Chemical Engineering Program

Department of Chemistry and Life Science

United States Military Academy

West Point, NY 10996

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Introduction

Traditionally, chemical engineers are responsible for design and control of large-scale chemical manufacturing plants for the production of basic chemicals, plastics, and fibers. Today's chemical engineers are also involved in food and fertilizer production, synthesis of electronic materials, waste recycling and remediation, and power generation. Chemical engineers also develop new materials (polymers, ceramics and semiconductors, for example) as well as biochemicals and pharmaceuticals.

The breadth of training in engineering and science gives chemical engineers a particularly wide spectrum of career opportunities. Chemical engineers work in the chemical and materials related industries, in government, and are readily accepted by graduate schools in engineering and chemistry. Chemical engineers are also accepted at medical and law schools (mainly for patent law). This breadth of training that makes the chemical engineering program at the United States Military Academy valuable as a basis for a career as an officer in the Army.

The Chemistry and Life Science Department offers an undergraduate program leading to a Bachelor of Science Degree in Chemical Engineering. There are five full-time chemical engineering faculty within the department, and we draw heavily on faculty in chemistry program, as well as accredited programs in mechanical, civil, and electrical engineering. The faculty are listed in the Faculty section of this booklet.

All chemical engineering undergraduates are members of the student chapter of the American Institute of Chemical Engineers (AIChE). The cadets started the AIChE student chapter to promote chemical engineering among the cadets and to enhance student life, and the chapter participates in field trips, social events, and engineering outreach programs. We also learned this year that our chapter has been recognized by the AIChE, which provides free membership for all of our students.

All graduates of the United States Military Academy serve as officers in the United States Army for a minimum of five years after graduation. During that time, you may find yourself faced with problems such as how to start up a refinery or how to secure a pipeline. The training in chemical engineering enhances your leadership, problem solving, and officership skills. After your five-year tour, we are confident that the skills you learned at USMA, as well as your leadership skills developed in the Army, will prove valuable and highly marketable to civilian employers.

Program Objectives and Outcomes

The Chemical Engineering program supports the academic mission of the United States Military Academy. The mission statement is fully articulated in the document "Educating Future Army Officers for a Changing World." The mission is to educate, train, and inspire the Corps of Cadets so that each graduate is a "leader of character." The Academy's mission is closely aligned with the Code of Ethics promoted by the American Institute of Chemical Engineers (http://www.aiche.org/About/Code.aspx). In summary, this code states that the qualities of honesty, integrity, and competence are all qualities that society demands of its engineers. These qualities are also deeply engrained in the cadet and Army cultures.

Our institutional mission also calls on us to inspire our graduates to professional growth throughout their careers. We believe our program provides the intellectual tools to do this, and that our faculty provides the cadets with proper and appropriate civilian and military role models. Each of our faculty believes in professional development on a daily basis, and also as part of his or her individual long-term faculty development process.

Beyond the Academy's mission statement, our program also provides graduates with additional objectives, specified below. Cadets who complete the chemical engineering program are:

- capable of recognizing and assessing engineering infrastructure and operational problems involving chemical technology, and contributing to the solution of these problems as they arise.
- prepared for advanced study in chemical engineering or in related engineering professions.
- capable of clear communication in technically precise language, either orally or in writing.
- capable of providing advice and expertise to the Army on matters of chemical technology and industrial chemical processes.

To assist our graduates in the pursuit of these objectives, and to maintain the quality of our program, the Chemical Engineering Program fully supports ABET, Inc. and its accreditation process. Specifically, on completion of the chemical engineering program, our graduates will be able to:

- apply knowledge of mathematics, science, and engineering.
- design and conduct experiments, as well as analyze and interpret data.
- design a system, component, or process to meet desired needs within economic, environmental, social, political, ethical, health and safety, manufacturing, and sustainability constraints.
- function on multidisciplinary teams.
- identify, formulate, and solve engineering problems.
- understand professional and ethical responsibilities.
- communicate effectively.
- understand the impact of engineering solutions in a global economic, environmental, and societal context.
- recognize the need and develop the skills required for life-long learning.
- demonstrate knowledge of contemporary issues.
- demonstrate an ability to use techniques, skills, and modern engineering tools necessary for engineering practice.

The program provides the graduate with a thorough grounding and working knowledge of the chemical sciences, including:

- general, organic, physical, and analytical chemistry.
- material and energy balances on chemical processes, including safety and environmental factors.
- thermodynamics of physical and chemical equilibria.
- heat, mass, and momentum transfer.
- chemical reaction engineering.
- continuous and staged separation operations.
- process dynamics and control.
- modern experimental and computing techniques.
- process design.

