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Officers of Instruction
### Faculty

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
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<tbody>
<tr>
<td>Charles C. Nguyen, D.Sc.</td>
<td>Dean and Professor of Electrical Engineering and Computer Science</td>
</tr>
<tr>
<td>Jandro Abot, Ph.D.</td>
<td>Clinical Associate Professor of Mechanical Engineering</td>
</tr>
<tr>
<td>Mohammad Arozullah, Ph.D.</td>
<td>Professor of Electrical Engineering and Computer Science</td>
</tr>
<tr>
<td>Gregory Behrmann, Ph.D.</td>
<td>Clinical Assistant Professor of Biomedical Engineering</td>
</tr>
<tr>
<td>Ujjal Bhownik, Ph.D.</td>
<td>Clinical Assistant Professor of Electrical Engineering and Computer Science</td>
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<tr>
<td>J. Steven Brown, Ph.D., P.E.</td>
<td>Associate Professor of Mechanical Engineering</td>
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<tr>
<td>Mario J. Casarella, Ph.D.</td>
<td>Professor Emeritus of Mechanical Engineering</td>
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<tr>
<td>Lin-Ching Chang, Ph.D.</td>
<td>Associate Professor of Electrical Engineering and Computer Science</td>
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<tr>
<td>Chanseok Jeong, Ph.D.</td>
<td>Assistant Professor of Civil Engineering</td>
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<tr>
<td>Edward D. Jordan, Ph.D., P.E.</td>
<td>Professor Emeritus of Mechanical Engineering</td>
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<tr>
<td>John A. Judge, Ph.D.</td>
<td>Associate Professor of Mechanical Engineering</td>
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<tr>
<td>Timothy W. Kao, Ph.D., P.E.</td>
<td>Professor Emeritus of Civil Engineering</td>
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<tr>
<td>Ozlem Kilic, D.Sc.</td>
<td>Associate Professor of Electrical Engineering and Computer Science</td>
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<tr>
<td>Eric Kommer, Ph.D., P.E.</td>
<td>Assistant Professor of Mechanical Engineering</td>
</tr>
<tr>
<td>Sahana N. Kukke, Ph.D.</td>
<td>Assistant Professor of Biomedical Engineering</td>
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<tr>
<td>Sang Wook Lee, Ph.D.</td>
<td>Assistant Professor Biomedical Engineering</td>
</tr>
<tr>
<td>Hang Liu, Ph.D.</td>
<td>Associate Professor in Electrical Engineering and Computer Science</td>
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<tr>
<td>Max Liu, Ph.D., P.E.</td>
<td>Assistant Professor of Civil Engineering</td>
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<tr>
<td>Gunnar Lucko, Ph.D.</td>
<td>Associate Professor of Civil Engineering</td>
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<tr>
<td>Peter Lum, Ph.D.</td>
<td>Associate Professor of Biomedical Engineering</td>
</tr>
<tr>
<td>Xiaolong Luo, Ph.D.</td>
<td>Assistant Professor of Mechanical Engineering</td>
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<tr>
<td>Arash Massoudieh, Ph.D.</td>
<td>Associate Professor of Civil Engineering</td>
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</tbody>
</table>
Scott Mathews, Ph.D.  Associate Professor of Electrical Engineering and Computer Science

John J. McCoy, D.Sc.  Professor Emeritus of Civil Engineering

Robert Meister, Ph.D.  Professor Emeritus of Electrical Engineering and Computer Science

Nader M. Namazi, Ph.D.  Professor of Electrical Engineering and Computer Science

Georges Nehmetallah, Ph.D.  Assistant Professor of Electrical Engineering and Computer Science

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Christopher Raub, Ph.D.  Assistant Professor of Biomedical Engineering

Phillip A. Regalia, Ph.D.  Professor of Electrical Engineering and Computer Science

Patricio D. Simari, Ph.D.  Assistant Professor of Electrical Engineering and Computer Science

Michael C. Soteriades, D.Sc., P.E.  Professor Emeritus of Civil Engineering

Lu Sun, Ph.D.  Professor of Civil Engineering

Harold Szu, Ph.D.  Research Ordinary Professor of Biomedical Engineering

Binh Q. Tran, Ph.D.  Associate Professor of Biomedical Engineering

Diego Turo, Ph.D.  Clinical Assistant Professor of Mechanical Engineering

Joseph Vignola, Ph.D.  Associate Professor of Mechanical Engineering

Zhaoyang Wang, Ph.D.  Associate Professor of Mechanical Engineering

Yun Chow Whang, Ph.D.  Professor Emeritus of Mechanical Engineering

Otto C. Wilson, Ph.D.  Associate Professor of Biomedical Engineering

**Associates of the Faculty**

http://announcements.cua.edu/2015-2016/graduate/engineering.cfm
Mostafa Ardakani, Ph.D.  
**Lecturer in Civil Engineering**

Ejaz Azad, Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Abdella Battou, Ph.D.  
**Adjunct Assistant Professor of Electrical Engineering and Computer Science**

John Bonita, Ph.D., P.E.  
**Lecturer in Civil Engineering**

Charles E. Campbell Jr., Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Alan B. Carr, M.S.  
**Lecturer in Engineering Management**

Vincent Casella, Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Isaac Chang, Ph.D.  
**Adjunct Assistant Professor of Biomedical Engineering**

Keefe Coburn, Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Aysegul Cuhadar, Ph.D.  
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Azad Ejaz, Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Joseph Findaro, J.D.  
**Lecturer in Civil Engineering**

Jeffrey E. Fernandez, Ph.D., P.E., C.P.E.  
**Lecturer in Engineering Management**

Larry D. Ferreiro, Ph.D.  
**Lecturer in Engineering Management**

Jeffrey E. Giangiuli, M.S.E.  
**Lecturer in Engineering Management**

Wenjun Gu, M.S.  
**Lecturer in Civil Engineering**

Lei He, Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Liling Huang  
**Lecturer in Electrical Engineering and Computer Science**

James W. Hudson, B.S.  
**Lecturer in Civil Engineering**

Boyd A. Jones, Ph.D.  
**Lecturer in Engineering Management**

Philip C. Jones, J.D.  
**Lecturer in Civil Engineering**

Vadim Knyazev, Ph.D.  
**Lecturer in Electrical Engineering and Computer Science**

