Graduate Program Handbook

Department of Chemical Engineering

College of Engineering and Architecture
Howard University
Washington, D.C.

A. Objectives and curriculum design of the Graduate Program in Chemical Engineering

The goal of the graduate program in Chemical Engineering is to give an incoming B.S. Engineering student an

- Advanced knowledge in Chemical Engineering Fundamentals
- Ability to integrate Chemical Engineering Principles with the other STEM fields
- Ability to apply principles of Chemical Engineering and allied disciplines for research and innovation in one of the four applied areas of the department's core strength.

The department has core strengths in the following applied areas:

- Nanotechnology (Allied disciplines: Chemistry, Physics)
- Biomolecular engineering (Allied disciplines: Biology, Medicine, Physics)
- Environmental Science and Engineering (Allied disciplines: Chemistry, Civil Engineering)
- Energy (Allied disciplines: Chemistry, Mechanical Engineering)

In accordance with this mission, the department's course offerings at the graduate level are structured as follows:

- 4 advanced Chemical Engineering Fundamentals core courses
- 4 elective courses; these elective courses will be of the student's own choosing, based on their interests and in consultation with their graduate and thesis advisors. They may be in any of the four research areas; they may be courses that focus on applied study by integrating principles of chemical engineering with that of allied disciplines; or they may be interdisciplinary elective courses in any of the four research areas.

B. Curriculum design of master's and Ph.D.[1] program

A student entering with a bachelor's degree has to earn 72 credits for graduating with a Ph.D. in Chemical Engineering, of which 30 credits can be applied towards a master's degree. The credit load is designed to satisfy the objectives of the graduate program. The student has to demonstrate an in-depth knowledge of Chemical Engineering Principles, experience in applying them in interdisciplinary fields, an ability to do mentored (master's) and independent (Ph.D.) research.
The breakdown of the credit load is described below and a schematic is given in Figure 1.

[1] The Ph.D. program is not yet implemented as of Fall 2019

B.S. to Master's Level (31 credits):

At the master's level, the student is expected to take:

1. 12 credits (4 courses of 3 credits) of Ch.E. Advanced Fundamentals Core Courses (in depth knowledge of the foundation principles in chemical engineering)
2. 1 credit of seminar series (overview of advances in the field),
3. 12 credits (3 courses of 3 credits) of STEM graduate electives and up to one undergraduate course in their research focus area (specialized study)
4. 6 Thesis Credits (Ability to integrate Chemical Engineering principles for solving/innovating in the different applied areas)

B.S. to Ph.D. Level:

At the Ph.D. level, the student is expected to have:

1. 12 credits of Ch.E. Advanced Fundamentals Core Courses (in depth knowledge of the foundation principles in chemical engineering) – included in the master's level
2. 4 – 5 credits of seminar series (overview of advances in the field) - 1 credit included in the master's level
3. 12 – 24 credits that comprise of a graduate course in each of the core areas of the department (overview of advances in the field) and graduate STEM course in the research focus area (specialized study) – 12 credits included in the master's level
4. 6 – 8 credits of study in research methods, skills and techniques
5. 24 Dissertation Credits (ability to transition from mentored research to independent research and mentoring) – 6 credits included in the master's level

At the time of entry into the program, a detailed Program of Study is prepared by the students and the Director of Graduate Studies. The students' course work is signed and approved by the thesis advisor and a copy presented to the thesis committee for approval. The student will follow the guidelines of the Graduate school for the declaring candidacy and taking thesis credits.

The schematic of course work and its relation to a Master's and Ph.D. degree is presented in Figure 1. Appendix A lists the Advanced Core course for Chemical Engineering Fundamentals and for the 4 focus Areas.