Academic Plan – Class of 2010 and Beyond

Fall Semester	Course	Credit Hours
FOURTH CLASS		
CH101	General Chemistry I	3.0
EN101	Composition	3.0
HI107	History of the World	3.0
IT105	Introduction to Computing & IT	3.0
MA103	Mathematical Modeling & Calculus	4.0
MS101	Introduction to the Army	0.5
	Physical Education Elective	0.5
	Total	17.0
THIRD CLASS		
MA205	Calculus II	4.5
PH201	Physics I	3.5
EV203	Physical Geography	3.0
Elective	Foreign Language Elective	3.0
SS201	Economics	3.5
MS201	Fundamentals of Tactics I	0.5
	Physical Education Elective	0.5
	Total	18.5
SECOND CLASS		
CH363	*Separation Processes*	*3.0*
EE301	*Fundamentals of Electrical Engineering*	*3.0*
CH383	*Organic Chemistry I*	*3.5*
ME311	*Thermal-Fluid Systems I*	*3.5*
MA206	Probability and Statistics	3.0
PL300	Military Leadership	3.0
MS301	Combined Arms Operations I	0.5
	Physical Education Elective	0.5
	Total	20.0
FIRST CLASS		
CH459	*Unit Operations Laboratory*	*3.0*
CH481	*Physical Chemistry I*	*3.0*
ME480	*Heat Transfer*	*3.5*
SS307	International Relations	3.5
HI301	History of the Military Art	3.0
MS401	Tactical Leadership	0.5
	Total	17.5

Courses in red are part of the 18-course Chemical Engineering sequence

Spring Semester	Course	Credit Hours
FOURTH CLASS		
CH102	General Chemistry II	3.0
EN102	Literature	3.0
HI108	History of the World	3.0
MA104	Calculus I	4.5
PL100	General Psychology	3.0
MS103	Introduction to War fighting	0.5
	Physical Education Elective	0.5
	Total	17.5
THIRD CLASS		
CH362	*Mass and Energy Balances*	*3.0*
MA364	*Engineering Mathematics*	*3.0*
PH202	Physics II	3.5
Elective	Foreign Language Elective	3.0
SS202	American Politics	3.5
PY201	Philosophy	3.0
MS203	Fundamentals of Tactics II	0.5
	Physical Education Elective	0.5
	Total	20.0
SECOND CLASS		
CH364	*Chemical Reaction Engineering*	*3.0*
XE472	*Dynamic Modeling and Control*	*3.0*
CH384	*Organic Chemistry II*	*3.5*
ME312	*Thermal-Fluid Systems II*	*3.5*
CH371	*Introduction to Analytical Chemistry*	*3.5*
EN302	Advanced Composition	3.0
MS303	Combined Arms Operations II	0.5
	Physical Education Elective	0.5
	Total	20.5
FIRST CLASS		
CH402	*Chemical Engineering Process Design*	*3.5*
	Program Elective	*3.0*
CE300	*Engineering Mechanics & Design*	*3.0*
CH400	*Chemical Engineering Seminar*	*1.5*
HI302	History of the Military Art	3.0
LW403	Constitutional and Military Law	3.5
MS403	Transition to the Army	0.5
	Total	18.0

Courses in red are part of the 18-course Chemical Engineering sequence

Course Descriptions

Core Courses that Support Chemical Engineering Program

CH101/102 - General Chemistry I and II

This two-course sequence provides a solid background in chemistry principles and applications. It includes a study of the nature of matter, its atomic and molecular structure, and the associated energies involved. Fundamental concepts, principles, theories, and laws of chemistry are stressed. Stoichiometry, states of matter, solutions, kinetics, thermodynamics, acid-base and redox equilibria, electro-, organic, and nuclear chemistry are stressed. The course also provides the student with a strong foundation in materials chemistry, the chemistry of life, environmental chemistry, and military chemistry. A laboratory program is integrated within the course and is designed to develop an appreciation of classical and modern investigative techniques and to illustrate fundamental concepts.

PH201 – Physics I

This is the first term of a two-semester introductory calculus-based physics sequence. It is a comprehensive study of nuclear phenomena, waves, geometric and physical optics, and mechanics designed to provide a solid foundation in physics principles and problem-solving techniques for all cadets. The course consists of an in-depth study of radioactivity, mechanical and electromagnetic waves, geometric optics, lasers, and the laws of motion as applied to simple physical systems undergoing translational and rotational motion. An integrated laboratory program introduces basic experimental techniques and serves to stimulate intellectual curiosity by connecting physics to the design and function of simple military hardware. The course is structured around a military storyline that demonstrates the relevance of physics to the technology of the Army of the 21st Century.

PH202 – Physics II

This is the second course of a two-semester introductory calculus-based physics sequence. It is a comprehensive study of mechanics and electromagnetism designed to provide a solid foundation in physics principles and problem-solving techniques for all cadets. The course includes a detailed study of the principles of conservation of energy and momentum for translational and rotational motion, and orbital mechanics. It concludes with a study of electrostatics, magnetic fields, and circuits. An integrated laboratory program introduces cadets to the principles of experiment design, error analysis, and technical writing. The course is structured around a military storyline that demonstrates the relevance of physics to the technology of the 21st Century Army.

MA103 - Mathematical Modeling and Introduction to Calculus
MA103 is the first course of the mathematics core curriculum, and it emphasizes applied mathematics through modeling using effective problem solving strategies and modeling theory to solve complex and often ill-defined problems. The course exercises mathematical concepts while nurturing creativity, critical thinking, and learning through activities performed in disciplinary, interdisciplinary, and multidisciplinary settings. Special emphasis is placed on introducing calculus using continuous and discrete mathematics through applied settings. The course exploits a variety of technological tools to develop numerical, graphical, and analytical solutions that enhance understanding.

