemical Engineering Ph.D. Program

Department of Chemical and Biomolecular Engineering
University of Delaware Newark, DE 19716
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Introduction

For an engineer, the Ph.D. represents the final phase of formal academic training, in preparation for a variety of careers in industry, government, and academia. The PhD program aims to equip students to conduct research; enable them to develop the maturity of judgment necessary for critical, creative, and independent thinking; and prepare them to contribute to scientific and engineering knowledge in a particular area of scholarship. The degree of versatility necessary to succeed in research and, in general, to be a productive member of the profession, requires a breadth of knowledge of chemical engineering fundamentals and their proper application.

The requirements specified below represent the minimum that the department expects every student to meet. They are designed to be sufficiently flexible to accommodate differences in interests, aptitude, and expected career paths among students. Students are encouraged to take the initiative in seeking opportunities for formal and informal intellectual exploration beyond the guidelines imposed by the degree requirements. Keep in mind that these guidelines will change with time, and that the faculty will continue to refine and improve the PhD program in consultation with the graduate students and Graduate College.

Course Requirements

The aim of the course requirements is to establish a foundation of technical knowledge in chemical engineering. This foundation should be established in a way that fosters a fundamental understanding of basic principles in general, while also providing depth in certain specific areas. An overall GPA of 3.00 or above must be maintained in courses taken toward meeting these requirements.

There are three components to the course requirements:

- chemical engineering science core (thermodynamics, transport phenomena, and chemical kinetics and reaction engineering)
- advanced mathematics
- chemical engineering technical electives

The core courses should all be taken during the first year (prior to the qualifying exams). Eight credits of chemical engineering electives are required. At least three of these credits must be at the 800-level; the remainder may be at the 600- or 800-level, with the possibility of substituting suitable courses from outside chemical engineering. The chemical engineering technical electives may be started during the fall semester of the first year and are usually completed during the second year. Nine credits of CHEG 969-xxx Doctoral Dissertation are also required. These credits should be taken *after* all other course work is completed. The curriculum is reviewed each year and updated often. A typical schedule of courses for the first year is shown below:

FALL

CHEG 825 Thermodynamics
CHEG 835 Chemical Kinetics
CHEG 831 Chemical Engineering Principles 1
CHEG 6xx/8xx Technical Elective

SPRING

CHEG 845 Advanced Transport Phenomena
CHEG841 Chemical Engineering Principles II
CHEG 6xx/8xx Technical Elective
CHEG 6xx/8xx Technical Elective

An overview of course and non-course requirements and timeline to progress toward a Ph.D. degree is provided in the Appendix.

A graduate student who receives a C+ or lower letter grade in any core graduate course must retake the course. Students who receive one or more B- grades in any core graduate course may choose not to retake the course as long as the student meets the overall 3.00 GPA requirement in the graduate classes.

Ph.D. Qualifying Procedures

The Ph.D. qualifying procedures serve several purposes. They provide the faculty an opportunity to evaluate each student's analytical skills and ability to think critically and generate original ideas. In addition, qualifying procedures provide students a chance to practice their communication skills and faculty an opportunity to evaluate those skills. The qualifying exams are oral exams given toward the end of the student's first year, after completion of the core courses. This ensures that all students have the necessary chemical engineering background to take the exams and allows students to become involved in their research in a efficient and effective manner. To avoid unnecessary delays in formal admission to the Ph.D. program, students are given only a single opportunity to take and pass the qualifying exams. The faculty feel strongly that we have more than enough information to make an appropriate decision about Ph.D. candidacy after students have spent a full year in the department.

The central formal component of the qualifying procedures is an oral examination that typically takes place near the end of August of the students' first year, unless other legitimate activities, such as special graduate training programs, compel a postponement. The oral exam is intended to evaluate each student's abilities in several areas: creative thinking, progress in understanding and formulating a research project, mastery of the relevant underlying chemical engineering fundamentals, and effective communication of ideas in both oral and written forms. The specific guidelines for the oral exam vary from year to year as the technology of the oral presentation advances, and as needed to improve the examination process. The procedures are as follows:

Each **oral exam** lasts 60 minutes. The first 12-15 minutes are reserved for oral presentation with the remaining time reserved for faculty questions. Presentation files (Powerpoint or PDF) are used. Each student's exam is administered by a group of at least five faculty, including at least two members of the student's thesis committee, and the thesis advisor. It is the student's responsibility to establish the thesis committee prior to scheduling the exam, in consultation with the research advisor.

