Chemical and Life Science Engineering, Bachelor of Science (B.S.) with a concentration in chemical engineering

The department offers a Bachelor of Science in Chemical and Life Science Engineering, and includes a chemical engineering concentration and a life science engineering concentration. Each student must choose the desired concentration upon initial registration.

As part of the B.S. degree in chemical and life science engineering, all students complete an approved internship or cooperative education experience.

Student learning outcomes
Upon completing this program, students will demonstrate:

1. An ability to identify, formulate and solve complex engineering problems by applying principles of engineering, science and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety and welfare, as well as global, cultural, social, environmental and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies
8. An understanding of the hazards associated with physical, chemical and/or biological processes

Special requirements
Students must receive a grade of C in all engineering courses in order to graduate. Minimum grades of C in CLSE 115, CLSE 201 and CLSE 202 are required before students may take additional CLSE courses. After passing CLSE 202 with a minimum grade of C, students are allowed to continue with one D grade in any CLSE course. They must retake that course in order to graduate, but may continue taking other CLSE courses. Students are not allowed to continue with two grades of D in CLSE courses and must successfully retake at least one of those courses with a minimum grade of C to take additional 300- and 400-level CLSE courses.

Degree requirements for Chemical and Life Science Engineering, Bachelor of Science (B.S.) with a concentration in chemical engineering

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>Select 30 credits of general education courses in consultation with an adviser.</td>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

Major requirements

• Major core requirements
  CLSE 101 Introduction to Engineering 3
  CLSE 115 Introduction to Programming for Chemical and Life Science Engineering 4
  CLSE 201 Chemical Engineering Fundamentals I: Material Balances 4
  CLSE 202 Chemical Engineering Fundamentals II: Energy Balances and Engineering Thermodynamics 4
  CLSE 301 Transport Phenomena I 3
  CLSE 302 Transport Phenomena II 4
  CLSE 305 Thermodynamics of Phase Equilibria and Chemical Reactions 3
  CLSE 312 Chemical Reaction Engineering 3
  CLSE 320 Instrumentation Laboratory 3
  CLSE 402 Senior Design Studio I (Laboratory/Project Time) 2
  CLSE 403 Senior Design Studio II (Laboratory/Project Time) 2
  CLSE 409 Process Control in Chemical and Life Science Engineering 3
  CLSE 440 Unit Operations Laboratory 3
  ENGR 395 Professional Development 1
  ENGR 402 Senior Design Studio (Seminar) 1
  ENGR 403 Senior Design Studio (Seminar) 1

• Additional major requirements
  Approved internship or cooperative education experience 0
  ENGR 296 Part-time Internship Experience 1
  or ENGR 396 Internship Experience 1
  or ENGR 398 Cooperative Education Experience 1
  Review of internship or cooperative education experience 0
  ENGR 496 Internship Review 1
  or ENGR 498 Review of Cooperative Education Experience 1

• Major electives
  Select engineering electives as described below. 6

Ancillary requirements

| BIOL 151 | Introduction to Biological Sciences I | 3 |
| CHEM 101 | General Chemistry I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning) | 3 |
| CHEZ 101 | General Chemistry Laboratory I | 1 |
| CHEM 102 | General Chemistry II | 4 |
| & CHEZ 102 | and General Chemistry Laboratory II | 4 |
Chemical and Life Science Engineering, Bachelor of Science (B.S.) with a concentration in chemical engineering

CHEM 301 & CHEZ 301
Organic Chemistry and Organic Chemistry Laboratory I 5
CHEM 302 & CHEZ 302
Organic Chemistry and Organic Chemistry Laboratory II 5
ECON 205
The Economics of Product Development and Markets (satisfies general education BOK for social/behavioral sciences and AOI for global perspectives) 3

MATH 200
Calculus with Analytic Geometry I (satisfies general education quantitative foundations) 4
MATH 201
Calculus with Analytic Geometry II 4
MATH 301
Differential Equations 3
MATH 307
Multivariate Calculus 4
PHIL 201
Introduction to Ethics (satisfies general education BOK for humanities/fine arts and AOI for diversities in the human experience) 3

PHYS 207
University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning) 5
PHYS 208
University Physics II 5
STAT 441
Applied Statistics for Engineers and Scientists 3

Technical electives (Select 300+-level science, math, business or management courses as described below.) 9

Total Hours 126

The minimum number of credit hours required for this degree is 126.