MA104 – Calculus I
This is the second semester of the mathematics core curriculum. This course and Calculus II, the third semester of the mathematics core curriculum, provide a foundation for the continued study of mathematics and for the subsequent study of the physical sciences, the social sciences, and engineering. Combined coverage includes single and multi-variable differential calculus, single and multi-variable integral calculus, and differential equations. Throughout both courses mathematical models motivate the study of topics such as optimization, accumulation, change in one and several variables, differential equations, motion in space, and other topics from the natural sciences, the social sciences, and the decision sciences. MA104 covers single and multi-variable differential calculus including 3-dimensional geometry and vectors.

MA205 – Calculus II
This is the third semester of the mathematics core curriculum. This course with Calculus I, the second semester of the mathematics core curriculum, provides a foundation for the continued study of mathematics and for the subsequent study of the physical sciences, the social sciences, and engineering. Combined coverage includes single and multi-variable differential calculus, single and multi-variable integral calculus, and differential equations. Throughout both courses mathematical models motivate the study of topics such as optimization, accumulation, change in one and several variables, differential equations, motion in space, and other topics from the natural sciences, the social sciences, and the decision sciences. MA205 covers single and multi-variable integral calculus and elementary ordinary differential equations. The sequence culminates with an introduction to the mathematics most applicable to each cadet's major or engineering stem.

MA206 – Probability and Statistics
This is the final course in the mathematics core curriculum. It provides a professional development experience upon which cadets can structure their

reasoning under conditions of uncertainty and presents fundamental probability and statistical concepts that support the USMA core curriculum. Coverage includes descriptive statistics; basic probability concepts; discrete, continuous and joint random variables and their distributions; point and interval estimation; and hypothesis testing. Academic projects are used in the course to motivate concepts presented. Students are introduced to and make use of computer capabilities for statistical analysis.

IT105 – Introduction to Computing and Information Technology

Designed to meet the needs of the core curriculum, this fundamental course provides an introduction to the principles behind the use, function, and operation of digital computers and information technology. The course presents program design and construction techniques in moderate detail, with consideration given to principles of software engineering. Cadets will use a PC-based, integrated program development environment and sophisticated application software. Problem solving using the computer as a tool is a central theme throughout the course as cadets will employ a design methodology to solve problems efficiently and logically. Emphasis is placed on learning how to learn and individual discovery. Cadets are introduced to the internet, the use of the World Wide Web, other information technology tools, and information security.

EV203 - Physical Geography

This core course provides cadets with a fundamental understanding of scientific principles and processes of earth science, meteorology, climatology, geomorphology and environmental systems, as well as an introduction to cultural geography. Further, the course furnishes cadets with the technical skills - digital terrain analysis, image interpretation and spectral analysis, remote sensing, global positioning system, geographic information systems cartography - to delineate the geographic distribution of landforms, weather, climate, and culture systems; and evaluate their potential impact on military operations. Lessons are reinforced by extensive use of in- and out-of-class practical exercises, terrain walks and computer exercises to demonstrate the interrelationship between physical and human systems, and their impact on the environment. Historical vignettes are employed to demonstrate how the factors of weather, climate, terrain, soils, vegetation and culture are important, cogent and frequently decisive in military operations.

SS201 – Economics

This standard course presents the basic principles of economic analysis and their application to contemporary economic problems and supports the further study of economics and related disciplines in the social sciences. The course is organized into three general sections: microeconomics, outlining basic theory of allocation by supply and demand in a market economy and relating this theory to

contemporary issues; macroeconomics, surveying the theory of aggregate economics and illustrating the application of macroeconomic theory to public policy in the American economy; and international economics, introducing trade theory and international monetary theory and policy and application of economics to selected public policy issues (taxation and resource allocations, provision of public goods, etc). Cadets examine the implications of economics on national security and defense, and the use of economic analysis to improve decisions they will make as Army officers.

Chemical Engineering Program Required Courses

MA364 Engineering Math

This course provides additional mathematical techniques and deepens the understanding of concepts in mathematics to support continued study in science and engineering. Emphasis is placed upon using mathematics to gain insight into natural and man-made phenomena that give rise to problems in differential equations and vector calculus. Calculus topics focus on three-dimensional space curves, vector fields and operations, divergence and curl, line and surface integrals. Analytic and numerical solutions to differential equations and systems of differential equations are found using a variety of techniques. Linear algebra topics include solutions to homogeneous and non-homogeneous systems of equations. An introduction to classical partial differential equations is included in the Spring semester.

EE301 – Fundamentals of Electrical Engineering

This first course in electrical engineering for the non-electrical engineering major provides a foundation in basic circuit theory and analysis, power in circuits and electric power systems, and analog electronics. Lectures, laboratory work, classroom demonstrations and discussions showing practical applications emphasize and illustrate the fundamental theories and concepts presented in the course. Engineering design is reflected in laboratory work and minor design problems.

XE472 – Dynamic Modeling and Control

This course covers dynamic modeling and control of linear systems. The course provides an overview of classical control theory as the foundation for control applications in electrical, mechanical, and aeronautical systems. Topics here include system modeling using Laplace transform, frequency domain, and state variable methods. Mathematical models are developed for electrical, mechanical, aeronautical, and other physical control systems. Control systems analysis and design techniques are studied within the context of how each system is physically controlled in practice. Laboratory exercises include feedback design and system

identification. Computer design exercises include dynamic modeling and control of various engineering systems.