In preparation for the exam, students are also required to prepare a **written document**, to be made available to the faculty in electronic form (as a PDF file) at least 2 weeks before the exam, with a common deadline for all students set by the department each year. The written document should contain the following four elements:

1. A title page stating the title of your thesis, your full name, and your thesis advisor's name. This title page should not have any other text besides these three items.
2. The main document, including all tables and figures, should not exceed 10 pages on standard paper.
3. Any (appropriate) number of pages (beyond the 10-page limit of the main document) listing

relevant references in a bibliography using the format listed in the NSF grants preparation guide website. *“Each reference must include the names of all authors (in the same sequence in which they appear in the publication), the article and journal title, book title, volume number, page numbers, and year of publication.”*

4. One page of an appendix (not counted as part of the main document’s 10-page limit), which outlines goals, plans, and a timeline for the proposed thesis research, with particular emphasis on the goals for the coming year.

You are expected to adhere strictly to the following format in all four elements listed above:

- Times New Roman with font size 11, OR Arial with font size of 10, OR Computer Modern with font size 11 (if you use LaTeX) for all text in the 10-page report and appendix, including figure captions, tables and references/bibliography.
- No more than six lines of text within a vertical space of one inch in the 10-page report and appendix, including figure captions, tables and references/bibliography.
- Margins, in all directions of the page, must be at least one inch. Do not include any text (e.g., references, footnotes, etc.) or figures within these 1-inch margins. Only page numbers can appear within the margin region.

Failure to comply with these formatting guidelines will result in a failure of the qualifying exam and the need to undertake a Master’s defense before continuation in the PhD program.

The exam date and time for each student will be scheduled by the Department’s faculty Graduate Program Director in consultation with the faculty.

Both the oral and the written presentations should provide succinct and clear descriptions of the concepts underlying the proposed thesis research, the goals of the project, and the methods to be used in achieving those goals. While they may be incomplete, results obtained to date provide a useful focus for the exam. Questions asked by the faculty may address specific details or the broader context of the project presented, the proposed approaches, and associated chemical engineering principles. Clear communication in both the oral and written presentations and in interpreting and answering questions is essential to pass the exam.

In each student's preparation for the exam, the advisor is likely to be the principal source of information and guidance. However, since it is expected that both the written and the oral presentations represent the student's own work, **advisors do not work with the students on the structure or content of either presentation, e.g., by reading drafts of the written document or the slides, or being present during practice talks.**

In reaching a decision on admission to Ph.D. candidacy, the student’s performance in the required first-year courses is also considered in addition to the oral exam. These courses provide perhaps the best view of each student’s analytical skills. In recognition of the important role that course work plays in providing a good assessment of the analytical capabilities essential for successful completion of the Ph.D., in a situation in which a student does not meet the minimum grade requirements (i.e., receiving B- or lower grade in one or more core graduate courses), the department will consult with the thesis advisor(s) on a case-by-case basis to determine the student’s eligibility to take the qualifier exam before retaking any courses.

The faculty will also consider other information in addition to performance in the formal qualifying procedures in assessing the student’s suitability for admission to Ph.D. candidacy. Course instructors and, most importantly, each student's advisor, because they have more opportunities for closer

interactions, are expected to have informed perspectives on each student's comprehensive performance in the program.

The faculty, as a group, will make their decisions on admission into the Ph.D. program within a week after all the oral presentations have been completed. The decisions will be conveyed to the students in writing by the Department Chair. All of the components of the exam are equally important. A strong showing in only one area will probably not be sufficient to ensure admission into Ph.D. candidacy, but neither will a weak showing in any single area lead to automatic failure.

The faculty member in charge of each student's thesis committee will provide a written summary of the faculty's feedback to the student within one week after candidacy decisions are completed. This summary will include strengths and weaknesses identified by the committee in the student's written report and oral exam, as well as recommendations regarding the student's goals and time line for the coming year's research efforts.

The department admits students into its graduate program with the expectation that they will be successful in the qualifying procedures and matriculate into the Ph.D. program. Consequently, the qualifying procedures are an evaluation intended to be a constructive learning and training experience, and not a barrier to the student's overall educational and professional goals.