Michael P. Kushner, M.B.A., P.M.P.  
**Lecturer in Engineering Management**
<table>
<thead>
<tr>
<th>Name</th>
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<tr>
<td>William LaPlante, Ph.D.</td>
<td>Lecturer in Mechanical Engineering</td>
</tr>
<tr>
<td>Mesfin Lakew, M.S.</td>
<td>Lecturer in Civil Engineering</td>
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<tr>
<td>S. Samuel Lin, Ph.D.</td>
<td>Lecturer in Civil Engineering</td>
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<tr>
<td>Francis Linehan, M.E.E.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>George Mattingly, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>John McTyre, M.S.</td>
<td>Lecturer in Civil Engineering</td>
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<tr>
<td>Patrick Mehl, Ph.D.</td>
<td>Lecturer in Biomedical Engineering</td>
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<tr>
<td>Mamita Nagaraja, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>William Newnam, M.S.</td>
<td>Lecturer in Engineering Management</td>
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<tr>
<td>Tien Nguyen, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>Tuan Nguyen, Ph.D., P.E.</td>
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<td>Silas C. Nichols, Ph.D.</td>
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<tr>
<td>Ken O'Connell, Ph.D., P.E.</td>
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<tr>
<td>Neil Palumbo, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>Mark Pettinato, M.S.</td>
<td>Lecturer in Biomedical Engineering</td>
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<tr>
<td>Long Phan, Ph.D.</td>
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<tr>
<td>Donald Purcell, J.D.</td>
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<tr>
<td>Sridava Rao, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>Kenneth Romney</td>
<td>Lecturer in Mechanical Engineering</td>
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<tr>
<td>Kevin Russo, M.S.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>Alfonz Ruth, Ph.D.</td>
<td>Lecturer in Civil Engineering</td>
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<tr>
<td>Lawrence Schuette, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<td>Matthew D. Sermon, M.S.E.</td>
<td>Lecturer in Engineering Management</td>
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<tr>
<td>Hanney Shaban, Ph.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
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<tr>
<td>Jeffrey W. Shupp, M.D.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
</tr>
<tr>
<td>Randy Swisher, M.S.</td>
<td>Lecturer in Electrical Engineering and Computer Science</td>
</tr>
</tbody>
</table>
Computer Science

Richard C. Thompson, Jr., Ph.D., M.B.A., A.I.A.  Lecturer in Engineering Management

Diego Turo, Ph.D.  Lecturer in Mechanical Engineering

Khanh Vu, M.S.  Lecturer in Electrical Engineering and Computer Science

Adam Wolfe, Ph.D., P.E.  Adjunct Assistant Professor in Mechanical Engineering

Bing Xu, Ph.D.  Lecturer in Civil Engineering

Abdulkadir Yavuz, Ph.D.  Adjunct Assistant Professor in Mechanical Engineering

Tse-Fou Zien, Ph.D.  Adjunct Professor of Mechanical Engineering

Biomedical Engineering Advisory Council

Barbara Bregman, Ph.D.  Professor, Georgetown University, Department of Neuroscience, Washington, DC

Kevin Cleary, Ph.D.  Technical Director, Bioengineering Initiative, The Zayed Institute for Pediatric Surgical Innovation, Children’s National Health System, Washington, DC

Diane L. Damiano, Ph.D.  Chief, Functional & Applied Biomechanics Section, NIH, Bethesda, Md.

Joseph Hidler, Ph.D.  Chief Operating Officer, Aretech LLC, Ashburn, Va.

Corinna Lathan, Ph.D.  President, Anthrotronix Inc., Silver Spring, Md.

Joel B. Myklebust, Ph.D.  Deputy Director, Office of Science & Engineering Laboratories, FDA, Silver Spring, Md.

Civil Engineering Advisory Council

Dr. Timothy W. Kao, P.E.  Professor Emeritus of Civil Engineering and Former Chair, Department of Civil Engineering, The Catholic University of America

Mr. Lawrence E. Moore, II, P.E.  Director of Engineering, Clark Concrete Contractors, LLC, Bethesda, Md.

Dr. Dennis McCahill  Retired
Dr. Steven Smith  Principal Engineer and Group Manager, CTL Group, Washington Office, Columbia, Md.

Ms. Melissa Prelewicz  Associate Executive Director, American Association of Engineering Societies

Mr. Bill Whiting  Vice President, Whiting-Turner Contracting Co., Washington, DC

Mr. Scott Stewart  Principal, SK&A Structural Engineers, Washington, DC

Electrical Engineering and Computer Science Advisory Council

Ramesh Bharadwaj, Ph.D.  Senior Software Technology Researcher, Naval Research Laboratory, Washington, D.C.


Kevin Cleary, Ph.D.  Technical Director, Bioengineering Initiative, Sheikh Zayed Center for Pediatric Surgical Innovation, Children’s National Medical Center, Washington, D.C.

Tarek El-Ghazawi, Ph.D.  Professor, IEEE Fellow, Department of Electrical and Computer Engineering, The George Washington University, Washington, D.C.

Jon Huppenthal  President and CEO, SRC Computers, LLC, Colorado Springs, Co.

Cheng Guan Koay, Ph.D.  Senior Image Data Analyst, Walter Reed National Military Medical Center, Bethesda, Md.

Jose R. Latimer, Ph.D.  Business Area Executive for Homeland Protection, Applied Physics Laboratory, Johns Hopkins University, Baltimore, Md.

Dunling Li, Ph.D.  Senior Software Engineer, BTS Software Solutions, Columbia, Md.

Seong Mun, Ph.D.  Professor and Director, Institute of Advanced Study Virginia Tech, Alexandria, Va.


Kay Stepper, Ph.D.  Regional Business Unit Leader, Robert Bosch LLC, Plymouth, Mi.

Mechanical Engineering Advisory Council
Richard Dame, Ph.D.  
*President (Retired), Mega Engineering, Silver Spring, Md.*

David Didion, Ph.D.  
*Retired NIST Fellow, National Institute of Standards and Technology, Port Republic, Md.*

Stan Halperson  
*Executive Committee Member of ASME, Washington, D.C.*

Peter Herdic  
*Naval Research Laboratories, Washington, D.C.*

Don Marlowe  
*Standards Administrator (Retired), Science and Health Communication, U.S. Food and Drug Administration, Rockville, Md.*

Jude Nitsche  
*Nitsche and Associates LLC, Alexandria, Va.*

Steven Russell, Ph.D.  
*Project Manager, Ship Systems Engineering Office of Naval Research, Arlington, Va.*

Jaclyn A. Schade  

Owen G. Thorp, III, Ph.D.  
*Captain, USNR, Permanent Military Professor Weapons and Systems Engineering Department, US Naval Academy, Annapolis, Md.*

Stephen Wilson  
*Deputy Director, Ship Signature Department, NSWC - Carderock, West Bethesda, Md.*

**History**

The engineering program was established in 1896, soon after the founding of The Catholic University of America. The School of Engineering was formally established as a separate school in 1930 and was shortly thereafter renamed the School of Engineering and Architecture. In 1992 the School of Engineering and Architecture separated and became the School of Engineering and the School of Architecture and Planning. Prior to 1950, the primary focus of the school was on undergraduate professional programs, although graduate programs had always been offered. However, research activity and graduate professional offerings have increased at a steady rate since 1950. Today the School of Engineering offers bachelor's, master's and doctoral degrees in five academic programs as well as a master's degree in Engineering management and material Science and Engineering. The school prides itself on being a small Catholic engineering school that provides quality education with a personal touch.

Students can expect close interaction with faculty, small class sizes, a small student-to-teacher ratio and a faculty dedicated to teaching and research. All members of the full-time faculty hold doctoral degrees and are very active in funded research and scholarly publication.

The school's strong ties with local research institutions such as NASA,
NIH, NIST, NRL etc., foster research collaborations and enable our faculty to bring research experience into the classroom. Students can benefit from research assistantships from funded research projects.

Goals
As stated in its strategic plan updated in 2012, The Catholic University of America's School of Engineering provides a personalized learning and research environment in which faculty, staff and students achieve excellence in research, education and service. The program emphasizes research and scholarship of the highest caliber and provides personalized instruction at both the graduate and undergraduate levels.

Graduate programs in the school emphasize both theory and application of advanced engineering principles. The goal of the school is to produce professional engineers, scientists and researchers who can contribute significantly to society through their chosen profession and scientific and research activities.