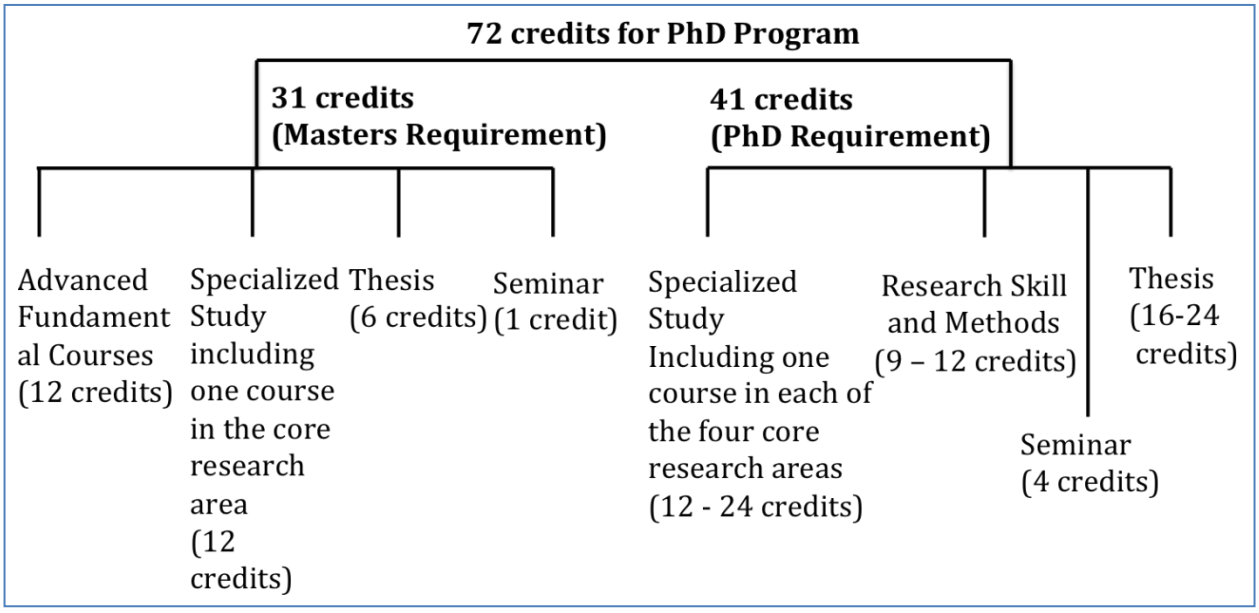

Figure 1. Curriculum flow chart for a graduate program in Chemical Engineering

C. Advanced Fundamental Course

Following are four required core courses for graduate students:

1. CHEG-50l Advanced Transport Phenomena (3 Credits)

Course description: Advanced treatment of the mechanisms of heat, mass, and momentum transport on a continuum basis. Methods of solution to transport problems are looked at in depth with emphasis on coupled systems where two or more transport processes interact. Introduction to boundary layer and turbulent systems.
Offered: Spring Semester
Pre-requisites: The following undergraduate Chemical Engineering courses: 3 credits of Fluid mechanics or Unit Operation 1 (equivalent to CHEG 301) 3 credits of Heat transfer on Unit Operation II (equivalent to CHEG 302) Permission of instructor

2. CHEG-502 Advanced Chemical Engineering Thermodynamics (3 Credits)

Course description: Advanced treatment of the fundamentals of thermodynamics; Energy; Reversibility, concepts and consequences. Thermodynamics of mixtures; phase equilibria; and chemical equilibria.
Offered: Spring Semester
Pre-requisites: The following undergraduate Chemical Engineering courses: 3 credits of Thermodynamics (equivalent to CHEG 303)

3. CHEG-504 Advanced Mathematics for Chemical Engineers (3 Credits)

Course description: Use of the basic laws of conservation of momentum, mass and energy to formulate partial differential equations describing chemical engineering processes. Analytical

and numerical solution of partial differential equations. Matrices, vector analysis, and selected topics.
Note: If this course is not offered, an Advanced Math Course from the Department of Physics, PHYS-216 or PHYS-217 may be substituted with permission of Graduate Advisor.
Offered: Fall Semester