Research

A graduate education is the development of the skills necessary to conduct and present independent research. The Ph.D. thesis should demonstrate that the student has (1) acquired the skills necessary to conduct high-quality research, including the ability to think creatively and critically, and (2) completed a coherent piece of independent research that makes a meaningful contribution to engineering scholarship. The length of the actual thesis, the number of associated publications, and the time required, will necessarily vary, depending on the abilities and effort of the student, the details of the project, and the philosophy of the thesis advisor.

The department does not prescribe, *a priori*, how long any given student will remain in residence. However, the Ph.D. program is a transition period, one that provides students with an opportunity to expand their intellectual horizons, to learn how to conduct research, and to be creative. The transitional nature means that students should progress as rapidly as possible toward completion of all of the objectives and requirements of the Ph.D. degree. The following sections describe the policies and guidelines that have been established to assist the student in the selection, conduct, and completion of the doctoral thesis.

Thesis topic selection

The Department does not allow students to choose thesis topics or advisors prior to arriving at Delaware. Since research is such a critical component of the graduate program, students need time to gather information about available projects, to clarify their own personal research interests, and to think carefully about their own long-term objectives. To start this process, a set of written descriptions of available projects (prepared by the faculty offering them) is provided to the students at the beginning of the fall semester. Over the course of the ensuing few weeks, each faculty member presents his or her projects in a 30-minute talk. Graduate students are expected to attend all thesis topic presentations, even if they have no interest in that particular research area. These presentations are an ideal way to meet the faculty and to become exposed to the full range of chemical engineering research activities in the department and broader profession. Students should talk individually to faculty members and other graduate students to gain a more thorough understanding of possible research topics. Several meetings

may be required to fulfill this objective, and students are even encouraged to work with the faculty to develop project ideas that match their personal research interests.

In early-to-mid November, students are required to provide a list of their advisor preferences and a paragraph describing their reasoning to the faculty Graduate Program Coordinator. This date can vary by a few weeks from year to year depending on funding or project availability as dictated by funding agencies.

The advisor–thesis project preference list must include at least three unique proposed advisors. Matching students to research topics and advisors is a difficult constrained multivariable problem. Many factors are involved in the determination of the final assignments, including current research group sizes, faculty objectives, department objectives, funding, and student preferences. Often the final solution may not be a perfect match of student and preferred project. Nevertheless, the department is committed to finding the best possible solution, which might involve having some students meet again with the faculty Graduate Program Coordinator and individual faculty to discuss options.

Thesis committee

Research projects are carried out independently, but not in isolation. Graduate students are encouraged to involve many faculty, both inside and outside the department. Since students often feel uncomfortable asking other faculty members questions about research, a formal structure for this interaction is provided in the form of a thesis committee.

The thesis committee consists of at least two other faculty members chosen by the student in consultation with the thesis advisor; other PhD holders (e.g., those working in industry or national laboratories) may also be included, as deemed appropriate. The faculty members of the committee will usually be from the Chemical and Biomolecular Engineering department, but outside faculty may also be included. However, the committee for the final thesis defense must include one outside faculty member. This external member of the committee does not need to be identified prior to qualifying exams, but they must be included in subsequent committee meetings and decisions once a student has been admitted to Ph.D. candidacy. Additional committee members may be added at any time before the thesis defense. However, removal of a committee member requires that the committee member in question give written approval to the department’s faculty Graduate Program Coordinator, or else requires special approval from the Department Chair if the faculty member in question is unable or unwilling to fulfill his or her role as a committee member within a reasonable time frame.

The thesis committee members make a commitment to provide input and feedback throughout the course of the thesis research. This includes feedback on your departmental research presentations and during committee meetings. Students are strongly encouraged to provide the committee with written progress reports and copies of manuscripts and publications.

Several departmental requirements for formal interactions with the thesis committee are described here. These interactions are intended to encourage flexibility and to ensure that substance, rather than form, prevails. However, the requirement of a minimal set of interactions is intended to help facilitate measurable progress toward degree completion at a reasonable pace, without stifling creativity and inhibiting the thesis direction from evolving freely. **Each student is required to meet with his or her thesis committee around the end the second year, prior to the start of the third year.** This is separate from the second year research talk presented to the department as a whole. The purpose of the meeting is for the student to present results and update the committee on progress made and any changes in direction since the qualifying exam. It is also intended to ensure that sufficient progress is being made to justify department funding commitments. Another committee meeting is required around the end of the fourth year, provided that the student has not already graduated. **A formal committee meeting is**

not required in the third year, but students must provide the committee members with a brief written summary as an update between the 2nd-year and 4th-year meetings. The exact format is flexible. Students are encouraged to seek additional informal or formal feedback proactively from individual committee members as needed.

