CHEMICAL AND LIFE SCIENCE ENGINEERING, DOCTOR OF PHILOSOPHY (PH.D.)

Program mission

The mission of the Ph.D. in Engineering degree program is to provide graduate students with learning opportunities for acquiring a broad foundation of engineering knowledge, an in-depth original research experience at the frontiers of engineering, and skills for lifelong learning and professional development. Graduates of this program will pursue careers in research and development or academia.

1. Advanced research skills: To produce graduates who possess the necessary advanced analytical, technical and research skills in engineering and the sciences – responds directly to the higher goal of fulfilling the needs of industry, academe and research laboratories for effective, productive engineers, professors and researchers
2. Communication: To produce graduates who possess a facility with both written and oral communications – emanates from the requirement that engineers, researchers and professors must be able to interact and share ideas with others in the work environment, and at a higher level, be capable of creative self-expression, conveying knowledge and leadership
3. Advanced problem-solving: To produce graduates who demonstrate creativity and innovation in solving technological problems – stems from the realization that new knowledge and new solutions to existing problems are necessary to meet the needs of our changing society and to advance the quality of human life

Student learning outcomes

1. Apply advanced knowledge of mathematics, science or engineering: Graduates will demonstrate an ability to apply advanced knowledge of mathematics, science or engineering.
2. Communicate effectively: Graduates will demonstrate an ability to communicate effectively.
3. Identify, formulate and solve engineering problems: Graduates will demonstrate an ability to identify, formulate and solve engineering problems.
4. Demonstrate abilities in research: Graduates will demonstrate the ability to identify pertinent research problems, to formulate and execute a research plan, to generate and analyze research results, and to communicate those results through oral presentations and written publications. Graduates will be able to creatively solve the research problems posed.

VCU Graduate Bulletin, VCU Graduate School and general academic policies and regulations for all graduate students in all graduate programs

The VCU Graduate Bulletin website documents the official admission and academic rules and regulations that govern graduate education for all graduate programs at the university. These policies are established by the graduate faculty of the university through their elected representatives to the University Graduate Council.

It is the responsibility of all graduate students, both on- and off-campus, to be familiar with the VCU Graduate Bulletin as well as the **Graduate School website** and academic regulations in individual school and department publications and on program websites. However, in all cases, the official policies and procedures of the University Graduate Council, as published on the VCU Graduate Bulletin and Graduate School websites, take precedence over individual program policies and guidelines.

Visit the academic regulations section for additional information on academic regulations for graduate students.

Degree candidacy requirements

A graduate student admitted to a program or concentration requiring a final research project, work of art, thesis or dissertation, must qualify for continuing master's or doctoral status according to the degree candidacy requirements of the student's graduate program. Admission to degree candidacy, if applicable, is a formal statement by the graduate student's faculty regarding the student's academic achievements and the student's readiness to proceed to the final research phase of the degree program.

Graduate students and program directors should refer to the following degree candidacy policy as published in the VCU Graduate Bulletin for complete information and instructions.

Visit the academic regulations section for additional information on degree candidacy requirements.

Graduation requirements

As graduate students approach the end of their academic programs and the final semester of matriculation, they must make formal application to graduate. No degrees will be conferred until the application to graduate has been finalized.

Graduate students and program directors should refer to the following graduation requirements as published in the Graduate Bulletin for a complete list of instructions and a graduation checklist.

Visit the academic regulations section for additional information on graduation requirements.

Other information

Student handbook (http://www.egr.vcu.edu/current-students/graduate-student-services/resources-forms/) is available on the College of Engineering website.