4. CHEG-505 Advanced Chemical Reaction Engineering (3 Credits)

Course description: Advanced treatment of chemical reaction engineering including effects of non-ideal flow and fluid mixing on reactor design. Multi-phase reaction systems of non- heterogeneous catalysis and catalytic kinetics.
Offered: Fall Semester
Pre-requisites: The following undergraduate Chemical Engineering courses: 3 credits of Chemical Reaction Engineering (equivalent to CHEG 403)
3 credits of Fluid Mechanics (equivalent to CHEG 301) 3 credits of Heat Transfer (equivalent to CHEG 302)
3 credits of Separations or Unit Operations III (equivalent to CHEG 401) 3 credits of Differential Equations (equivalent to MATH 159)

D. Suggested Master's Degree Course Plan for Candidates with B.S. in Chemical Engineering

Fall Semester (First Year)

CHEG 505 Chemical Reaction Engineering CHEG 504 or PHYS 216 Advanced Mathematics Graduate Elective (Either one or two)

Department Requirements:
Complete forms for MSChE Program of Study
Graduate School Requirements:
Course on Responsible Conduct of Research Workshop on Technical Writing

Spring Semester (First Year) CHEG 501 Transport Phenomena CHEG 502 Advanced Thermodynamics Graduate elective (One)

Fall Semester (Second Year)

Graduate Elective (One – Total of Four elective courses) Thesis Credits

Department Requirements:
Complete forms for MSChE Degree Plan
Forms available with DGS and Department Secretary

Spring Semester (First Year)
Thesis Credits

D. Course and Program Requisites

An incoming graduate student should have the necessary undergraduate pre-requisite courses to do the Advanced Fundamentals in Chemical Engineering courses.

An incoming student with an undergraduate Chemical Engineering major has typically taken these pre-requisite courses. If the student does not have an undergraduate Chemical Engineering degree, he/she will be admitted as a provisional student with the proviso to complete the required pre-requisite courses prior to be permitted to enroll in the advanced core chemical engineering course. A course plan will be presented to such a candidate at the time of admission, along with an estimated time at which the student will be eligible to declare candidacy and take thesis credits.

In order to take core and elective courses in the four research areas, a student only requires instructor's permission. For elective courses offered by other STEM departments, the student will follow the course prerequisites prescribed by the respective departments.

E. Funding

Graduate students can be funded through research grants awarded to the advisors, and through graduate and teaching assistantships awarded through the department. Students have to maintain a GPA >3.0 to be eligible for assistantships. Students are encouraged to apply for university fellowships that are listed at gs.howard.edu.

F. Available Elective Courses

Consortium: Elective courses can also be taken at University of Maryland, College Park, Catholic University, Georgetown and George Washington University, through the consortium.

Electives that can be found at HU:

Electives in Nanotechnology and Nanoscience

CHEG-610 Advanced Topics: Nanoscience, Engineering and Technology (3 Credits) Leading edge research and potential impacts of nanotechnology will be covered. Nanomaterials and processing is emphasized and production of nanoassemblies and nanomedicine applications will be reviewed. Prerequisite: Permission of Instructor.

CHEG-606 Introduction to Polymer Engineering (3 Credits)
Elective; Treats the fabrication and characterization of polymeric materials. Prerequisite: None.

CHEG-611 Fundamentals of Membrane Science and Technology (3 Credits)
Emphasis on separations at micro, nano, and molecular/angstrom scale with membranes. Relationship between structure/morphology of dense and porous membranes and their separation characteristics. Use of nanotechnology for design of selective membranes and models of membrane transport (flux and selectivity). Examples provided from various fields/applications, including biotechnology, microelectronics, chemical processes, sensors, and biomedical devices.

CHEG-622 Polymer Processing (3 Credits)
Applies the power law and linear viscoelasticity to extrusion, injection molding, and fiber spinning. PREREQ: Permission of Instructor.

CHEM 205-266 Physical Properties of Polymers **(3 credits)**
Examination of the physical characteristics of polymer including the glassy and rubbery state, crystalline polymers, polymer thermodynamics and chain conformation.

