

BIOMEDICAL ENGINEERING, DOCTOR OF PHILOSOPHY (PH.D.)

Program mission

The mission of the Doctor of Philosophy in Biomedical Engineering is to educate biomedical engineering students to be significant contributors in health care and in research and development in biomedicine and bioengineering. The curriculum closely links technical fundamentals in science, engineering and the life sciences, together with the ability to function on multidisciplinary teams, to communicate effectively and to achieve the knowledge tools necessary for lifelong learning.

Program goals

1. Provide students with a graduate education that prepares them for current and future challenges in biomedical engineering
2. Produce graduates who possess the necessary advanced analytical and technical skills in engineering and sciences – responds directly to the higher goals of fulfilling the needs of industry for effective, productive engineers and of providing economic development for the region, state and nation
3. Produce graduates who possess a facility with both written and oral communications – emanates from the requirement that engineers 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 and leadership
4. 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

Graduates possess the ability to formulate, analyze and solve problems, analytically and/or experimentally, in the biomedical engineering industry, in the clinical setting or in biomedical research. Graduates can work effectively in teams to solve biomedical and/or clinical problems including the interconnection of engineering and clinical personnel toward the solution of problems of compelling clinical and biomedical interest and need, with particular reference to the biomedical engineering industry, in the clinical setting or in biomedical research. The career paths of BME graduates in these arenas would be enhanced as a result of these skills.

Student learning outcomes

1. Graduates will demonstrate an ability to apply advanced knowledge of mathematics, biomedical sciences and engineering.
2. Graduates will demonstrate an ability to communicate effectively.
3. Graduates will demonstrate an ability to identify, formulate and solve biomedical engineering problems.
4. Graduates will demonstrate an ability to conduct independent research.

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 (<http://www.graduate.vcu.edu/>) 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. (<https://bulletin.vcu.edu/academic-regs/>)

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. (<https://bulletin.vcu.edu/academic-regs/grad/candidacy/>)

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. (<https://bulletin.vcu.edu/academic-regs/grad/graduation-info/>)

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)	Dec 15	International students require TOEFL
	Spring	Oct 1	

Special requirements

- Acceptance of an applicant is based upon the recommendation of the admissions committee.

In addition to the general admission requirements of the VCU Graduate School (<https://bulletin.vcu.edu/graduate/study/admission-graduate-study/admission-requirements/>), biomedical engineering has the following admission criteria for all entering graduate students:

1. Statement of intent: Applicants must state their reasons for pursuing a Ph.D. in Biomedical Engineering at VCU.
2. Letters of recommendation: Three letters of recommendation from instructors or professional references in the applicant's intended field of study are required. Letters should address the applicant's academic and professional abilities and preparation for graduate study. One or more letters may be waived upon request to the graduate program director.

Biomedical engineering will accept a maximum of 12 credit hours for transfer into the Ph.D. program if the original grades for such courses are B or higher (or equivalent).

Degree requirements

In addition to the VCU Graduate School graduation requirements (<https://bulletin.vcu.edu/academic-regs/grad/graduation-info/>), the Ph.D. will require a minimum of 72 credit hours beyond the B.S. or a minimum of 60 credit hours beyond the M.S. Students may enter the Ph.D. program with either a B.S. or an M.S.

Qualifying examinations

In order to advance to doctoral candidacy, the student must pass both written and oral qualifying examinations. The written examination consists of a research proposal that is reviewed by a committee of three biomedical engineering faculty members. The oral examination is administered by the same committee and assesses the ability of the student to integrate information and display an appropriate mastery of problem-solving capabilities. For further details, see the graduate program director or the program chair.

Research adviser and graduate dissertation committee

Students are expected to select a research adviser within the first year of enrollment in the Ph.D. program. Students are expected to form their dissertation committee by the end of the second year of enrollment in the program and formally meet with the committee at least once every 12 months until the final dissertation defense. The dissertation committee will consist of five faculty members, including the primary research adviser, two faculty members from the biomedical engineering graduate program and two faculty members from outside of the biomedical engineering graduate program. This committee reviews and votes to approve or disapprove the student's dissertation research proposal and

the final Ph.D. dissertation and oral defense. This committee also makes the final recommendation to award the Ph.D. degree.