Degree Programs
Through its four departments and two non-departmentalized engineering programs, the school offers graduate programs leading to the Master of Science (M.S.) degree and Doctor of Philosophy (Ph.D.) degree in the following concentration areas:

- Biomedical Engineering (M.S., Ph.D.)
- Civil Engineering (M.S., Ph.D.)
- Electrical Engineering (M.S., Ph.D.)
- Computer Science (M.S., Ph.D.)
- Mechanical Engineering (M.S., Ph.D.)
- Engineering Management (M.S. only)
- Materials Science and Engineering (M.S. only)

The curricula of the master's degree programs aimed at a particular discipline provide in-depth coverage of topics related to the discipline.

Special Regulations
Admission

Admission to the School of Engineering follows the general university regulations (see Admission to Graduate Study in these Announcements). We present here general admission regulations pertaining only to the graduate degree programs of the School of Engineering. Additional specific requirements for admission to particular programs, if any, are given in the departmental sections. Admission to all graduate degree programs is made by the dean of the School of Engineering upon the recommendation of the chair/director of the appropriate graduate program.

Doctoral Degree Programs
The minimum grade point average, GPA, required for admission to the doctoral degree programs is 3.4. In special circumstances, program chairs and faculty may petition for students to be admitted who do not meet the GPA guideline. There is no provisional admission for the doctoral programs.

http://announcements.cua.edu/2015-2016/graduate/engineering.cfm
Master Degree Programs

The minimum requirement for admission to the M.S. degree program is a baccalaureate degree from an accredited university. The minimum requirement for admission to the master's degree program of a particular engineering program is an undergraduate degree from an accredited engineering program. Additional requirements may apply based on undergraduate performance. The minimum GPA required for regular admission to master's degree programs is 3.0 for bachelors-level courses. Provisional admission may be granted to students with a bachelor's-level GPA less than 3.0. Provisional admission will be converted to regular admission after the student passes a set of approved graduate level courses with a minimum GPA of 3.0.

Degree Requirements

The degree requirements for graduate studies in the School of Engineering generally follow the university requirements (see General Requirements of Graduate Studies). We present here general degree requirements pertaining only to the graduate degree programs of the School of Engineering. Additional specific degree requirements for particular programs, if any, are provided in the departmental sections.

Grade Point Average for Graduation

A minimum cumulative GPA of 3.0 in coursework taken in the School of Engineering is required for graduation in all graduate programs.

Master's Degree

The university's general requirements for graduate study for the master's and licentiate degrees apply to all master's degree programs offered in the School of Engineering. There are, however, two exceptions: competency in a foreign language is not required and a comprehensive examination is not required. The minimum requirements for the master's degree are the successful completion of an approved program of study consisting of at least 30 semester credit hours. Individual programs may require more than 30 semester credit hours. Two options are available to complete the requirements.

Non-thesis Option

A student may complete the required semester credit hours through graduate coursework with a cumulative GPA of at least 3.0.

Thesis Option

A student may write a master's thesis whose topic is approved by the appropriate graduate program. If this option is selected, the student registers for a total of six semester credit hours of master's thesis guidance. Upon approval of the written thesis, six semester credit hours, which count toward the minimum 30, will be posted to the student's academic record. The remaining number of semester credit hours of graduate coursework must be completed with a minimum cumulative GPA of 3.0.

Core Masters-Level Course

All students pursuing a master's degree in the programs of biomedical, civil, electrical and mechanical engineering are required to pass with a
grade of C or better in two of the four courses: Graduate Level Applied Mathematics, Numerical Methods in Engineering, Engineering Economics and Engineering Systems Analysis. Each program may impose further restrictions regarding which courses their students must take.

Joint Master's Degree Programs
Some graduate programs in the School of Engineering participate in joint degree programs that allow students to earn two engineering master's degrees. The student must satisfy all requirements for both degrees but may be allowed to designate up to four approved graduate engineering courses to partially satisfy the requirements for both degrees. Typically, this would reduce the total number of graduate engineering courses required to earn both master's degrees from 20 courses to 16 courses. Contact the dean's office of the School of Engineering for more information.

Doctoral Degree
The university's general requirements for graduate study for the doctoral degree apply to all doctoral programs of the School of Engineering, with one exception: the foreign language competency exam is not required. The requirements for a doctoral degree (Ph.D.) of the school include:

1. A minimum of 53 semester hours of graduate work in a program of study prepared and approved in consultation with an adviser;
2. The successful passing of a comprehensive examination upon completion of the graduate coursework;
3. The approval of a dissertation proposal submitted and presented by the candidate; and
4. The approval and successful defense of the dissertation in an oral examination conducted as specified by university procedures.

Transfer of Credit
Up to six semester credit hours of graduate work earned at another accredited institution with a grade of B or higher may be applied toward course requirements for master's degrees upon recommendation of the appropriate graduate program and with the approval of the dean of the school. Up to 24 semester credit hours of graduate work earned at another accredited institution with a grade of B or higher may be applied toward course requirements for the doctoral degrees upon recommendation of the appropriate graduate program and with the approval of the dean of the school. As part of the 24 credits eligible for transfer, up to six credits of thesis coursework may be eligible for transfer. The thesis work and topic are subject to review by the department chairperson and the transfer must be approved by both the department chairperson and dean. For students who earned their master's degrees at CUA, up to 30 semester credit hours of coursework with a grade of B or above may be applied toward the course requirements for the doctoral degrees.

General Engineering

Courses Offered
A full listing of general engineering graduate courses offered by the School of Engineering is found below. Additional courses can be found in each of the following departmental sections. Consult Cardinal Station for additional information about courses and to determine course offerings by
## Course Catalog for Engineering, General and General Engineering

### ENGR

<table>
<thead>
<tr>
<th>Course No.</th>
<th>Course Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>501</td>
<td>Introduction to Mechatronics</td>
<td>Fundamental concepts for the synergistic combination of mechanical and electrical engineering, computer science, and information technology. This includes basic control systems as well as numerical methods used to design products with built-in intelligence. The fundamental aspects of mechatronics include: system modeling, simulation, sensors, actuation, real-time computer interfacing, and control.</td>
</tr>
<tr>
<td>503</td>
<td>Control Systems</td>
<td>This course will cover concepts related to classical system analysis and control theory, beginning with system modeling and analysis, and concluding with control design. Since most engineering disciplines take this class, we will cover electrical, mechanical, and biomedical systems.</td>
</tr>
<tr>
<td>504</td>
<td>Modern Control Systems</td>
<td>Analysis of control systems in state space, control system design via pole placement, design of state estimators, quadratic optimal control systems design. MATLAB used extensively for analysis and design problems.</td>
</tr>
<tr>
<td>506</td>
<td>Basic System Design of Space Payloads</td>
<td></td>
</tr>
<tr>
<td>507</td>
<td>Testing &amp; Data Analysis of Space Payloads</td>
<td></td>
</tr>
<tr>
<td>510</td>
<td>Strategic Standardization</td>
<td>A survey course, intended for graduate engineering and law students. Provides students with a broad understanding of the interdisciplinary issues associated with standardization, which is a difficult concept to define. From a broad perspective, the term covers every product, material, and service in commerce, anywhere in the world; it is one of the most critical components associated with the development of the global economy and all of its individual parts.</td>
</tr>
<tr>
<td>516</td>
<td>Computational Methods for Graduate</td>
<td>Discretization methods (finite differences, finite volumes, finite elements), stability and convergence;</td>
</tr>
</tbody>
</table>
Students: Students will study parabolic, hyperbolic, and elliptic PDEs: model equations and numerical solutions method. Numerous programming exercises will be assigned.