Apply online today. (https://www.vcu.edu/admissions/apply/graduate/)

Admission requirements

Degree:	Semester(s) of entry:	Deadline dates:	Test requirements:
Ph.D.	Fall (preferred)	Jun 1 (Jan 15 for financial assistance)	TOEFL required for international students
	Spring	Nov 15	

In addition to the **general admission requirements of the VCU Graduate School** and the College of Engineering, admission to the Ph.D. in Chemical and Life Science Engineering program requires that applicants demonstrate the following specific requirements:

- Proof of graduation from an accredited college or university or its equivalent with a degree in chemical engineering or a related

discipline, such as petroleum engineering, biochemical engineering or materials science and engineering
- A minimum undergraduate GPA of 3.0 on a 4.0 scale in chemical engineering or a related discipline for at least the last two years of undergraduate work
- A written statement of intent for pursuing graduate studies in chemical and life science engineering

Note: The GRE is not required but students are encouraged to submit their scores as additional evidence of their qualifications. Competitive scores are greater than 300 for combined Quantitative and Verbal and 4.0 Analytical score. The GRE cannot be used in place of other admissions requirements.

Transfer credits will not be counted toward core or required courses.

International students will submit an official transcript evaluation from a recognized foreign educational credentials evaluation service accredited by the National Association of Credential Evaluation Services or the American Association of Collegiate Registrars and Admissions Officers. International students must also provide proof that they can support themselves financially for the duration of the program.

Non-native English speakers will provide evidence of proficiency in English by one of the following:

- A test of English as a Foreign Language minimum composite score of 100 for the Internet-based test or 600 for the paper-based score
- An International English Language Testing System score minimum of 6.5 on the academic exam

Acceptance of an applicant is based upon the recommendation of the department's graduate admissions committee. The admissions committee is composed of the CLSE graduate committee, chaired by the graduate program director. The admission recommendation is based on an overall assessment of the applicant's potential for success in the program. The recommendations will be approved by the program director and the associate dean for graduate studies for the College of Engineering.

Degree requirements

In addition to the VCU Graduate School graduation requirements (https://bulletin.vcu.edu/academic-regs/grad/graduation-info/), students must meet the following requirements.

The Chemical and Life Science Engineering Ph.D. program requires a minimum of 68 credit hours for students entering with a B.S. and a minimum of 45 credit hours for students entering with a M.S. degree.

Post-baccalaureate students undergo a course- and research-intensive program with 41 didactic credit hours and at least 27 research credit hours. The post-M.S. route requires 18 didactic credit hours and at least 27 research credit hours. At least half of the minimum required course work credit hours must be at the 600-level or higher.

To graduate, degree applicants must achieve an overall minimum grade point average of 3.0 on a 4.0 scale. Grades below a B will require remediation of the course as instructed by the course instructor. The GPA for graduation will be based on all graduate courses attempted after acceptance into the program. Graduates must also achieve a passing performance on their qualifying and comprehensive examination.

Typically, a student entering with a B.S. degree requires around four years of study to complete the Ph.D. degree. A student entering with an M.S. degree requires around three years to complete the Ph.D. A period of residence of at least three consecutive semesters is required. Residency is defined as registration for at least nine credit hours per semester. A time limit of seven calendar years, beginning at the time of the first registration, is placed on work to be credited toward the Ph.D., although the CLSE graduate committee may extend the time limit by one year, not to exceed the total of eight years.

Ph.D. qualifying examinations

To advance to doctoral candidacy, the student must pass the Ph.D. qualifying examination by the end of their first year of graduate study. Students may not take the examination if their overall GPA is less than 3.0 and if they have not completed the foundation and/or core courses. The qualifying examination has the same requirements for all students: an open-ended research question aimed at assessing critical thinking, research skills, technical writing and oral communication. The qualifying examination is in two parts.

Part I: This part will require submission of a written research proposal within a specified time period. The report will be graded by members of the program faculty who will be appointed in a rotating fashion each year. If unsuccessful on their first attempt, students will be asked to take a grant-writing course and work with their advisers to improve their research and writing skills. A second attempt will be provided to pass Part I in a re-examination. If a student fails to pass on the second attempt, they will be asked to leave the program with an M.S. degree.

Part II: This part will require an oral examination within a specified time period. The oral examination is designed to assess the ability of the candidate to integrate information and to display appropriate knowledge and problem-solving skills fundamental to chemical and life science engineering. The oral examination consists of a student's defense of their written research proposal and includes questions related to fundamental concepts in chemical and life science engineering. The presentation will be graded by a minimum of three members of the program faculty not including the student's research adviser. If unsuccessful on their first attempt, students will be allowed one additional attempt to pass the subject area questions in a re-examination. If they fail to pass on the second attempt, they will be asked to leave the program with an M.S. degree.