Technical electives

Technical electives are satisfied by completing courses that meet all of the following criteria:

1. 300 level or greater
2. Offered in BIOC, BIOL, BIOZ, BNFO, BUSN, CHEM, CHEZ, ENVS, ENVZ, FRSC, FRSZ, INNO, LFSC, MATH, MEDC, MGMT, OPER, PHIS, or STAT
3. Three or more credit hours
4. Not otherwise required for the major by the effective Bulletin

Other courses may be used to satisfy the technical elective requirements with prior written approval from the department chair.

Engineering electives

Engineering electives are satisfied by completing courses that meet all of the following criteria:

1. 300-level or greater
2. Offered in the College of Engineering (CLSE, CMSC, EGMN, EGRB, EGRC, EGRE, EGRM, EGRN or ENGR)
3. Offered for three or more credit hours
4. Not otherwise required for the major by the effective Bulletin

Note: A minimum of four credits of ENGR 497 must be completed to use the course to satisfy an engineering elective requirement. Other courses may be used to satisfy the engineering elective requirements with prior written approval from the department chair.

What follows is a sample plan that meets the prescribed requirements within a four-year course of study at VCU. Please contact your adviser before beginning course work toward a degree.

Freshman year

Fall semester

CHEM 101 General Chemistry I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning) 3
CHEZ 101 General Chemistry Laboratory I 1
CLSE 101 Introduction to Engineering 3
MATH 100 Calculus with Analytic Geometry I (satisfies general education quantitative foundations) 4
UNIV 111 Play course video for Focused Inquiry I (satisfies general education UNIV foundations) 3

Term Hours: 14

Spring semester

CHEM 102 General Chemistry II & CHEZ 102 General Chemistry Laboratory II 4
CLSE 115 Introduction to Programming for Chemical and Life Science Engineering 4
ENGR 395 Professional Development 1
MATH 201 Calculus with Analytic Geometry II 4
UNIV 212 Play course video for Focused Inquiry II (satisfies general education UNIV foundations) 3

Term Hours: 16

Sophomore year

Fall semester

CHEM 301 Organic Chemistry & CHEZ 301 Organic Chemistry Laboratory I 5
CLSE 201 Chemical Engineering Fundamentals I: Material Balances 4
MATH 301 Differential Equations 3
PHYS 207 University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning) 5

Term Hours: 17

Spring semester

CHEM 302 Organic Chemistry & CHEZ 302 Organic Chemistry Laboratory II 5
CLSE 202 Chemical Engineering Fundamentals II: Energy Balances and Engineering Thermodynamics 4
MATH 307 Multivariate Calculus 4
PHYS 208 University Physics II 5

Term Hours: 18

Summer semester
The minimum number of credit hours required for this degree is 126.

**Accelerated B.S. and M.S.**

The accelerated B.S. and M.S. program allows qualified students to earn both the B.S. in Chemical and Life Science Engineering and the M.S. in Engineering with a concentration in chemical and life science engineering in a minimum of five years by completing approved graduate courses during the senior year of their undergraduate program. Students in the program may count up to six hours of graduate courses toward both the B.S. and M.S. degrees. Thus, the two degrees may be earned with a minimum of 150 credits rather than the 156 credits necessary if the two degrees are pursued separately.

Students holding these degrees will have a head start for pursuing careers in industry or continuing in an academic setting. The M.S. degree provides formal research experience and can lead to expanded job opportunities, greater potential for job advancement and higher starting salaries.

**Entrance to the accelerated program**

Interested undergraduate students should consult with their adviser as early as possible to receive specific information about the accelerated program, determine academic eligibility and submit (no later than two semesters prior to graduating with a baccalaureate degree, that is, before the end of the spring semester of their junior year) an Accelerated Program Declaration Form to be approved by the graduate program director. Limited spaces may be available in the accelerated program. Academically qualified students may not receive approval if capacity has been reached.

Minimum qualifications for entrance to this accelerated program completion of 99 undergraduate credit hours including CLSE 301, CLSE 302, CLSE 305, CLSE 312 and CLSE 320; a minimum overall GPA of 3.0; and a GPA of 3.2 in chemical and life science engineering (CLSE) course work. Students who are interested in the accelerated program should consult with the graduate program director before they have completed 99 credits. Successful applicants will enter the program in the fall semester of their senior year.

Once enrolled in the accelerated program, students must meet the standards of performance applicable to graduate students as described in the "Satisfactory academic progress" section of the Graduate Bulletin, including maintaining a 3.0 GPA. Guidance to students admitted to the accelerated program is provided by both the CLSE undergraduate program director and the CLSE graduate program director.