Department Research Symposia

Good presentation skills are necessary for the practice of good research. Participation in the departmental research symposia provides the student an opportunity to develop these skills. Each student is expected to present two symposia talks during his or her graduate studies: one during the 2nd year and another during the 4th year. These talks are given as part of a day-long Departmental Research Review that provides students, faculty, and postdocs an opportunity to learn about different research areas, discuss alternative approaches to research, and provide comments and feedback to colleagues.

The content of the talks will vary with the state of the projects, but a typical content will include background, experimental approach, results, and future plans. Typically, the second year talk is essentially a preliminary report and a research proposal; the fourth year talk is more polished, featuring a more coherent presentation of project results. The student can improve his or her skills by soliciting feedback from faculty members and other students; at a minimum each thesis committee member should be consulted. Students are encouraged to make use of video equipment, which is available for recording and reviewing presentations.

Final thesis defense

The final oral defense is a presentation of a summary of the completed research to the department, the defense committee, and the public research community. The defense committee may be the same as the thesis committee discussed above, with the addition of one member from outside the department. The student must provide a copy of the thesis to each member of the defense committee at least 2 weeks before the defense. At this time, the departmental Graduate Services Coordinator should also be informed of the date and venue of the defense, and an announcement, including an abstract, should be distributed to the department.

The period leading up to the final defense should involve close interaction of the student, the advisor, and the thesis committee. Since a good research project is often open-ended, questions such as which specific goals are to be pursued and which are to be set aside as secondary require substantial discussion. To allow all possible points of view to be brought to bear on these issues, continuous involvement of the thesis committee is recommended to obtain the best advice possible. Such involvement of several faculty also ensures good communication of progress and expectations, and that impartial reviews of any divergent views occur promptly. At a minimum, each student must hold a thesis committee meeting no less than six months prior to the intended defense date. This meeting may preempt the 4th-year committee meeting requirement described above.

Funding

Funding will be available on a continuing basis provided the student maintains satisfactory progress toward completion of the degree. During the first year, the main criterion is that a 3.00 GPA must be maintained in course work throughout the program. After the first year, progress will primarily be in research, where a clear quantitative measure of performance is infeasible. In general, the thesis advisor is responsible for this progress review, but in cases where there is disagreement between advisor and student, the thesis committee will provide an independent evaluation to determine if there is satisfactory progress for continuation of funding. In the event that progress is deemed unsatisfactory, the student

will be provided at least three months notice that funding is in danger of being discontinued, and, wherever possible, will be given sufficient opportunity to rectify the situation. Although the likelihood of this happening during the early stages of the research is slim, students should be aware that all thesis projects must eventually end, and thus the likelihood of funding being discontinued increases with increasing residence time in the program. Funding is not guaranteed beyond four years.

The majority of students in the department are supported on research contracts, grants, and other funds obtained by their faculty advisors. Students on projects without external funding will be provided support (as long as their progress is satisfactory) using either departmental funds or by appointment as a teaching assistant. No student will be supported by departmental funds for more than five semesters; funds beyond such a commitment must be provided by the thesis advisor or by appointment as a teaching assistant.

External Fellowships

Ph.D. students who independently receive external fellowships that provide funding toward their stipend will have their standard graduate stipend supplemented by an amount equal to half the external fellowship amount or 1/3 of the regular Ph.D. graduate student stipend applicable at the time, whichever is smaller. Internal fellowships are considered to be those managed by the university (e.g. Delaware Space Grant Consortium), training grants, and fellowships.

Teaching Assistants

The ability to communicate ideas, concepts, and factual information in any environment is an essential skill for all PhD graduates, even those who have no interest in an academic position. Consequently, all PhD students are required to fulfill a teaching requirement, which consists of serving as a TA for two lecture-style courses or for one Junior or one Senior laboratory course. Students who serve as a TA for a lab will be considered full-time TAs for that semester, while students who serve as a TA for a lecture will be considered half-time TAs. All TAs are expected to continue to be actively involved in their research while serving as a TA. Although the exact timing of TA appointments is flexible, it is highly desirable that students complete all TA responsibilities relatively quickly (by the end of the 3rd year if possible) to allow them to focus entirely on their research as they near the end of their graduate studies.