The Ph.D. qualifying examination will be organized by the graduate program director who, with the CLSE graduate committee, will review all results and issue recommendations.

Dissertation committee

Following the qualifying examination, the research adviser will work with the student to select members of the dissertation committee. The dissertation committee should to be formed within 12 months of selecting the research adviser, and no later than 24 months after enrollment. This committee will consist, at a minimum, of five members. Three members must be from the CLSE program faculty and two members must be from outside the program. The primary adviser will serve as the committee chair. The outside members may be from VCU, another university or from industry. All outside committee members must be members of the VCU graduate faculty. Those not already graduate faculty members must apply for membership via the dean of the VCU Graduate School. The selection of the research adviser and the

dissertation committee is to be approved by the CLSE graduate program director.

Ph.D. proposal defense

A dissertation proposal must be presented for defense within 36 months from enrollment. The proposal defense will present progress in the chosen research area and demonstrate problem-solving capabilities related to dissertation research.

The proposal defense has two parts: a written and an oral examination. The student is required to prepare a written dissertation proposal and to defend it in front of the dissertation committee. The proposal will include a research plan, initial results and a thorough literature review to judge the feasibility, scope and potential impact of the research. At the proposal defense, the candidate's oral presentation is followed by questions from the dissertation committee. A favorable decision with no more than one negative vote from the committee is required to pass.

Admission to candidacy

The admission to doctoral degree candidacy is a formal statement by the graduate student's faculty regarding the student's academic achievements and readiness to proceed to the final research phase of the doctoral program. Before admission to candidacy for the doctorate, a student in good standing must have:

- Completed required course work
- Successfully passed the qualifying examination and the Ph.D. proposal defense

Dissertation research and review

The student must complete a minimum of 27 research credit hours conducting an original investigation under the guidance of the adviser. The student's dissertation committee will conduct a yearly review of progress based on a report prepared by the student. The student's report, along with written minutes of the dissertation committee recommendations, signed by all committee members will be submitted to the graduate program director.

Final dissertation defense

At the completion of the research, the student will prepare a dissertation reporting the results of this research. There should be a dissertation committee meeting no later than six months prior to dissertation defense to certify student readiness to write the dissertation. When the dissertation has been written, copies in the required form and style are submitted to the members of the dissertation committee. If the committee accepts the dissertation for defense, the candidate appears before them for a final oral examination.

The oral defense of the dissertation is open to all members of the community. There will be an announcement of the candidate's name, department and title of dissertation, specifying day, place and time of the final oral examination at least 14 days in advance. Following the presentation and questions, the candidate is excused and committee members vote. A favorable decision by the dissertation committee with no more than one negative vote is required for passing the examination. The committee can approve the final oral examination conditionally, subject to the corrections, to the satisfaction of either the adviser or the entire committee.

Publication requirement

To encourage research at the highest level and foster a spirit of innovation and discovery, it is important that the graduate students have conducted high quality original research. Peer-reviewed evidence of the quality of work, in terms of at least one accepted journal paper or published high-quality conference paper in a student's research area and a second manuscript submitted for review to a journal or a high-quality conference must be approved by the dissertation committee and the CLSE graduate committee prior to the Ph.D. defense.

Curriculum requirements

Total graduate credit hours required for post-baccalaureate students is 68 (minimum). Total graduate credit hours required for post-M.S. students is 45 (minimum).

The curriculum comprises the following components:

Core courses

This component is common to all students in the Ph.D. program, comprising three courses for a total of nine credits. Core courses provide foundational material for advanced courses and research, while providing the fundamental concepts critical to chemical engineering for all graduate students.

Research focus area courses

Students work with their research advisor to select courses appropriate for their research focus areas.

- Life science engineering

  Course work will educate students on the principles of life sciences toward applications such as engineering better medicines, biochemical engineering (enzymatic pathways and cell growth) and using systems biology to model diseases as well as engineer biofuels. Students will select courses such as CLSE 560, CLSE 561, CLSE 563, CLSE 570, CLSE 660, CLSE 562 and CLSE 544.