Proposal presentation exam

The student will submit one copy of an original dissertation research proposal based upon their proposed research project to each member of their dissertation committee before the end of the third year of enrollment in the Ph.D. program. The proposal consists of the research topic and proposed research plan. The proposal should include a thorough literature review of the topic and contain information sufficient to judge the feasibility, scope and potential impact of the research. The dissertation committee will then administer an exam based on the material submitted in the dissertation research proposal. The format of the exam is an oral presentation by the candidate with questions by the dissertation committee members. A favorable decision by the dissertation committee with no more than one negative vote (all members are required to vote) shall be required to pass the exam. If a student fails the exam, one re-examination may be given with the consent of the dissertation committee. Failure to pass the second exam will result in dismissal from the program.

Publication requirement

A Ph.D. student appearing for the final defense in the Department of Biomedical Engineering must provide evidence of a minimum of one first-author manuscript accepted for publication in an archival journal and a second co-authored manuscript accepted for publication or under review. Both publications must be based on the student's dissertation research, peer-reviewed, recognized by the ISI Web of Science and approved by the student's dissertation committee and the graduate program director. Review articles or other works not representing original research will not count toward the publication requirement; however, other original research publications that comply with the aforementioned requirements may be allowed for the second publication at the committee's discretion. The stated publication policy represents the minimum requirement across the department; the student's dissertation committee and/or individual development plan may specify reasonable additions to the publication requirement to confirm readiness for the final defense.

Dissertation defense

No earlier than six months after passing the oral candidacy examination, the student will defend the dissertation in an open forum administered by the dissertation committee. At least two weeks prior to the defense, the candidate will submit a written copy of the dissertation to each committee member and schedule a date for the defense. The defense will be advertised and faculty and student colleagues will be invited to attend. During the defense, the student will present a detailed summary of their research project, which should be the original problem presented and approved during the proposal presentation exam. If a solution of the original problem proves elusive for reasons beyond the student's control, the student may be allowed to redirect the research with permission from the dissertation committee and find an alternate pathway to the solution of a redefined problem. The format of the dissertation defense will be a presentation by the student followed by questions from the dissertation committee and other attendees. After the first round of questions are completed, the non-committee members in attendance will be asked to leave and the dissertation committee members will hold a second round of questions in closed session. After the second round of questions is completed the student will be asked to leave and the committee members will deliberate privately. The problem presented and solved must be of sufficient importance and interest to warrant publication in a peer-reviewed journal in the student's area of specialization. A favorable

decision by the dissertation committee with no more than one negative vote (all members are required to vote) shall be required to pass the dissertation defense. If a student fails the dissertation defense, one re-examination may be given. Failure to pass the second dissertation defense will result in dismissal from the program.

Students entering with a B.S. degree who are terminated from the Ph.D. program because of a failure to pass the QE, proposal presentation exam or dissertation defense (but not for other reasons such as academic dishonesty) will have the option to continue toward the M.S. in Biomedical Engineering.

Time limit

It is anticipated that students entering with a B.S. will complete the program in four years from the time the student passes the qualifying examination. Students must be continuously enrolled in the program (minimum of one credit hour per semester). All requirements for the Ph.D. must be completed within eight years of passing the qualifying examination.

It is anticipated that students entering with an M.S. will complete the program in three years from the time the student passes the qualifying examination. Students must be continuously enrolled in the program (minimum of one credit hour per semester). All requirements for the Ph.D. must be completed within six years of passing the qualifying examination.

Any student may request a one-year extension of the maximum time for extenuating circumstances such as a medical situation. The graduate program committee will review and approve or deny all such requests. The maximum time cannot be extended longer than one year. Students who do not satisfy the degree requirements within the maximum time will be dismissed from the program.