CE300 – Fundamentals of Engineering Mechanics and Design
The engineering design process and the method of design are introduced. Principles of equilibrium are used to analyze forces on statically determinate rigid bodies and structures to include trusses and frames. The behavior of deformable bodies under axial, flexural, and combined loading is examined. The concepts of stress, strain, and material properties are introduced and are used to relate external forces applied to a body to the resulting internal forces and deformations so that performance can be evaluated. Practical applications involving the design and adequacy of mechanical and structural elements under various loading conditions are emphasized.

ME311 – Thermal-Fluid Systems I
Thermal-Fluid Systems I is an integrated study of fundamental topics in thermodynamics and fluid mechanics. The course introduces conservation principles for mass, energy, and linear momentum as well as the 2nd Law of Thermodynamics. Principles are applied to incompressible flow in pipes and turbomachinery, external flows, power generation systems, refrigeration cycles, and total air-conditioning focusing on the control volume approach. Laboratory exercises are integrated into classroom work. This course includes completion of a comprehensive, out-of-class design problem. This design problem provides the opportunity for students to apply engineering science and the engineering design process to a hands-on project.

ME312 – Thermal-Fluid Systems II
ME 312 Thermal-Fluid Systems II continues the integrated study of fundamental topics in thermodynamics and fluid mechanics. The course applies conservation principles for mass, energy, and linear momentum as well as the 2nd Law of Thermodynamics. Principles are applied to an automotive system to examine engine performance (Otto and Diesel Cycles) and heat exchangers and to high performance aircraft to examine the Brayton Cycle, compressible flow, external flow, lift, and drag. Laboratory exercises are integrated into classroom work. This course includes completion of a comprehensive, out-of-class design problem. This design problem provides the opportunity for students to apply engineering science to the design of a comprehensive thermal-fluid system.

ME480 – Heat Transfer
The three modes of heat transfer, conduction, convection, and radiation, are studied in detail and applications are made to various engineering systems. The principles of conduction and convection are used to study the mechanisms of heat transfer during condensation and the design and operation of heat exchangers.

Students are introduced to the use of the computer to solve engineering heat transfer design problems.

CH362 – Mass and Energy Balances
Introduction to mass and energy balances in single phase and multiphase, nonreactive and reactive systems. Course topics include an introduction to engineering calculations and process variables, use of computers in solving chemical engineering problems, fundamentals of material balances in single-phase and multi-phase systems, energy balances on nonreactive and reactive processes, applications of combined material and energy balances, balances on transient processes, introduction to chemical engineering unit operations, and a general introduction to the field of chemical engineering.

CH363 – Separation Processes
This course covers methods for the physical separation of chemicals. Topics include dew point and bubble point calculations, adiabatic flash, distillation, chromatography, liquid-liquid and gas-liquid absorption. Students are taught the significance of staging of unit operations. Heavy emphasis is placed on theory of operation, numerical methods of solution, and simulation.

CH364 – Chemical Reaction Engineering
This course studies the effects of chemical reaction kinetics on systems of engineering significance. It introduces selection and operation of commercial chemical reactors, emphasizing chemical kinetics and transport phenomena. It studies currently practiced engineering techniques associated with each of these reactors. Topics covered in this course include ideal reactors including batch, CSTR and PFR, isothermal and nonisothermal reactors, transient and steady state design, pressure drop in reactors, recycle, stability, and numerical methods.

CH459 – Unit Operations Laboratory
This course provides laboratory experience in selected chemical engineering unit operations, such as gas absorption, evaporation, distillation, liquid-liquid extraction, cooling tower operation, chemical reactors, heat transfer, and mass transfer/diffusion studies. Written and oral reports required.

CH402 – Chemical Engineering Process Design
This course provides a capstone experience that brings together material from previous courses to examine problems in chemical engineering process design. It provides instruction in the conceptual design of process networks to achieve a design goal as well as the optimization of the network. It emphasizes use of computer simulations, theory of selected unit operations, process control and environmental and economic factors. The effect of changes in design on the economics of chemical production will be investigated. In addition, political and

social aspects of chemical engineering design will be incorporated into the analysis of the capstone design project.

CH371 – Introduction to Analytical Chemistry
The course teaches the fundamental concepts of analytical chemistry. Topics include acid-base equilibria, redox potentials, compleximetric titrimetry, separations, electrochemistry, and absorption spectroscopy. The course provides an overview of modern analytical techniques being used in various fields. The course emphasizes the development of rigorous laboratory techniques and introduces the cadet to computer based data acquisition. Cadet laboratory work is evaluated in terms of the student's ability to accurately determine the identity and quantity of an unknown sample. (The content and emphasis of this course is currently undergoing review and modification to reflect its importance within the chemical engineering program)

CH383 – Organic Chemistry I
Organic chemistry I is an introduction to the relationship between chemical structure and the physical and chemical properties of molecules. A qualitative description of structure and bonding is presented. The relationships between free energy changes and equilibria, and between activation energy and rate of reaction are developed. Stereochemistry and isomerism are explored. The concept of the mechanism of reaction is presented and the relationships between mechanism, the least energy path, stable intermediates and transition states are exemplified by the reactions of the alkanes, alkenes, alkyl halides, and alcohols. The use of instrumental methods of structural analysis is also introduced.