518 Experimental Techniques for Graduate Students: This course introduces students to the different aspects of experimental research in engineering. The course will cover fundamental issues such as: planning and design of an experimental campaign, laboratory safety, data acquisition and signal processing. State-of-the-art experimental techniques in different areas of engineering research will also be presented, with focus on modern, non-intrusive, laser-based measurement methods. The goal is provide students with the knowledge required to plan, design and conduct an experimental campaign, which they can eventually apply to their own research efforts.


522 Mechanical Properties of Materials: This course will teach students about the response of materials to loading. Mathematical foundations: linear transformations, vectors and tensors will be covered. Fundamentals of linear elasticity: stress, strain, Hook’s law, solution of static problems, antiplane and plane strain elasticity will be taught. Wave propagation through elastic media, criteria for plastic yielding will be explained. Fundamentals of dislocation theory and fracture, forces on dislocations, dislocation interactions, Griffith criterion, ductile fracture, etc. will be discussed.

526 Electrical Properties of Materials: This course covers the fundamental concepts that determine the electrical, optical, magnetic and mechanical properties of metals, semiconductors, ceramics and polymers. The roles of bonding, structure (crystalline, defect, energy band and microstructure) and composition in influencing and
controlling physical properties will be discussed. Also included will be case studies drawn from a variety of applications: semiconductor diodes and optical detectors, sensors, thin films, and others. Students will be introduced to the fundamentals of quantum mechanics and will be taught the concepts of tunneling, superconductivity, giant-magneto resistivity with the help of such concepts.

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<th>Course Code</th>
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<tr>
<td>529</td>
<td><strong>Computational Fluid Mechanics</strong> Course provides an in-depth introduction to the methods and analysis techniques used in computational solutions of fluid mechanics and heat transfer problems. Contemporary methods for incompressible viscous flows are studied and some basics of turbulent flow will also be presented. CFD methods for internal and external flows will be discussed. Finite differences and finite volume techniques are emphasized.</td>
</tr>
<tr>
<td>538</td>
<td><strong>Introduction to Environmental Engineering</strong> A first course for students interested in environmental engineering. The course discusses air pollution, indoor air quality, and global climate change; emission and control of air pollutants; water supply, quality, and pollution; treatment of drinking water and wastewater; and characterization and management of solid/hazardous waste. The problem-solving techniques based on mass balance, chemical kinetics, environmental microbiology, and energy conversion calculations are rigorously taught for quantitative analysis of environmental problems and their engineering solutions. Open-ended problems will be assigned and a field trip to a local waste treatment plant will be arranged.</td>
</tr>
<tr>
<td>540</td>
<td><strong>Reliability Engineering</strong></td>
</tr>
<tr>
<td>541</td>
<td><strong>Transport Phenomena in Biological Systems: Engineering Applications</strong></td>
</tr>
<tr>
<td>543</td>
<td><strong>Wireless Sensor Networks</strong> This course is a hands-on introduction to wireless sensor networks, an <strong><a href="http://announcements.cua.edu/2015-2016/graduate/engineering.cfm">http://announcements.cua.edu/2015-2016/graduate/engineering.cfm</a></strong></td>
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emerging technology that leverages large numbers of spatially-distributed, autonomous, small, low-cost, low-power consumption processors equipped with sensors, storage, and wireless communications. Sensor network applications include large-scale data collection, people- or object-tracking, monitoring and control of environmental, industrial, and other complex physical processes, civil structures, and perimeter security. The design of sensor networks requires a different design approach from traditional computing systems due to severe energy constraints, unreliable network connectivity, low bandwidth, and small physical size. Topics covered include a survey of sensor technologies, introduction to wireless communication technologies and protocols (802.15.4/ZigBee, WiFi, Bluetooth, 3G/4G, RFID), self-organizing networks and routing protocols, energy management principles, energy harvesting technologies, fault-tolerance and reliability principles, real-time operating system programming techniques, sensor data acquisition, signal conditioning, and signal processing. Emphasis will be on the design of wireless sensor network architectures and students will complete several hands-on design projects with programmable wireless sensors. Suitable for graduate students and advanced undergraduates from all engineering disciplines. Prerequisites: some programming experience and ENGR 212 Electric Networks

545  High-Resolution Radar Signal Processing

547  Intermediate Thermodynamics

552  Introduction to Imaging Technologies

Introduction to common imaging modalities such as ultrasound, x-rays, computer-aided tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Advanced computer methods of 2-D and 3-D image reconstruction as well as digital signal processing methods used in image recognition and enhancement of medical images will be covered.
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<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
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<tr>
<td>565</td>
<td>Nonlinear Dynamics and Chaos</td>
<td>Physical principles of imaging, images reconstruction techniques, and advanced digital processing techniques will be discussed.</td>
</tr>
<tr>
<td>570</td>
<td>Basics of High Performance Computing for Engineers</td>
<td>An introduction to nonlinear differential equations and chaos, with emphasis on applications from various fields of engineering and science. Topics include stability analysis and bifurcations, phase plane analysis, limit cycles, Poincare maps, chaos, iterated maps, fractals, and strange attractors.</td>
</tr>
<tr>
<td>575</td>
<td>Introduction to Systems Analysis</td>
<td>This course will explore the concepts and capabilities of high performance computing using modern GPUs (graphics processing unit). GPUs are not only used for traditional graphics applications, many engineering computations can be performed faster on the GPU than on a traditional CPU. The concept of general-purpose GPUs will also be introduced. Emphasis will be given on how to program GPUs to solve complex engineering problems efficiently. Topics Included: History of GPUs, Modern GPUs : A Hardware Perspective, CUDA Programming Model, CUDA Threads, CUDA Memories, GPU Performance, Advanced Techniques, Heterogeneous Systems, Multi-GPU systems. Pre-requisite: Basic understanding of C/C+ is desired but experience in any programming language (or MATLAB) will suffice.</td>
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<tr>
<td>583</td>
<td>Mech. Design &amp; Optimization of Electronic Syst.</td>
<td>Introduces a scientific approach to decision making, usually under conditions requiring the allocation of scarce resources. Provides several of the most useful and realistic mathematical models available for solving engineering management problems, including linear programming, transportation and assignment models, deterministic economic order quantity inventory models, and network models. Same as CMGT 575.</td>
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<tr>
<td>584</td>
<td>Introduction to Nanotechnology</td>
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<td>Course Code</td>
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<tr>
<td>585</td>
<td>Optimization Methods for Engineering Systems</td>
<td>This is a survey course of advanced numerical and computational optimization methods as applied to equations governing engineering systems. It will employ the MATLAB numerical package and review engineering modeling techniques: first principles, empirical data and numerical solution techniques for ordinary differential equations, partial differential equations. The course will then cover fundamental principles of optimization techniques as applied to modeled engineering systems. This is an applied course that will consist of assigned problems requiring computer-based solutions to optimize engineering systems.</td>
</tr>
<tr>
<td>621</td>
<td>Kalman Filtering</td>
<td>ENGR 621: Fundamental of Kalman Filtering This course covers basic problem of state estimation (prediction, Kalman filtering, smoothing), the steady-state Kalman filtering for linearized state variable model, and state estimation for the &quot;not-so-basic&quot; state estimation. The state estimation is also discussed for nonlinear model. The course is accompanied with computer projects. Prerequisites: Random Signal Theory, EE 561 or equivalent.</td>
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<tr>
<td>623</td>
<td>Numerical and Analytical Methods in Partial Differential Equations and Inverse Problems</td>
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<tr>
<td>626</td>
<td>Wave Propagation Analysis</td>
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<td>627</td>
<td>Multiphysics Finite Element Analysis</td>
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<tr>
<td>634</td>
<td>Digital Image Processing</td>
<td>ENGR 634: Digital Image Processing This course deals with the fundamentals of the major topics of digital image processing. The topics used in the course include the two-dimensional systems and mathematical preliminaries, image sampling and quantization, image transforms, stochastic models, image</td>
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</table>
enhancement, filtering, restoration, reconstruction, and compression. This course is accompanied with computer projects. Prerequisites: Random Signal Theory, EE 561 or equivalent.