BIOL 532. Molecular Biology of the Cell (4 credits)
This lecture and laboratory course introduces the student to how the sequence of DNA specifies all temporal and special information required for the assembly and function of living organisms. Students are taught how the chemical nature of the monomers of biological polymers interacts to yield the Ultimate structure and function of these molecules. The mechanisms of DNA replication, repair, transcription, translation, regulation of gene expression, cell-cell signaling, and cell division are studied in detail. The experimental techniques based on these mechanisms are studied on a theoretical and in some cases a hands-on basis. Among the applications covered are DNA sequencing, polymerase chain reaction (PCR), radio-isotopic and non-Isotopic methods of visualization, hybridization and immunoselection methods, and recombinant DNA techniques.

CHEM 205-284 Introduction to Molecular Modeling (3 credits)
A lecture/laboratory course where concepts and applications of molecular modeling are covered. These include ab initio and semi-empirical molecular orbital theory, density functional theory and molecular mechanics and molecular dynamics.

Electives in Biomolecular Engineering

CHEG 525 Fundamental of Biomedical Engineering (3 credits)
This course will be jointly taught by Drs. Chandran and Ymele-Leki. It consists of four modules:

- Biotransport (covers transport of biomolecules in tissues and cells, with application to drug delivery)
- Biomaterials (covers biopolymer rheology, with application for biofilms and tissue engineering)
- Biofluid Dynamics (covers fluid and suspension mechanics in the human circulatory systems, with application to atherosclerosis, and artificial heart/lung design)
- Biomechanics (biopolymers and gel biophysics, with application to cell architecture and regenerative medicine)

CHEG-624 Advanced Bioprocess Engineering (3 Credits)
Study of life sciences, microbiology, enzyme kinetics, biochemistry and genetic engineering. Use of these in the design and analysis of biologically based production and purification processes. Emphasis is placed on design of bioreactors and bioseparations processes.
Prerequisite: Permission of instructor

CHEG-627 Principles, Practices, and Policies in Biotechnology (3 Credits)
Presentation of technologies, regulatory practices, and policies required for product development and review of opportunities for new technology development. Topics include fermentation processes, protein engineering, rational drug design, medical and microscopic imaging, and intellectual property issues.

BIOL 413 Developmental Biology (4 credits)
Discusses gametogenesis, fertilization, cleavage, differentiation and mechanisms controlling these processes. Laboratory includes study of living invertebrate specimens.

BIOL 416 Advanced Cytology (4 credits)
Analyzes untrastructural cytology, with emphasis on current techniques in transmission and scanning electron microscopy and cytochemistry.

BIOL 430 Biostatistics (4 credits)
Deals with measures of central tendency and dispersion; binominal, student, and chi-square distribution; and hypothesis testing related to biological problems. Prerequisite: college algebra or the equivalent.

BIOL 443 Animal Physiology (4 credits)
Functions of animal requirement for survival. This course covers homeostasis, circulation, osmoregulation, digestion, respiration, metabolism and reproduction.

BIOL 444 Neurobiology (4 credits)
This course introduces how nerve cells receive, transmit and integrate information in an animal. The first part deals with the cellular and molecular aspects of neuronal signaling. The second part deals with neural nets, sensory motor integration and brain functions.

BIOL 450 Molecular Genetics (4 credits)
Lecture-laboratory course in which studies of plant and microbial genomes are conducted through nucleic acid analysis and applications of recombinant-DNAÂ technology and environmental mutagenesis.

CIEG-514 Finite Element Analysis (3 credits)
Analysis of the theoretical and conceptual bases for finite elements in structural mechanics, element relationships and system solutions and applications to various structures.

Electives in Environmental Engineering

CHEG-529 Air Pollution Control Engineering (3 Credits)
Elective; Selection and design of air pollution abatement programs, including alternate process methods and process materials. Prerequisite: Permission of instructor.

CHEG-616 Advanced Fundamentals of Environmental Engineering (3 Credits) Elective; Study of environmental media, water treatment and wastewater treatment, chemical, physical and biological mechanisms for environmental remediation; analysis and design of environmental remediation and control processes and systems. Prerequisite: Permission of instructor.

BIOL 424 Environmental Microbiology (3 Credits)
An Integrated approach to studying the role of microorganism in environmental waste management. The microbiology of air, water, soil and sewers are addressed. Emphases are placed on the public health implications of microbes and their products in the environment, and the role of microbes in bioremediation of hazardous chemical wastes.