CH384 – Organic Chemistry II
The reactions of the important functional groups are explored: conjugated alkenes; aldehydes; ketones; carboxylic acids; and amines. The concept of aromaticity is explored and its mechanistic implications are developed. Selected topics in carbohydrate and lipid chemistry are also studied. Functional group interconversions and synthetic strategy are presented. The laboratory capstone synthesis introduces cadets to multi-step synthetic sequences.

CH481 – Physical Chemistry I
The major areas of study in this course are chemical thermodynamics with a special focus on chemical equilibrium, and chemical kinetics, introduction to intermolecular interactions. Some of the specific topics covered include properties of real gases, the kinetic theory of gases, the laws of thermodynamics as related to chemical systems, diffusion as a description of mass transport, rates of chemical reactions, and molecular reaction dynamics. The laboratory program illustrates the fundamental topics covered through precision measurements, utilizing modern instrumental and computational methods.

Chemical Engineering Program Elective Courses

CH490 – Individual Research

One term of work (3.0 credit hours) are normally required for graduation with honors from the chemical engineering program. The honors program is described in more detail on p. 22. A faculty advisor individually supervises the cadet in a research program selected by him/her and approved by the department. The cadet, with the assistance of his/her supervisor, must obtain the necessary theoretical background, and develop the techniques and procedures required. Requirements may include periodic oral and/or written reports over the course of the two semesters. At the completion of the project, cadets normally submit a final report (research paper) and present an oral seminar. Cadets may perform research for one term instead of two only with prior approval of the head of the department.

MA371 – Linear Algebra

This course emphasizes both the computational and theoretical aspects of linear algebra one encounters in many subjects ranging from economics to engineering. The course covers solutions of linear systems of equations and the algebra of matrices. The foundational aspects of vector spaces and linear transformations to include linear dependence and independence, subspaces, bases and dimension, inner products, and orthonormalization are developed. This is rounded out with a detailed investigation of eigenvalues and eigenvectors as they relate to diagonalization, quadratic equations, and systems of differential equations. The Invertible Matrix Theorem is explored as the conceptual/theoretical thread of the course. A computer algebra system is used to explore concepts and compute solutions to problems. Applications of the course material are included in the form of special problems to illustrate its wide scope.

MA396 – Numerical Methods for the Solution of Differential Equations

The focus of this course is to find numerical solutions of differential equations that result when modeling physical phenomena. The numerical solution of both initial value problems and boundary-value problems that arise with ordinary differential equations are covered. Techniques for solving partial differential equations are introduced. Four projects incorporate mathematical software libraries in developing solutions to applied problems.

CH357 – Microbiology

This course is an introduction to general bacteriology. The course starts with the structure prokaryotic cells and the major biochemical processes they carry out. The remainder of the material covers a broad range of information including genetics and genetic exchange, epidemiology, microbial diseases, applications of

microorganisms in ecology, sewage disposal, food production, biodegradation and molecular biology. Viruses and viral diseases are also examined. Extensive laboratory exercises focus the classroom material with practical applications. Labs will cover aseptic techniques, growth, identification of microorganisms, enrichment cultures, effects of environmental factors and antimicrobial agents on growth, and the microbiology of food, water, soil and sediments.

CH385 – Introduction to Cell Biology
The course will cover the structure and function of prokaryotic and eukaryotic cells. The course will present an introduction to biomolecules and detailed discussion of the cell cycle; DNA replication; gene structure, expression, and replication; organelle biogenesis; cell-to-cell signaling, and microtubules and filaments. Emphasis will be placed on research methods and techniques that have lead to our understanding of how the cell works. The course will conclude with a discussion of applications of cell biology to include cancer and immunity.

CH387 – Human Physiology
This course consists of an in-depth study of human physiology and the interrelationships between major organs and systems of the body. Topics will build on studies of cell structure and function covered in CH385. This course will concentrate on homeostatic reflex mechanisms of the human body. Major topics covered include neural physiology, muscles, cardiovascular physiology, respiratory physiology, renal physiology, digestion, immunology, and reproductive physiology. The laboratory program will concentrate on exposing cadets to histology and will culminate in a lab practical.

CH471 – Applications of Polymer Chemistry
This course is an introduction to modern polymer chemistry and engineering. It provides an introduction to macromolecules and their properties. It covers polymerization methods, copolymerization, the morphology of polymers, and the testing and characterization of polymer products. The course also introduces the flow properties of polymers, polymer additives, natural and biomedical polymers and modern polymer technology, including the military uses of polymer products.

CH472 – Inorganic Chemistry
This course features an in-depth study of main group and transition elements and their compounds, with emphasis on chemical bonding and both atomic and molecular structures. The fundamentals of quantum chemistry to include the valence bond and molecular orbital theories as applied to inorganic chemistry are studied. An introduction to symmetry/group theory, coordination chemistry/crystal field theory, chemistry in aqueous and nonaqueous solutions, and organometallic compounds are also included in the course. Chemical principles and spectroscopic techniques will also be emphasized. Journal articles

from the chemical literature are used to supplement the text with topics of current interest.