652 Advanced Optical & Imaging Processing

696 Master's Thesis Guidance

696B Master's Thesis Continuation This course bills at the equivalent of one credit hour.

724 Multiphysics Finite Element Analysis

797 Special Topics

798 Special Topics II

993A Directed Research - Doctoral

996 Dissertation Guidance This course bills at the equivalent of one credit hour.

998A Doctoral Comprehensive Examination (w/Classes)

998B Doctoral Comprehensive Examination (w/o Classes) Enrollment in this course bills at the equivalent of one credit hour.

Department of Biomedical Engineering

Associate Professors Peter Lum, Chair; Binh Tran; Otto Wilson, Jr.

Assistant Professors Sang Wook Lee; Gregory Behrmann; Sahana Kukke, Christopher Raub

Lecturers Kenneth A. Byrd; Patrick Mehl; Mark Pettinato

Adjunct Assistant Professors Isaac Chang; Jeffrey Shupp
Research Ordinary
Professor

Harold Szu

The Department of Biomedical Engineering offers graduate programs leading to the degrees of Master of Science in Biomedical Engineering, and Doctor of Philosophy, Ph.D. The focus of graduate education is to provide biomedical engineers with the principles and tools of modern engineering, applied to solving problems in medicine or biology.

Courses are offered in the following areas of concentration:

- Biomaterials and Biotechnology
- Biomechanics & Rehabilitation Engineering
- Biomedical Instrumentation & Medical Imaging
- Home Care Technologies & Telemedicine
- Clinical Engineering

The Biomedical Engineering Program has strong interaction with the Department of Mechanical Engineering and the Department of Electrical Engineering and Computer Science in terms of course offerings and research activities. Graduate students may follow one of two tracks-thesis or coursework designed for two distinct groups of students. The first track offers both master's and doctoral programs and is directed at those students pursuing research activities that will culminate in a thesis or dissertation. The coursework requirements are intended to prepare the student for research.

The second track offers only a master's degree program intended for recent graduates, practicing engineers and/or medical professionals interested in specialized areas pertinent to career objectives. These professional degree programs enable the engineer or scientist to become familiar with new developments and advances in technologies. These programs allow flexibility in course selection, including those outside the department.

Qualified CUA undergraduate students are encouraged to pursue graduate studies via the accelerated BS-MS program.

Admission

In addition the school's admissions guidelines (under Special Regulations) for regular admission status to the masters and doctoral degree programs in biomedical engineering, students will be admitted based upon enrollment availability and their ability to meet the following recommended entrance requirements:

Students must have received a bachelor's degree in engineering, science or mathematics from an accredited institution and, in addition must satisfy:

All minimum university requirements

A cumulative undergraduate GPA of at least a 3.0 out of 4.0 (master's) or 3.4 out of 4.0 (doctoral)

Students not meeting the above minimum requirements may receive
provisional admission (master's only) as recommended by the graduate committee and/or department chair. Performance of provisional students will be reviewed after one semester of graduate study for transfer to regular admission status.

Students from nonengineering disciplines may be required to take prerequisite courses (e.g., statics, dynamics, electrical circuits, differential equations, fluid mechanics, etc.), as appropriate.

**Master's Degree**

Graduate students plan their program in consultation with an adviser and may elect to pursue a broad master's degree program without specific concentration or to major in one of the areas identified above. Maximum flexibility in scope of studies is afforded by utilization of courses offered in other departments of the university or other local universities through the Consortium of Universities of the Washington Metropolitan Area.

Requirements for the master's degree programs follow those established for the school. Please refer to Degree Requirements.

**Doctoral Degree**

Requirements for the doctoral degree program follow those established for the school. Please refer to Degree Requirements.

**Typical Courses Offered**

Please consult the registrar's Web site at [https://cardinalstation.cua.edu](https://cardinalstation.cua.edu) for descriptions of courses offered in the current semester.

**Courses Offered**

A full listing of graduate courses offered by the department is found below. Consult [Cardinal Station](https://cardinalstation.cua.edu) for additional information about courses and to determine course offerings by semester.

**Course Catalog for Biomedical Engineering**

- **BE 501 Biomaterials**
  
  Introduction to materials, their surface and mechanical properties. Biomaterials used in prosthetic devices, dentures, arterial grafts, orthopedic implants, and other medical applications. Biocompatibility, biomaterial/tissue interactions, and other factors involved in the design of implants.

- **BE 502 Advanced Biomechanics**
  
  This course provides students with advanced topics of traditional and contemporary biomechanics. Study will address mechanisms by which experimental and computational biomechanics investigate human and joint dynamics (kinetics and kinematics) and its association to...
ergonomics, orthopedic and sports biomechanics. Selected topics will include: biological materials, measurement techniques, advanced force system analysis, energy considerations, simulation using musculoskeletal models, optimization of inverse and forward dynamics, and applications of finite element techniques in biomechanics.

504 Biomechanics of Hard Tissue
The inter-relationships among nanoscale and macroscale structural features and functional properties will be covered from a mechanical properties of materials and fracture mechanics perspective. Topics that will be covered in this course include atomic bonding, mechanical properties characterization tools and techniques for various length scales, and case studies involving unique biological hard tissues and biomineralized structures such as bone, teeth, nacre, arthropod shell, and hard organic materials such as wood and nut shells.

506 Mechanics of Soft Tissue

508 Biomedical Applications of Origami

513 Biomedical Instrumentation I
Introduces the fundamental principles of biomedical instrumentation and their application to real-world devices. In a combination of laboratory and classroom exercises, students design, construct, and test biomedical instruments from the ground level up. Emphasis on use of computers and digital signal processing techniques in biomedical instruments. Prerequisites: Engr 321, 355 or equivalent.