Because of the maximum time limits imposed on students in the Ph.D. program, the program does not accept part-time students.

Curriculum requirements

B.S. to Ph.D. in Biomedical Engineering

Course	Title	Hours
Required biomedical engineering courses		
EGRB 601	Numerical Methods and Modeling in Biomedical Engineering	4
EGRB 602	Biomedical Engineering Systems Physiology	4
EGRB 605	Grant Writing in Biomedical Engineering	1
Restricted electives		
Select nine credits from the following or other courses as recommended by the graduate advisory committee and approved by the graduate program director.		9
EGRB 507	Biomedical Electronics and Instrumentation	
EGRB 521	Human Factors Engineering	
EGRB 603	Biomedical Signal Processing	
EGRB 604	Biomechanics	
EGRB 613	Biomaterials	
EGRB 616	Cell Engineering	
Required courses in other departments		
OVPR 601	Scientific Integrity	1

or OVPR 602	Responsible Scientific Conduct	
or OVPR 603	Responsible Conduct of Research	
STAT 641	Applied Data Analysis ¹	3
or STAT 642	Design and Analysis of Experiments I	
Minimum elective courses		
e.g., EGRB, EGRM, ENGR, PHYS, MATH, BIOL, PHIS, BIOC, CMSC at 500 level or above		12
Research		
EGRB 690	Biomedical Engineering Research Seminar	4
EGRB 697	Directed Research in Biomedical Engineering (required at a level to be determined by each student's graduate advisory committee)	34
or ENGR 701	Post-Candidacy Doctoral Research	
Total Hours		72

For students entering with a B.S., the minimum number of graduate credit hours required for this degree is 72.

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Students may select another graduate-level STAT or BIOS course if approved by adviser.

M.S. to Ph.D. in Biomedical Engineering

Course	Title	Hours
Required biomedical engineering courses		
EGRB 601	Numerical Methods and Modeling in Biomedical Engineering	4
EGRB 602	Biomedical Engineering Systems Physiology	4
EGRB 605	Grant Writing in Biomedical Engineering	1
Restricted electives		
Select six credits from the following or other courses as recommended by the graduate advisory committee and approved by the graduate program director.		6
EGRB 507	Biomedical Electronics and Instrumentation	
EGRB 521	Human Factors Engineering	
EGRB 603	Biomedical Signal Processing	
EGRB 604	Biomechanics	
EGRB 613	Biomaterials	
EGRB 616	Cell Engineering	
Required courses in other departments		
OVPR 601	Scientific Integrity	1
or OVPR 602	Responsible Scientific Conduct	
or OVPR 603	Responsible Conduct of Research	
STAT 641	Applied Data Analysis ¹	3
or STAT 642	Design and Analysis of Experiments I	
Minimum elective courses		
e.g., EGRB, EGRM, ENGR, PHYS, MATH, BIOL, PHIS, BIOC, CMSC at 500 level or above		3
Research		
EGRB 690	Biomedical Engineering Research Seminar	4

EGRB 697	Directed Research in Biomedical Engineering (required at a level to be determined by each student's graduate advisory committee)	34
or ENGR 701	Post-Candidacy Doctoral Research	
Total Hours		60

For students entering with an M.S., the minimum number of graduate credit hours required for this degree is 60.

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Students may select another graduate-level STAT or BIOS course if approved by adviser.

M.D.-Ph.D. opportunity

The M.D.-Ph.D. program allows students to pursue both the M.D. and Ph.D. degrees using a coordinated program of study and apply a limited number of M.D. requirements toward fulfillment of requirements for the Ph.D. See the dual degree program page (<https://bulletin.vcu.edu/graduate/dual-degree-ops/md-biomedeng-phd/>) for additional details.

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Program website: [biomedical.egr.vcu.edu \(https://egr.vcu.edu/departments/biomedical/\)](https://egr.vcu.edu/departments/biomedical/)