- Chemical kinetics and process engineering

  Course work will educate students on the principles of engineering pertinent to the development of large scale industrial processes (e.g. manufacture of chemicals, polymers and biologicals at the level of kilograms to tons) that can translate innovations from the laboratory to the marketplace. These engineering principles include the ability to design reactions and processes for the faster and more cost effective synthesis of drugs (synthetic and biological), understanding environmental mitigation strategies to reduce pollution and the design of catalysts for industrial processes. Students will select courses such as CLSE 549, CLSE 543, BNFO 530, MEDC 630 and ENVS 591 (environmental chemistry).

- Materials science and engineering

  Course work will educate students on the principles of materials science relevant to chemical and life science engineering. These include the ability to evaluate, design, improve and fabricate unique materials for applications in human health (e.g. tissue engineering and regenerative medicine, medical devices, biosensors), energy and sustainability (e.g. novel batteries, economical solar energy, capturing carbon emissions) and the environment (e.g. health effects of nanomaterials, membranes for water purification). Students will select courses such as CLSE 675,

ENGR 591 (introduction to materials science and engineering), CLSE 575, CLSE 645 and ENVS 602.

Seminar

All students will register for CLSE 690. This component will expose students to cutting-edge research from invited speakers and researchers from academia and industry each semester. Students are expected to participate in the department's seminar program for the duration of their doctoral studies.

Directed research

All students will complete at least 27 credit hours of CLSE 697 and/or ENGR 701. This component emphasizes research directed toward solving an open, challenging problem under the guidance of the research adviser and dissertation committee.

B.S. to Ph.D. curriculum

Course	Title	Hours
Foundation courses		
CLSE 650	Quantitative Analysis in Chemical and Life Science Engineering	3
CLSE 656	Advanced Chemical Reaction Engineering	3
Core courses		
CLSE 654	Equilibrium Analysis in Chemical and Biological Systems	3
CLSE 655	Nonequilibrium Analysis in Chemical and Life Science Engineering	3
CLSE 690	Research Seminar in Chemical and Life Science Engineering (repeated over six semesters for six credits)	6
Seminar courses		
CLSE 690	Research Seminar in Chemical and Life Science Engineering (additional credits for B.S. degree entry students)	2
Research focus area courses		
Students will work with their research adviser to select the elective courses appropriate for their research focus areas. Students will have the option of selecting technical elective courses across disciplines such as engineering, chemistry, biology, medicine, mathematics or computing to help tailor educational backgrounds to specific research topics and future professional scientific interests. Research focus area courses exclude CLSE 690, CLSE 697 and ENGR 701.		21
Directed research		**27**
CLSE 697	Directed Research in Chemical and Life Science Engineering (variable credit courses; may be repeated)	
or ENGR 701	Post-Candidacy Doctoral Research	
Total Hours		**68**

For students entering with a baccalaureate degree, the minimum number of graduate credit hours required for this degree is 68.

M.S. to Ph.D. curriculum

Course	Title	Hours
Core courses		
CLSE 654	Equilibrium Analysis in Chemical and Biological Systems	3
CLSE 655	Nonequilibrium Analysis in Chemical and Life Science Engineering	3
CLSE 690	Research Seminar in Chemical and Life Science Engineering (repeated for six credits)	6
Research focus area courses		
Students will work with their research adviser to select the elective courses appropriate for their research focus areas. Students will have the option of selecting technical elective courses across disciplines such as engineering, chemistry, biology, medicine, mathematics or computing to help tailor educational backgrounds to specific research topics and future professional scientific interests. Research focus area courses exclude CLSE 690, CLSE 697 and ENGR 701.		6
Directed research		**27**
CLSE 697	Directed Research in Chemical and Life Science Engineering (variable credit course)	
ENGR 701	Post-Candidacy Doctoral Research (may be taken multiple times)	
Total Hours		**45**

For students entering with a master's degree, the minimum number of graduate credit hours required for this degree is 45.

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