514 Introduction to Biomedical Optics
This course introduces the fundamental principles of biomedical optics and their applications to real-world devices. In a combination of laboratory and classroom exercises, student will design optical systems for evaluation of optical properties of biological media as well as learn computational methods to simulate light transport into such media.
<table>
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<tbody>
<tr>
<td>515</td>
<td>Biomedical Signal Processing</td>
<td>Provides a comprehensive treatment of signal processing techniques used in biomedical applications. Discusses fundamentals of digital signals and systems; covers classical spectral estimation techniques, including discrete Fourier transform, periodogram and Blackman-Tukey method, and cepstrum method. Covers adaptive filters such as the adaptive noise cancelling method and adaptive zero tracking; discusses modern signal processing methods such as autoregressive (AR), autoregressive moving average (ARMA), the Prony method, and neural networks and wavelets. Introduces and explores numerous biomedical examples.</td>
</tr>
<tr>
<td>516</td>
<td>Bioelectromagnetics</td>
<td>Introduces use of linear systems analysis and control techniques in the field of biomedical engineering. Aims to provide students with the opportunity to use systems analysis techniques to enhance their understanding of biological systems and to use control systems engineering techniques to design control systems for medical devices. Extensively uses computer simulation to understand system causality, to perform sensitivity analysis, and to implement control system tools. Prerequisites: ENGR 222; BE 315.</td>
</tr>
<tr>
<td>518</td>
<td>Biomedical Sensors</td>
<td>This course introduces to various types of biomedical sensors including sensors measuring pressure, flow, motion, temperature, heat flow, evaporation, biopotential, biomagnetism, and chemical quantities. Underlying measurement principles and design will be emphasized. Various practical applications will be introduced.</td>
</tr>
<tr>
<td>521</td>
<td>Neural Control of Movement</td>
<td>This course examines the role of the nervous system in the production of voluntary movement in humans. Fundamental concepts and current issues will be incorporated into classroom discussions. Neural structures and pathways involved in motor control and feedback, including the cerebral cortex, basal ganglia, cerebellum, brainstem, spinal cord, muscle, sensory receptors, reflex</td>
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</table>
arcs, and other control circuits will be introduced. The interaction of the motor control system with the environment in functional movements (e.g., reaching, locomotion, and balance) will be examined. Typical development and learning of motor control as well as atypical motor control, in the case of motor disorders, will be discussed.

522 Human Locomotion
Studies the biomechanics and neural control of human locomotion. Topics include kinematics, kinetics and muscle activity patterns of normal walking, measurement systems used in human motion analysis, and neurophysiological control of locomotion. Aims to provide students with the background required for work in the fields of musculoskeletal biomechanics, motor control, and rehabilitation.

523 Biomechanical Assessment of Locomotion Disorders
This is an introductory course in the application of biomechanical techniques to the assessment of disorders of human movement. This course is intended to provide a foundation for engineers working in a gait laboratory and similar clinical environments, enabling them to interpret and discuss biomechanical test results with clinical personnel. Prerequisites: BIOL 518 and BE 522.

524 Prosthetics & Orthotics
This is an introductory course in the theory and practice of prosthetics (artificial limbs), and orthotics (braces and splints). It is designed for Biomedical Engineering graduates working in the field of human locomotion. Prerequisites: BIOL 518 and BE 522.

525 Biomedical Heat and Mass Transfer
Analysis of heat and mass transfer, with examples chosen from the biomedical engineering field. Topics include review of the first law of thermodynamics; one-dimensional steady state and transient heat conduction; steady state and transient mass diffusion through a stationary medium; transfer of momentum, heat, and mass transfer in engineering problems; radiation from black surfaces; radiation heat transfer between black surfaces; elements of
Biomedical Transfer Processes

The purpose of the course is to provide the fundamentals of transport processes in the human body and principles of design of artificial kidney and heart-lung devices. Among topics covered are mass balances and physiological variables of the human body; physical and rheological properties of blood; dynamics of the circulatory system; heat production and transfer; modeling the body as biological membranes, especially the human kidneys. Artificial kidney devices; human lungs and artificial heart-lung devices, blood pumping devices.

Cell and Tissue Engineering

The structure and function of cells, basic principles involved in cell culture, and safety rules in handling cells. Experimental methods used to investigate the cell deformability, adherence strength, and cell motility. Particular emphasis on laminar flow assays and micromanipulation methods. Discussion of recently published papers on tissue engineering.

Rehabilitation Engineering

This course explores the principles and practices of rehabilitation engineering and the role of engineers in the delivery of health care to disabled individuals. Discussions of approaches to diagnosis and treatment of disorders involving motor function will be included as will an analysis of the design of devices and systems to aid the disabled. Disabilities as a result of stroke, spinal cord disorders, cerebral palsy and Parkinson's disease will be discussed. Examples of technologies examined include devices aiding mobility, limb prosthetics, robotic aids, functional electrical stimulation, and interfaces to microcomputers.

Clinical Engineering

This course is an introductory course relating engineering, life sciences, and medicine. Specifically, the course discusses various aspects of engineering in the clinical setting and discusses topics such as biomedical instrumentation, clinical laboratory measurements, medical device
sterilization techniques, reliability engineering, regulatory practices, and other topics.

530 Human Computer Interfaces Principles underlying the design, evaluation, and implementation of interactive computing systems, as well as the major research topics associated with such systems. Technical breakdown of interfaces that are multimedia-based front ends to complex networks. Introduces graphical user interfaces, with related physiological and human factors issues. Design of interfaces using virtual reality, World Wide Web, and advanced interfacing devices such as voice and eye movement activation.

531 Neural Stimulation in Rehabilitation Aims to provide students with an understanding of electrical stimulation techniques for medical rehabilitation that are currently in use and/or development. Focus will be on rehabilitation engineering aspects of replacing nervous system function with electrical stimulation. Covers several medical applications of electrical stimulation, but emphasis is on restoration of motor function.

532 Sensory Motor Integration This course integrates engineering principles with physiological systems. A systems approach will be used to study regulation of posture, balance and movement control. The feedforward and feedback control methods used by the central nervous system to regulate motor performance are discussed. Current theories are presented on acquisition of skill and adaptation to perturbations. Use of robotics will be presented as the primary method to perform perturbation and motor learning experiments. Course instruction will be from both text and literature surveys. As a final project, each student will develop a relevant hypothesis, perform experiments using available lab facilities, analyze data and present results. Required courses: BE528 Rehabilitation Engineering BE502 Advanced Biomechanics

533 Human Factors Engineering and This course explores the principles and practices of human factors and
**Ergonomics**

The use of ergonomic principles to recognize, evaluate, and control workplace conditions that cause or contribute to musculoskeletal and nerve disorders will be covered, and the methods available to reduce musculoskeletal injuries in the workplace will be introduced. Topics include: structure and function of musculoskeletal system, human biomechanical models, task evaluation, consideration in workplace design and device design. This course will emphasize case studies and exercises that require biomechanical/ergonomic analysis and development of ergonomic improvements for industrial applications.

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**534 Experimental techniques in motor neuroscience**

The course introduces experimental methods used in the study of human motor control. Some techniques covered will include electroencephalography, electromyography, sensory stimulation, movement analysis (kinematics and kinetics), and transcranial magnetic stimulation. The course will include lectures, the study and discussion of published studies of motor control, the development of a research project investigating the sensorimotor system, and the collection and analysis of data using techniques introduced in class. Special focus will be placed on the use of experimental techniques to probe the motor system in the case of movement disorders.

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**535 Optimization of Human Performance**

Principles of optimum design, as related to human performance and the human-technology interface. Overview of musculoskeletal mechanics, with emphasis on human-device interaction for postural and propulsive tasks. Neurobehavioral measures of human performance, with emphasis on goal-directed neuromotor tracking tasks. Use of sensitivity analysis; optimal control theory applied to simple goal-directed movements. Techniques in numerical optimization, especially computer-aided optimization tools. Projects related to computer-aided design of assistive technology,
interactive interface devices, performance evaluation technology, or human-powered vehicle interface. Prerequisite: BE 516 or similar control systems course.

