2021 Graduate Curriculum

Department of Chemical and Biomolecular Engineering

University of Delaware

UNIVERSITY OF DELAWARE
ENGINEERING

Rev. 6/18/21

CBE Graduate Program Aims

- 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 curriculum is a formal mechanism by which the program aims are implemented. **A new curriculum will put in practice in the fall of 2021.**
- In addition to the curriculum, there are **other formal and informal mechanisms** by which the program and UD offers opportunities for intellectual and professional growth:
  - Mentoring by advisors, thesis committees, external collaborators, etc.
  - Group meetings
  - Departmental Seminars, Centers' Seminars
  - The Colburn Club and other student organizations' activities
  - University-wide seminars, symposia and other events

Driving Change

- **Field has changed fundamentally**
  - Greatly expanded / **expanding diversity in research** areas
  - Computational toolsets available + data science revolution = **foundational changes in problem solving and problem types**
  - Life sciences + engineering = **biomolecular engineering**
  - **Multidisciplinary** collaboration has become the norm
  - Broader career landscape, **different/diverse industry problems**
  - **Entrepreneurship** is increasingly central to discipline
- **New vision of 21st Century Graduate Education has Emerged**
  - Provide **core and field-specific** scientific **competencies**
  - Provide **transferable** professional **competencies**: communication, leadership and ability to work in interdisciplinary teams
  - **Flexibility** to foster individual student's career development and preferences
  - Offer opportunities for career exploration

Course and Credit Requirements

New Curriculum

- Required Core Courses (14 credits)
  - 6 x 2 credit modules
    - 5 in fall
    - CHEG803 Science Communication
  - 2 x 1 credit CBE Seminar
- CBE Seminar series
  - 2 x 1-credit course in different years
- Electives (11 credits)
  - 2 x 2 credit modules (Spring)
    - A **Concentration** can be obtained if the two modules are in the same subfield
  - 7 credits of graduate electives minimum (600 and 800 level)
- Research
  - 9 credits of research
- **TOTAL = 34 credits**

Old Curriculum

- Required Core Courses
  - 3 x 3 + 2 x 4 = 17 credits core
- Electives
  - 8 credits of electives minimum (600 and 800 level)
- Research
  - 9 credits of research
- **TOTAL = 34 credits**

New Organizational Elements

- **A modularized, more adaptive core**
  - More relevant to student's research preferences
  - More flexible for students and across time
- **2-credit half-semester Course Units**
  - 4 x 50 min contact time per week
  - First unit meets Aug. 31st to Oct. 15th.
  - Second unit meets Oct. 18th to Dec. 10th.
- **Seminar Class**
  - Complements content and skill development provided elsewhere with professional competencies
- **Communication**
  - Addressed explicitly and in a systematic manner

Course Load (Electives not listed)

Fall Semester

Fall I

5-6 modules (10-12 credits)
Seminar (1 credit)

Fall II

Core Courses

Either/Or

Introduction to Data and Systems Analysis Linear Algebra, math underlying modern Chem Eng. research, analysis of data, math modeling & simulation

Molecular Thermodynamics Statistical thermodynamics of molecular systems. intermolecular potentials, molecular models of gases, crystals , liquids, molecular simulations

Kinetic Processes Reaction networks and rate theories, rates of complex reactions, model reduction methods, stochastic kinetics, catalysis and biocatalysis

Chemical and Biomolecular Engineering Seminar Responsible and effective research practices, student-advisor relationship, work-life balance and self-care, time management, teamwork and collaboration, mentor-mentee relationships, etc.

Modeling, Analysis and Acquisition of Data: Modeling and analysis of data with uncertainty, describing information in data, strategies for efficient data acquisition

Chemical Interfaces and Surfaces: Surface forces; Lifshitz theory; physisorption and chemisorption, adhesion and wetting; friction and lubrication

Diffusive Transport Processes Diffusive transport processes ranging from simple molecular models of transport in gases and liquids to macroscopic processes

Spring Semester

Spring I
2 modules = 4 cr
(1 req, 1 elective)

Spring II
1 module = 2 cr
(1 elective)

Research Communication Written and oral communication in science, Audience evaluation, creation and editing of scientific documents, persuasive writing and speaking, effective communication in person and through social media.

Continuum Transport in Materials Continuum mechanics of fluids and solids; boundary layer theory; creeping flows; scaling and asymptotic analysis; convective transport

Soft Materials, Colloids and Polymers Integrates continuum and molecular descriptions of matter as the basis for engineering soft materials

Rate Processes and Dynamics of Microbial Systems: enzyme kinetics, translation and transcription, genetic regulation, cell growth, chemotaxis and quorum sensing

Rate Processes and Dynamics of Mammalian Cellular Systems: Cell signaling, proliferation and growth, cell phenotype and function. Multicellular processes

Electrochemical Systems: Fundamental principles of electrochemistry, electrokinetics, transport and the electrochemical interface. Electro-analytical techniques

Applied Thermodynamics Principles of continuum thermodynamics, energy and entropy balances with applications to contemporary problems

Process Systems Engineering: Systems Approach to Problem Solving. Mathematical programming techniques for solution of process design, and operations problems.

Data Science for Chem. and Biomolecular Eng.: Data science, probability and statistics for application to small and big data problems in Chem. E.