CH473 – Biochemistry

This course is an introduction to biochemical systems and concentrates on studying them from the molecular approach. Three themes are emphasized: 1) Structure - Function relationships, 2) Metabolism, and 3) Regulation of the systems and processes studied. The fundamental goals of the course are to provide students the basic knowledge of biochemistry and to give them a framework for analyzing problems and questions in life science studies. Additional emphasis is placed on familiarizing students with the experimental techniques used in biochemistry and their application to current issues of interest.

CH474 – Instrumental Methods of Analysis

A laboratory course designed to develop proficiency in the selection and use of modern instrumental methods of chemical analysis. Topics include atomic spectroscopy, molecular absorption and fluorescence spectroscopy, infrared and Raman spectroscopy, nuclear magnetic resonance and mass spectrometry, and chromatography. The laboratory program includes a Capstone experimental procedure and methodology design component. Cadet laboratory work is evaluated in terms of the student's ability to determine the proper instrumental methodology to analyze a chemical sample.

CH482 – Physical Chemistry II

This course builds on the concepts covered in CH481 or CH480 through a study of the quantum mechanics of atoms and molecules, their interaction with radiation, and statistical thermodynamics. Some of the specific topics covered include the electronic structure of atoms and molecules, molecular geometry, molecular symmetry, several types of spectroscopy used for identification and monitoring of the local molecular environment, and the details of molecular motion. Various levels of theory are used to obtain increasingly more accurate descriptions of atomic and molecular systems with user-friendly software tools. Statistical thermodynamics enables understanding about the connection between the microscopic details in quantum mechanics and the macroscopic observations made in the laboratory. The laboratory program illustrates the fundamental topics through use of modern instrumental and computational methods.

Comparison with Civilian Programs

The Chemical Engineering Program at USMA is new, and a natural question is to what extent our program compares to more established programs at civilian institutions. The chart below provides a comparison, in checklist format, of our offerings to twelve representative civilian schools. For the courses where checkmarks are absent, the programs offer the courses as electives.

	US Military Academy	University of Notre Dame [c]	University of Michigan [c]	Cleveland State University [a,c]	Ohio State University [a,c]	Purdue University [c]	University of Virginia [a,c]	University of Kansas [c,d,e]	University of Oklahoma [c]	Christian Brothers University	Rowan University [c]	University of Texas at Austin [c]
Organic Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Physical Chemistry	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Analytical Chemistry	✓	✓	✓									
Engineering Math [b]	✓	✓		✓	✓	✓	✓		✓			✓
Electrical Engineering Circuits	✓			✓	✓			✓	✓	✓		✓
Statics and Dynamics	✓			✓	✓			✓	✓			
Thermodynamics	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Momentum Transfer	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Heat Transfer	✓		✓			✓		✓	✓	✓	✓	
Mass and Energy Balances	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Separation Processes	✓	✓	✓	✓		✓			✓	✓	✓	✓
Reaction Engineering	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Control Theory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Unit Operations Laboratory	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Chemical Engineering Design	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

[a] Students may take either statics or circuits

[b] Engineering math is one or more semesters beyond the typical 4-course requirement.

[c] Transport Phenomena, either 1, 2, or 3 semesters

[d] Engineering Math is available as an option

[e] Statics and Circuits offered in Petroleum Engineering Option

Comparison of Contact Hours for Subject Areas

For a more quantitative comparison with civilian programs, the chart below has courses grouped into subject areas, with the total number of credit hours in each subject listed under the corresponding school. USMA is on par in almost all of the topical areas.