536 Mechanics of Dance and Sports

An expose' of rigid body mechanics and its application to the study of human movement. The laws of motion and the extent to which they account for human and animal motion. Human body idealized as a collection of rigid bodies, connected by joints in a treelike configuration. Insights into mechanical aspects of leaps, tums, and other complex movements observed in ballet, diving, and gymnastics. Discussion of muscle force distribution during workout exercises such as pullups, situps, and pushups. Inclusion of examples where motion is determined by simulation software such as Autolev3 and Working Model 3D.

540 Home Care Technologies Seminar

A once-a-week seminar featuring guest lecturers and readings/discussions on alternate weeks. Each student will be required to write a short "breadth" paper and presentation.

541 Home Care Technologies I: Foundations

Introduction to the broad foundations related to home health care and roles of technology. Begins with a review of the current state of home care technologies, followed by learning modules: clinical health assessment tools, geriatrics and the aging process, telecommunications and information technologies, human factors design, and health policy related to home care and disability rights.

542 Home Care Technologies II: Product Evaluation

Focuses on the multi-faceted evaluation process and provides students with tools for evaluating home health care technologies. Students are exposed to the underlying science and different aspects of product evaluation for key areas, with modules on biosensors and noninvasive technologies, objective human performance evaluation tools, and human usability and human error. Actual off-the-shelf products are evaluated, with the final project being team-based evaluations.
Evaluation techniques include disassembly, technical engineering evaluation, user testing/usability evaluation, safety and risk management, economic considerations. Prerequisite BE 541 or consent of the instructor.

543 Home Care Technologies III: Product Design and Manufacturing
This course focuses on the product design and manufacturing processes involved with bring-home health care products to market in a rapidly changing environment. Begins with modules focusing on the design of new products, on development issues for biosensors and image-based systems for physiological measurement, on important manufacturing processes and finally, on moving new products from the development stages to the market. Practice-oriented, project-driven course that gives students an opportunity to apply their recently gained knowledge to real-world problems. Projects will be driven by industrial support, student interest, and faculty discretion. Prerequisites: BE 497 or BE 542 or consent of instructor.

544 Innovations in Healthcare Service Delivery
Faced with the challenges of our ever-changing healthcare environment, there is a tremendous need to improve the quality, accessibility, and cost of care. To meet this demand clinicians, researchers, engineers, and patients are working together to develop new innovative approaches to the ways in which people receive and deliver care. This course will offer an overview of the history, technology, underlying theories, and supporting research behind healthcare delivery innovations in areas such as telemedicine, mHealth, eHealth, home monitoring, and personal wellness. The objective of the course is to increase students' understanding and perspectives on how innovative approaches and technologies can be used to address real-world challenges and issues that face our healthcare system.

546 Medical Device Design and Regulation
This course will consider the multiple steps in the development of a medical device and examine the regulatory
processes applicable at each stage in the design, testing, manufacture and marketing of a medical device. The instructor and guest speakers will provide expert insight into device design planning, human factors engineering, device testing, quality systems requirements, marketing applications, device standards and guidances, data integrity and interacting with FDA.

548 Medical Reliability Engineering
Reliability is defined as the probability that an item or device will perform a required function without failure under stated conditions for a stated period of time. Reliability engineering is performed throughout the entire life cycle of a system, including development, test, production and operation. In this introductory course, we will explore such topics as: problem solving strategies, Failure Mode and Effects Analysis (FMEA); Failure Mode Effects and Criticality Analysis (FMECA); Reliability simulation modeling; Validation and Verification Analysis; Thermal analysis; Fault Tree analysis; Taguchi Method; Ishikawa Method; Human reliability; Built-in test (BIT); Maintainability, Maintenance and Availability Analysis's. Reliability Software will also be reviewed. Real life engineering failures will be examined and discussed. This course is designed to be project-oriented with hands-on experience. Major topics are tailored to student interests (student centered learning).

550 Nano-Medicine
Physicist Richard Feynman in his 1959 presentation There's Plenty of Room at the Bottom, described the possibility of synthesis via direct manipulation of atoms. Inspired by Feynman's ideas, K. Eric Drexler used the term nanotechnology in his 1986 dissertation, Engines of Creation: The Coming Era of Nanotechnology, which proposed the idea of a nanoscale assembler which would be able to build a copy of itself and of other items with atomic control. For centuries scientists have been inspired to design the Philosopher's Stone, which produces the Elixir of
Life; useful for rejuvenation and possibly for achieving immortality. There is an exciting possibility that through the use of nanomedicine via nanotechnology we are on the fringes of the Elixir of Life. Nanomedicine is an interdisciplinary science, which combines knowledge from Biology, Chemistry, Engineering, Physics and Medicine to treat conditions and diseases of the human body on an atomic and molecular level. Nanomedicine has many applications, from drug delivery to individual cell repair, to regenerative tissues and atomic level therapy.

552 Biotechnology & Biomedicine

554 Bioinformatics

560 Computational Models of Complex Biomedical Systems

This course explores the cross-disciplinary field of complex systems, which are pervasive in biological and biomedical engineering topics at all scales of resolution, from molecules to society. It combines a review of the scientific literature with hands-on, basic-level programming and simulation of models (in NetLogo and MATLAB). We will touch upon some of the most important topics on both sides of the science/engineering aisle: "natural" biomedical complex systems (such as gene regulation, multicellular development, neural networks, or epidemiology) and "artificial" engineered complex systems (such as synthetic biology, tissue engineering, brain-machine interfaces, or scientific data mining).

581 Medical Imaging

Introduction to the physical principles, image reconstruction techniques, and advanced digital processing techniques used in modern medical imaging systems. Introduces common imaging modalities such as ultrasound, x-rays, computer-aided tomography (CAT), magnetic resonance imaging (MRI), and positron emission tomography (PET). Discussion of advanced computer methods for 2-D and 3-D image reconstruction as well as digital signal processing methods used in image recognition and enhancement of
582 Medical Image Processing

586 Ultrasound Imaging & Therapy

This course is intended to teach the basic concepts of ultrasound, used for both diagnostic imaging and therapy. Starting with the basic wave equations and the physical and acoustic parameters that determine wave propagation, interactions with biological tissues will then be covered, leading to the basic principles of ultrasound imaging and the devices involved for their application. The biological effects of ultrasound will then be discussed in relation to the mechanisms by which they occur. These will be presented in context to specific therapeutic ultrasound applications, such as healing, ablation, thrombolysis, and the mediation of drug and gene delivery. Finally, image guided ultrasound devices will be presented, including special topics such as remote elastography, real-time monitoring of therapy, and the use of ultrasound contrast agents for both imaging and drug delivery applications.

595 BMED Grad Internship Projects

Lecture. Biomedical internship projects. On-campus supervised or off-campus student training, in which students are co-supervised by a professional at the supporting institution and a biomedical engineering faculty member. Includes a proposal, a mid-term report, and a final project presentation and report.