**Admission to the graduate program**

Entrance to the accelerated program enables the student to take the approved shared courses that will apply to the undergraduate and graduate degrees. However, entry into an accelerated program via an approved Accelerated Program Declaration Form does not constitute application or admission into the graduate program. Admission to the graduate program requires a separate step that occurs through Graduate Admissions no later than a semester prior to graduation with the baccalaureate degree, that is, before the end of the fall semester of the senior year. In order to continue pursuing the master’s degree after the baccalaureate degree is conferred, accelerated students must follow the admission to graduate study requirements outlined in the VCU Bulletin. One reference letter from a chemical and life science engineering
faculty member must accompany the application. The GRE is waived for admission to the program.

Degree requirements

The Bachelor of Science in Chemical and Life Science Engineering degree will be awarded upon completion of a minimum of 126 credits and the satisfactory completion of all undergraduate degree requirements as stated in the Undergraduate Bulletin.

A maximum of six graduate credits may be taken prior to completion of the baccalaureate degree. These graduate credits will apply as required major electives or open elective credits (engineering electives) for the undergraduate degree. These courses are shared credits with the graduate program, meaning that they will be applied to both undergraduate and graduate degree requirements.

Examples of graduate chemical and life science engineering courses that may be taken as an undergraduate, once a student is admitted to the program, are:

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLSE 543</td>
<td>Advanced Reaction Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 544</td>
<td>Applied Transport Phenomena</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 549</td>
<td>Process Biotechnology</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 551</td>
<td>Nanotoxicology</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 560</td>
<td>Protein Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 561</td>
<td>Stem Cell Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 562</td>
<td>Advanced Systems Biology Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 563</td>
<td>Metabolic Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 570</td>
<td>Molecular Physiology and Microanatomy for Chemical and Life Science Engineering</td>
<td>4</td>
</tr>
<tr>
<td>CLSE 575</td>
<td>Nanotechnology in Life Science and Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 580</td>
<td>Sustainable Chemical Engineering</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 591</td>
<td>Special Topics in Engineering</td>
<td>1-4</td>
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</table>

Required B.S. course work

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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<tbody>
<tr>
<td>ECON 101</td>
<td>Introduction to Political Economy</td>
<td>3</td>
</tr>
<tr>
<td>ENGR 403</td>
<td>Senior Design Studio (Seminar)</td>
<td>1</td>
</tr>
<tr>
<td>CLSE 403</td>
<td>Senior Design Studio II (Laboratory/Project Time)</td>
<td>2</td>
</tr>
<tr>
<td>Engineering elective (300+ level)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Engineering elective - CLSE 5xx (from list above)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>12</td>
<td></td>
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Fifth year

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>CLSE 650</td>
<td>Quantitative Analysis in Chemical and Life Science Engineering</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 655</td>
<td>Nonequilibrium Analysis in Chemical and Life Science Engineering</td>
<td>3</td>
</tr>
<tr>
<td>Graduate electives (500 and 600 level)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>12</td>
<td></td>
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</table>

Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLSE 654</td>
<td>Equilibrium Analysis in Chemical and Biological Systems</td>
<td>3</td>
</tr>
<tr>
<td>CLSE 656</td>
<td>Advanced Chemical Reaction Engineering</td>
<td>3</td>
</tr>
<tr>
<td>Graduate electives (500 and 600 level)</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Term Hours:</td>
<td>12</td>
<td></td>
</tr>
</tbody>
</table>

1

For example: 500-level (or higher) CLSE, ENGR, PESC, PCEU, EGRB, CHEM, NANO, PHYS, MATH, BIOL, PHIS or BIOC courses

Recommended course sequence/plan of study

What follows is the recommended plan of graduate study for students interested in the accelerated program beginning in the fall of the senior year.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
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</table>
| Fall semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
</table>
| Required B.S. course work
| CLSE 402 | Senior Design Studio I (Laboratory/Project Time) | 2     |
| CLSE 409 | Process Control in Chemical and Life Science Engineering | 3 |
| CLSE 440 | Unit Operations Laboratory                      | 3     |
| ENGR 402 | Senior Design Studio (Seminar)                 | 1     |
| ENGR 496 | Internship Review                              | 0     |
| PHIL 201 | Introduction to Ethics                         | 3     |
| Engineering elective - CLSE 5xx (from list above) | 3     |
| Term Hours: | 15 |

Spring semester

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
</thead>
</table>
| Required B.S. course work
|