In order to be an effective TA, it is essential that students have adequate command of the English language. Graduate students considered deficient in language ability will be required to correct this deficiency, for example, by taking an appropriate course through the University's English Language Institute. Language deficiencies can also be identified during the Oral Qualifying Examination. Final decisions on how to resolve these deficiencies are made by the Graduate Program Coordinator in consultation with the student's thesis advisors and the Department Chair.

Teaching Assistant positions are assigned by the faculty Graduate Program Coordinator in November (for the upcoming spring semester) and in May (for the following fall). 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, this may not always be possible. **In addition, the educational needs of the Department may require the Graduate Program Coordinator to ask students to fill specific TA positions.**

Every spring, the Department recognizes the contributions of our most outstanding TAs with the Robert L. Pigford Awards for Outstanding Teaching Assistants. These awards, which include modest financial gifts, are used to acknowledge exceptional TAs for their efforts toward advancing the Department's educational mission.

Teaching Fellowships

The Department has established the Teaching Fellowship program for graduate students with particular interest in academic careers. Each Teaching Fellow co-teaches a Chemical Engineering course with a faculty mentor, and is involved in all aspects of the course (lecturing, preparation of new material, grading, assessment, etc.). Graduate students interested in the Teaching Fellow program should meet with the Graduate Program Coordinator to discuss the various options. Teaching Fellows are chosen by a committee based on their performance in previous TA positions, recommendations from their thesis advisor, and comments from the prospective faculty mentor. It is strongly encouraged that students complete their TA requirements prior to applying for a Teaching Fellowship. The committee may award a particularly outstanding Teaching Fellow candidate the Shirley and Fraser Russell Teaching Fellowship.

Requirements for the MChE Degree

Students who obtain a MChE instead of a PhD or who do not matriculate into the PhD program have two options for graduate education leading to a Masters in Chemical Engineering (MChE) Degree.

The thesis option requires 6 credit hours of thesis work (CHEG869 Master's Dissertation) and 24 credit hours of course work; it is designed for full-time graduate students in residence. The course option requires 30 credits of course work and is designed for engineers who are studying part-time. The faculty member supervising the thesis research will act as an advisor for students in the thesis option. The Department's Graduate Program Director will act as an advisor to all students in the course work option.

Both options require 10 credits (three courses) of core courses in chemical engineering fundamentals: Thermodynamics (CHEG 825, 3 credits), Applied Chemical Kinetics (CHEG 835, 3 credits), and Advanced Transport Phenomena (CHEG 845, 4 credits). Students must also fulfill an advanced mathematics requirement, CHEG 831 (Chemical Engineering Principles) and CHEG841 (Chemical Engineering Principles II). The Department offers numerous technical electives in all areas of Chemical Engineering, and up to six credits of technical electives may be taken in suitable courses outside Chemical Engineering.

Continued funding is provided only for MChE students pursuing the thesis option. Students who have been provided support will generally not be allowed to pursue the non-thesis MChE degree. Funding will be available for students performing MChE thesis work on a continuing basis if they maintain satisfactory progress towards the degree. A 3.00 GPA must be maintained throughout the program. Students should be aware that theses must come to an end in a reasonable period of time (typically 18 months). Funding beyond the 18-month period is not guaranteed.

APPENDIX

Overview of formal requirements & milestones for progression of Ph.D. candidacy

YEAR 1: Fall: Take core classes and elective(s) and undergo advisor selection process

YEAR 1: Spring: Start research in assigned research lab, take core and elective classes

YEAR 1: Summer: Identify faculty members in the department who will serve as Ph.D. committee.

YEAR 1: August: Qualifying Exams

YEAR 2: Fall: Identify external thesis committee member once admitted to candidacy.

YEAR 2: Summer: Participate in 2nd year talk

YEAR 3: Prior to start of Year 3, set up a FORMAL committee meeting with your thesis committee. Another informal update to the committee is expected during the third year.

** *Complete 2 semesters of teaching assistantship (preferably in YEAR 2 or 3)*

YEAR 4: Winter: Participate in 4th year talk

YEAR 4-5: Set up a penultimate committee meeting ~6 months before final defense, Complete final defense.

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