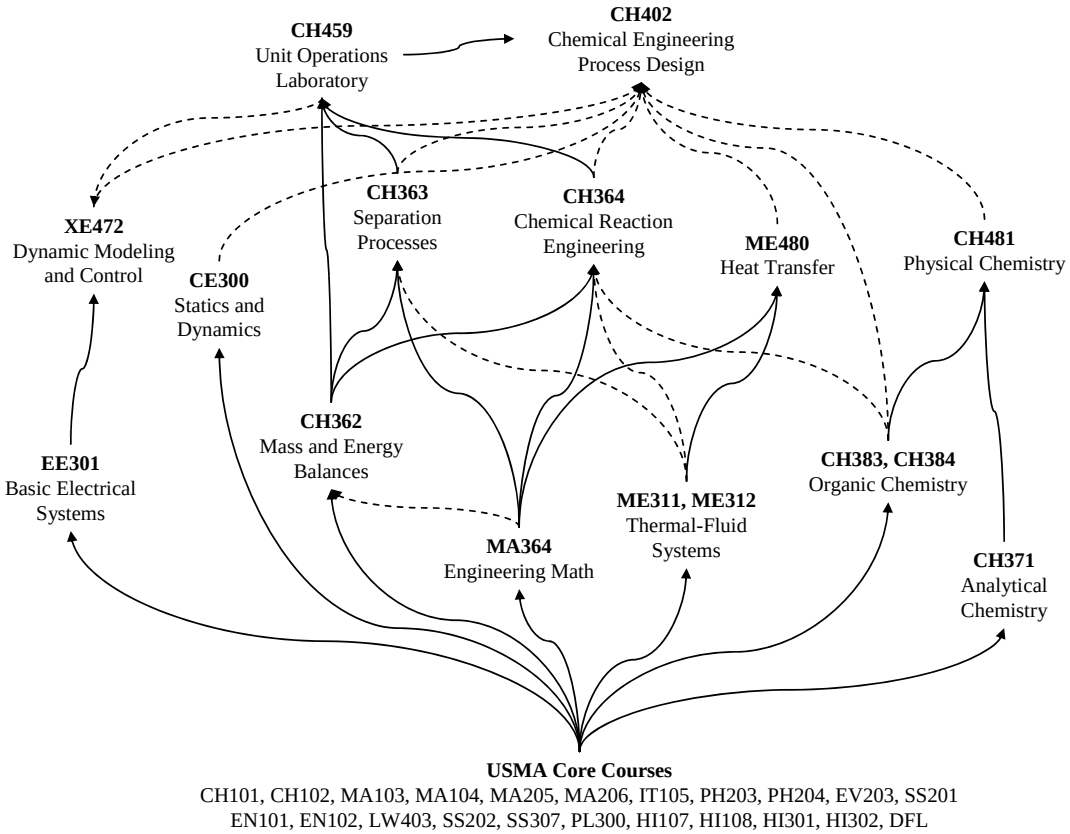
	US Military Academy [a]	University of Notre Dame	University of Michigan	Cleveland State University [b]	Ohio State University [b]	Purdue University	University of Virginia [a]	University of Kansas	University of Oklahoma	Christian Brothers University	Rowan University	University of Texas atTAustin	Non-USMA Average
Mathematics	16	18	16	16	24	19	12	18	15	12	12	12	15.8
Computer Programming	3	3	4	3	4	3	6	3	5	0	4	5	3.6
General Physics	7	8	10	10	15	7	8	8	8	8	4	8	8.5
General Chemistry	6	6	3	8	15	8	8	10	10	8	8	5	8.1
Organic Chemistry	7	7	10	6	12	8	4	5	8	8	4	8	7.3
Physical Chemistry	3.5	3	1	4	12	6	6	4	4	4	3	4	4.6
Analytical Chemistry	3.5	4	4	0	0	0	0	0	0	0	0	0	0.7
Electrical Engineering Circuits	3.5	0	0	1.5	1.5	0	0	0	0	3	0	3	0.8
Statics and Dynamics	3	0	0	1.5	1.5	0	0	0	0	3	0	0	0.5
Thermodynamics	3.5	4	3	7	6	3	6	6	3	6	3	3	4.5
Transport	3.5	6	8	7	9	6	8	10	6	6	9	6	7.4
Mass and Energy Balances	3	3	4	4	6	3	3	3	3	4	6	3	3.8
Separation Processes	3	3	3	4	0	3	0	0	3	3	4	3	2.4
Reaction Engineering	3	3	4	4	4	3	3	3	3	3	4	3	3.4
Control Theory	3	3	3	4	4	3	3	3	3	3	3	3	3.2
Unit Operations Laboratory	3	6	8	4	6	6	6	6	4	6	4	4	5.5
Chemical Engineering Design	3	3	4	6	12	3	3	6	6	6	7	4	5.5

[a] Students also take Prob. and Stats.

[b] Students required to take either statics or circuits

Prerequisites Flowchart

The diagram below shows the progression of prerequisites from the USMA core courses through the program subjects, and into the capstone course. Solid lines represent formal prerequisites as spelled out in the Redbook. Dashed lines represent significant information flow without a formal prerequisite.



Curriculum Enhancements

Academic Individual Advanced Development

The AIAD program provides cadets the opportunity to pursue an in-depth study of chemical engineering or a closely related field, outside of the typical classroom environment. Cadets participating in this program will spend approximately three to six weeks during the summer at an Army, Department of Defense, or civilian institution under the direct supervision of a research scientist or engineer. The length of time allocated to the program is variable and can be extended depending on the time constraints for the individual student. Recent AIAD locations include the Army Research Laboratory, National Security Agency, Washington Penn Plastics, Boehriner-Ingelheim, Yuengling, and Battelle. AIAD sign-ups are typically in January and project descriptions are posted on the Cadet Information System (CIS).

Honors Program

Beginning with the Class of 2007, cadets may be invited to enter the Chemical Engineering Honors Program at the end of the Second Class (Junior) Year. Cadets must maintain a grade point average of 3.5 in their major courses and must complete one semester of undergraduate research, CH489. Proposals for independent research are arranged with a faculty member in chemical engineering or a closely related field, and must be approved by the program director.

Undergraduate Research Opportunities

A wide variety of undergraduate research opportunities exist at the Academy, and cadets are encouraged to participate. Undergraduate Research opportunities are available through enrollment in the CH489/490 Individual Research Course. Cadets may also enroll in research courses offered by other departments, and arrangements should be made through the host department and the cadet's academic counselor.