BIOL 464 Biomonitoring (4 Credits)
This lecture/laboratory course examines the theory and techniques used in the assessment of populations of various biota and the pollutant levels in organisms with emphasis on application to environmental and ecological risk assessment.

CIEG-516 Properties of Air Pollutants (3 Credits)
Examination of the physical, chemical, and biological properties of dust, droplets, and gases in the atmosphere including air pollutant sampling and analysis.

CHEG-295 Introduction to Atmospheric Chemistry (3 credits)
General introduction to atmospheric sciences with an emphasis on the chemistry of the Earth's atmosphere. Examination of the current state of knowledge regarding the photochemistry, kinetics, chemical cycling, and evolution of the Earth's atmosphere.

CIEG-501 Water Treatment and Water Resources (3 Credits)
Water resources systems planning in relation to demographic, chemical, and biological factors. Modern advances in water treatment processes.

CIEG-502 Wastewater Treatment (3 Credits)
Point source treatment requirements and consideration of the theory, design, and specification of wastewater treatment alternatives.

CIEG-505 Fundamentals of Environmental Engineering A **(4 Credits)**
Fundamentals of process analysis and unit operations and processes used for the treatment of water and wastewater.

CIEG-506 Fundamentals of Environmental Engineering B (2 Credits)

Expounds on the fundamental concepts and processes of importance in water resources engineering.

CIEG-511 Chemistry of Water and Wastewater (3 Credits)
Analysis of the physical and chemical properties of water and wastewater, kinetic equilibrium in water and sewage; organic and inorganic constituents in water, including routine examination of water.

CIEG-601 Industrial Wastewater Management (3 Credits)
Includes the study of waste disposal technology and problems associated with various industries, and methods of treatment, including economic and regulatory aspects.

BIOL 533. Ecological and Environmental Biology (4 Credits)
This lecture and laboratory course will focus on the mechanisms underlying processes at the population, community and ecosystem level. Current research advances in these areas will be stressed including mathematical modeling.

Thesis Credits

CHEG-70l Master of Science Thesis Research I (1-3 Credits)
Thesis Guidance for MS students. Each student must choose a suitable thesis subject and must successfully pass a preliminary thesis examination by the Thesis Committee.

CHEG-702 Master of Science Thesis Research II (1-3 Credits)
Thesis guidance for MS students. Each student must present a seminar on their thesis work at a regularly scheduled Departmental Graduate Seminar Session.

Research and Methodology credits

BIOL 510. Experimental Techniques in Biology (3 credits)
Introduction to the literature, techniques, instrumentation, and preparation of reports for biological research.

BIOL 530. Graduate Topics in Biology (3 credits)
Graduate level seminars on selected topics chosen by graduate faculty according to faculty and student areas of interest. Seminars will focus on recently published articles and will include both discussion and presentations. This Course will be rotated among all faculty Such that each member of the graduate faculty will offer a section every other year or so. Two to four sections will be offered each semester. The seminar may include presentations from within and without the department, as well as presentations by students of dissertation research prior to the defense of the thesis or dissertation.

BIOL 534. Evolutionary and Systematic Biology (3 credits).
This lecture and laboratory course will explore the genetic basis of evolutionary change, molecular evolution, rates of evolution, macroevolutionary processes and modern principles of classification, including phylogenetic analysis.

CHEM 205-259 Techniques of Biological Chemistry (3 credits)
Theory and practice of biochemical techniques, including pH spectrophotometry, protein isolation, amino acid identification and enzyme kinetics.

CHEM 205-258 Biophysical Chemistry (3 credits)
Theory and practice of biophysical chemical techniques and physical chemistry with biochemical applications.

CHEM 205-235 Techniques in Analytical Chemistry (2 credits)
Theory and application of modern methods of instrumental analysis. Two lectures and one three-hour lab each week.

CHEM 205-238 Chemical Instrumentation (2 credits)
Special topics in modern chemical instrumentation.