Note: A few inconsistencies in the video have been corrected. RFL 6/18

Graduate Seminar Plays Seminal Role

- Improves students' knowledge of non-technical elements of a graduate engineering career
- Exposure to diverse perspectives on science, engineering and the role of PhDs in society
- Promotes wider mentoring opportunities and training among peers
- Expand informal advising network
- Improves knowledge of how to:
  - Develop a career plan
  - Work in teams effectively
  - Mental health at UD and beyond
  - Engage with entrepreneurship

Concentrations

- Students can pursue a concentration by taking two courses (4 credits) on the same subject during the spring semester
- Concentrations are optional
- Courses can be taken over more than one year

Spring Semester

	Data/Systems	Soft Matter	Energy	Biomolecular Eng.
Spring I	**Process Systems Engineering:** Systems Approach to Problem Solving. Mathematical programming techniques for solution of process design, and operations problems.	**Continuum Transport in Materials** Continuum mechanics of fluids and solids; boundary layer theory; creeping flows; scaling and asymptotic analysis; convective transport	**Electrochemical Systems:** Fundamental principles of electrochemistry, electrokinetics, transport and the electrochemical interface. Electro-analytical technques	**Rate Processes and Dynamics of Microbial Systems:** enzyme kinetics, translation and transcription, genetic regulation, cell growth, chemotaxis and quorum sensing
Spring II	**Data Science for Chem. and Biomolecular Eng.:** Data science, probability and statistics for application to small and big data problems in Chem. E.	**Soft Materials, Colloids and Polymers** Integrates continuum and molecular descriptions of matter as the basis for engineering soft materials	**Applied Thermodynamics** Principles of continuum thermodynamics, energy and entropy balances with applications to contemporary problems	**Rate Processes and Dynamics of Mammalian Cellular Systems:** Cell signaling, proliferation and growth, cell phenotype and function. Multicellular processes

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CBE Graduate Curriculum in Table Format

Semester	Data/Systems	Soft Matter	Catalysis and Energy	Biomolecular Engineering	Integrative Courses
Fall I	**CHEG802:** Introduction to Data and Systems Analysis	**CHEG810:** Molecular Thermodynamics	**CHEG820:** Kinetic Processes		**CHEG800:** Chemical and Biomolecular Engineering Seminar (1 semester)
Fall II	**CHEG807:** Modeling, Analysis and Acquisition of Data	**CHEG811:** Chemical Interfaces and Surfaces	**CHEG821:** Diffusive Transport Processes		
Spring I	**CHEG860:** Process Systems Engineering	**CHEG830:** Continuum Transport in Materials	**CHEG850:** Electrochemical Systems	**CHEG840:** Rate Processes & Dynamics for Microbial Systems	**CHEG803:** Advanced Scientific Communication (1 semester)
Spring II	**CHEG861:** Data Science for Chem. and Biomolecular Engineering	**CHEG832:** Soft Materials, Colloids and Polymers	**CHEG851:** Applied Thermodynamics	**CHEG 843:** Rate Processes & Dynamics for Mammalian Cellular Systems	

Curricular Flexibility Leads to a Range of Options

- **Fall Academic Load: 11-14 credits**
  - 5 required modules + seminar = 11 cr
  - 5 required modules + seminar + 2 cr elective module = 13 cr
  - 5 required modules + seminar + 3 cr elective = 14 cr
- **Spring Academic Load: 6-11 credits**
  - Science Communication + 2 modules = 6 cr
  - Science Communication + 3 modules = 8 cr
  - Science Communication + 3 modules + 3 credit elective = 11 cr

Representative Schedule I: Biomolecular Engineering Concentration

Fall I	Fall II
CHEG800: Seminar	CHEG800: Seminar
CHEG810: Molecular Thermodynamics	CHEG807: Modeling, Analysis and Acquisition of Data
CHEG820: Kinetic Processes	CHEG811: Chemical Interfaces and Surfaces
	CHEG821: Diffusive Transport Processes
Spring I	**Spring II**
CHEG803: Scientific Communication	CHEG803: Scientific Communication
CHEG840: Rate Processes & Dynamics for Microbial Systems	**CHEG843: Rate Processes & Dynamics for Mammalian Cellular Systems**
	CHEG 832: Soft Materials, Colloids, and Polymers

Representative Schedule II: Soft Matter Concentration

Fall I	Fall II
CHEG800: Seminar	CHEG800: Seminar
CHEG810: Molecular Thermodynamics	CHEG832: Chemical Interfaces and Surfaces
CHEG820: Kinetic Processes	CHEG821: Diffusive Transport Processes
CHEG802: Introduction to Data and Systems Analysis	
Spring I	**Spring II**
CHEG803: Scientific Communication	CHEG803: Scientific Communication
CHEG830: Continuum Transport of Materials	**CHEG832: Soft Materials, Colloids and Polymers**
CHEG850: Electrochemical Systems (Elective)	

FAQs

- Can I take any of these courses in my 2nd or 3rd year as a graduate student?
  - Yes, they would count as elective credits since your core is completed. Advisor approval is required.
- Can I take courses that are not part of this core graduate curriculum?
  - Yes. Several of the elective 3 cr courses offered during academic year count as graduate credits; look for CHEG8XX course numbers
- Can I take courses in another department?
  - Yes, there are courses in Chemistry and Biochemistry, Mathematics, Biology, etc., that count as elective graduate credits. These could be XXX6XX or YYY8YY depending on the department

Acknowledgments

- We acknowledge the departmental Graduate Studies Committee that developed and refined the new curriculum with input from many faculty members
- In particular, we acknowledge Prof. Millicent Sullivan whose leadership and perseverance were not only essential for the development of the new curriculum, but also were key to drive this new program through the University approval process seamlessly.