Scholarships and Fellowships

Cadets in the Chemical Engineering Program may compete for a variety of distinguished scholarship programs. Cadets from the United States Military Academy have traditionally made a strong showing in the Rhodes Scholarship, Hertz Foundation Fellowship, National Science Foundation Graduate Fellowship, Marshall Scholarship, Truman Scholarship, George Olmsted Foundation Scholarship, Daedalian Scholarship, Phi Kappa Phi Fellowship.

Selected Faculty

Andrew I. Biaglow, Ph.D., University of Pennsylvania, 1993
Associate Professor, Chemical Engineering Program Director

Robert Bozic, Ph.D., Rensselaer Polytechnic University, 2005
Assistant Professor, Chemical Engineering

Daisie Boettner, Ph. D., The Ohio State University, 2002
Associate Professor, Mechanical Engineering Program Director

Richard Comitz, M.S., Florida Institute of Technology, 2005
Assistant Professor, Organic Chemistry

Marc J. Franciszkowicz, M.S., Stanford University, 2006
Instructor, Chemical Engineering

Peter Hanlon, Ph.D., Air Force Institute of Technology, 1996
Associate Professor, Electrical Engineering

Richard Hoff, Ph.D., Utah State University, 1999
Associate Professor, Analytical Chemistry

Russell P. Lachance, Ph.D. Massachusetts Institute of Technology, 2005
Academy Professor, Chemical Engineering

Dawn Riegner, Ph.D., University of Texas, 1993
Associate Professor, Chemistry Program Director

Jeffrey Sheehan, M.S., Carnegie Mellon University, 2006
Instructor, Chemical Engineering

Barry Shoop, Ph. D., Stanford University, 1992
Professor, Electrical Engineering

Joseph Sloop, Ph.D., North Carolina State University, 2003
Associate Professor, Organic Chemistry

Gary Washington, Ph. D., University of California at Irvine, 1987
Associate Professor, Physical Chemistry

Resources

Chemical Engineering Laboratory
The Chemical Engineering Laboratory is equipped with a variety of equipment to allow the study of basic transport phenomena, chemical reaction engineering, and unit operations. Facilities include various heat exchangers, various equipment for studying heat and mass transfer, chemical reactors (including a CSTR, a tubular reactor, batch reactor, and a packed bed chemical and biological reactor), a wetted-wall gas absorption column, a liquid-liquid extraction column, a cooling tower, a packed-bed gas absorption column, a double-effect evaporator, a 1.2 kW fuel cell from Ballard Power Systems, and a 10-foot Deltech packed-bed distillation column.

Analytical Instrumentation Laboratory
The department also houses a fully-equipped instrumentation lab that includes a wide variety of equipment for chemical analysis, including gas and liquid chromatography, mass spectrometry, infrared and raman spectroscopy, solid and liquid NMR, X-ray diffraction and fluorescence, ICP, atomic absorption, coulometry, microcalorimetry, and themogravimetric analysis.

Computing Resources

In addition to the standard laptop computers issued to all cadets, students studying Chemical Engineering also have access to a wide variety of modern computing tools for process flow analysis, computational fluid mechanics, and computational chemistry calculations.

The Center for Molecular Sciences maintains a modern computational chemistry facility including a 128-node (256 processor) computer cluster capable of computational speeds in excess of 1 Teraflop. Resources for the cluster include a host of computational chemistry programs for electronic calculations and visualization, including Gaussian 03 and GameSS. Cadets use this facility for fundamental electronic and statistical mechanical calculations of properties.

The Department maintains resources for the cadet personal computers, including licenses with ChemCAD and VMG Sim for process design and thermodynamics calculations, Simulation Solutions Process Training Software, that includes a full simulation of an industrial distillation column, Chemkin chemical reaction software for detailed studies of reacting systems, Fluent, and Comsol Multiphysics. The Academy maintains a site license for Mathematica, MathCAD, Matlab and Maple. These programs are used throughout the core math and chemical engineering programs, and students have access to these resources for

independent study projects. We recently acquired ProCAD software for process design and developmet of piping and instrumentation diagrams.

Library Resources

A healthy undergraduate research and design program in engineering requires adequate library support from the institution. In support of our chemical engineering program, the Academy maintains a modern, state-of-the art library and learning center, with subscriptions to many important chemistry and chemical engineering publications. In addition, most of these resources are online, so students have instant access though the internet form any computer, on- or off-post.

Online site-wide access is available to important process design encyclopedias, including the Kirk-Othmer Encyclopedia of Chemical Technology, the Encyclopedia of Chemical Processing (formerly McKetta's), and Ullmann's Encyclopedia of Industrial Chemistry. Additional subscriptions include the Encyclopedia of Separation Science, the Encyclopedia of Nanoscience and Nanotechnology, and the Encyclopedia of Energy. In addition, the library collection includes a wide variety of other books, handbooks and chemical encyclopedias. We also maintain web access to Chemical Market Reporter, Engineering News Record, and the Chemical Engineering Plant Cost Index.

Web access includes most of the journals published by the American Chemical Society and Elsevier, such as Journal of the American Chemical Society, Journal of Chemical and Engineering data, Industrial and Engineering Chemistry Research, the Chemical Engineering Journal, and Separations Technology, just to name a few. Recently, we have added the Directory of Chemical Producers ant the Chemical Economics Handbook from SRI, Inc., which is an invaluable resource for researching a wide range of commercial chemicals and processes.