597 Biomedical Research Methods

This course provides students with basic and advanced tools for carrying out research at a graduate level. Specifically, the course discusses the essential aspects of the research process: formulation of hypotheses and project aims; literature review; biostatistics and hypothesis testing; data analyses and interpretation; research proposal writing. By using specific information and experimental data from previous research studies, students will obtain a basic understanding of each of these
aspects, as well as the manner by
which they are integrated in to a viable
research program.

613  Advanced Topics in Medical Instrumentation

617  Soft Computing-BioMonitoring and Bio-Control

621  Advanced Topics in Neural Control

651  Computations in Genetic Engineering

671  Cardio-Pulmonary Biomechanics


This course provides an in depth analysis of current computational neuroscience techniques as applied to vestibular and oculomotor physiology. Topics will include basic neurophysiology, clinical studies, and vestibular rehabilitation. Students will develop computer simulations of neural control models and develop research proposals for future studies.

Discusses the theory and practice of molecular database searching and sequence alignment in genetic engineering. Covers databases and Internet access, sequence homology searching, and multiple alignment and sequence motif analysis. Practical classes include analysis of software setup and usage, sequence analysis over the Internet, and the interpretation of the results of database searches and sequence alignments.

This course is designed to be a first course covering the broad fields of cardiac and pulmonary biomechanics. The course begins with a review of anatomy and physiology of the human circulatory and respiratory systems before focusing on engineering approaches to the study of these respective areas of study. Topic areas will include: rheology of blood, mechanics of blood vessels and the airway, steady and unsteady flow models, cardiac and pulmonary bioinstrumentation, cardiac ejection mechanics, mechanics of ventilation,
and applications of imaging techniques to study the cardiac and pulmonary systems. Prerequisite ENGR 331; Co-requisite BIOL 518.

681 Advanced Topics in Optical Imaging

683 Principles and Biomedical Applications of Fluorescence

Fluorescence techniques have been widely used in biology, medicine and pharmaceutics. Especially, fluorescence techniques have become powerful tools for researches in tissue molecular imaging for disease diagnosis and monitoring, biomedical sensing, clinical chemistry, environmental monitoring, and DNA sequencing. In this course, the principles of fluorescence, typical fluorophores and instruments (both in time-domain and frequency-domain) will be introduced. The modern fluorescence techniques will be demonstrated in laboratory, including measuring fluorescence lifetime at nanosecond order and molecular distance at nanometer distance.

721 Advanced Neuro-Mechanical Modeling

Approaches for modeling muscle mechanics, skeletal structures, spinal neural networks. Neuromuscular models that include sensory feedback. Simulations of simple models of human eye, eye-head, and elbow systems for a variety of movement tasks. Use of inverse and forward dynamic simulations to investigate human movement strategies. Addressing redundancy in larger-scale elastostatic models of the head and shoulder systems. Use of sensitivity analysis and optimization as tools for understanding goal-directed movement strategies. Includes modeling project. Prerequisites: BE 516; 535 or 621.

728 Advanced Topics in Rehabilitation Engineering

In-depth engineering and service delivery analysis of four key topics in rehabilitation engineering, emphasizing the human-technology interface. Possible topic areas include therapeutic intervention strategies and the provision of assistive technology for a specific population of persons with disabilities (e.g., stroke); passive- and active-assist arm orthoses; rehabilitation robotics; virtual reality in rehabilitation; wheelchair and seating
Advanced Topics in Biomaterials

Provides an overview of the physical and chemical properties of the materials used in health care and biotechnology. Topics include crystal structures of metallic and ceramic alloys used in dental and orthopedic implants, surface properties such as chemical inertness, surface roughness and adhesivity, and factors that contribute to implant failure.

Mathematical Modeling in Biology

Provides an overview of mathematical models of biological systems. Sliding filament theory of muscle contraction, mathematical models of cell migration and nerve signal propagation, regulation of cell division, etc. Mathematical models of the immune system, circulatory system, and other biological systems involving population dynamics and heterogeneity. Prerequisites: ENGR 222; BE 516, 621 or equivalent.

Molecular Dynamics and Simulation

Provides hands-on experience in the use of computational graphics and simulation in molecular dynamics such as the deformation of binding sites during bimolecular interactions. Emphasis is on rational design principles for drugs used in medicine.

Special Topics in Biomedical Engineering

Department of Civil Engineering

Professor Lu Sun, Chair

Professors Emeriti John J. Baltrukonis; Timothy Kao; Dennis McCahill; John McCoy; Hsien-Ping Pao; Michael C. Soteriades

Associate Professor Gunnar Lucko; Arash Massoudieh

Assistant Chanseok Jeong; Masataka Okutsu; Max Liu
Professors

Lecturers  Mostafa Ardakani; Joseph Bishop; John Bonita; Joseph Findaro; Minli Ge; Wenjun Gu; James W. Hudson; Philip C. Jones; William A. Joyce; Charbel Khoury; Mesfin Lakew; S. Samuel Lin; John McTyre; Silas Nichols; Kenneth O'Connell; Long Phan; Alfonz Ruth; Steven Sullivan; Richard C. Thompson; Bing Xu

The goal of the educational programs in civil engineering is to produce graduates who are schooled in engineering fundamentals and capable of doing advanced engineering work. To this end, programs offered in the Department of Civil Engineering are professional in nature and lead to the Master of Science degree, and the Doctor of Philosophy, Ph.D. Major areas include fluid and solid mechanics, structures and structural mechanics, geotechnical engineering, environmental engineering and management, systems engineering, transportation engineering, and construction engineering and management. The available courses include laboratory studies, applied mathematics, engineering analysis, engineering design and a variety of introductory and advanced level courses in various areas of engineering and applied science and construction management. The department also participates in an interdisciplinary graduate program in engineering management leading to the Master of Science, M.S. degree.

Mission

Please refer to Admission under Special Regulations for the school.

Master’s Degree

Graduate students plan their program in consultation with an adviser and may elect to pursue a broad Master of Science (M.S.) degree program major in one of the areas identified above. The minimum requirements for the master's programs in civil engineering are the successful completion of 30 semester credit hours. Maximum flexibility scope of studies is afforded by utilization of courses offered in departments of the university or other area universities through the Consortium of Universities of the Washington Metropolitan Area.

Doctoral Degree Programs

Candidates for the Ph.D. degree in civil engineering plan their program in consultation with an adviser. The program of studies is tailored individually to meet the needs of the student and the academic and professional standards of the department. Maximum flexibility in scope studies is afforded by utilization of courses offered in other departments of the university or other area universities through the Consortium of Universities of the Washington Metropolitan Area.

Other requirements for the doctoral degree program follow those established for the school. Please refer to Degree Requirements.

For students interested in pursuing a Ph.D. degree, a Master's thesis is strongly recommended.

Courses Offered

A full listing of graduate courses offered by the department is found below.

http://announcements.cua.edu/2015-2016/graduate/engineering.cfm
Consult Cardinal Station for additional information about courses and to determine course offerings by semester.

**Course Catalog for Civil Engineering**

**CE**

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<tr>
<th>Course</th>
<th>Title</th>
<th>Description</th>
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<tbody>
<tr>
<td>501</td>
<td>Advanced Mechanics of Solids</td>
<td>Analysis of stress and strain, stress-strain relations for elastic materials, Mohr's circle in three dimensions, strain energy, distortional energy, theories of failure, mechanical behavior of materials, unsymmetrical bending, shear center, shear flow, and curved beams.</td>
</tr>
<tr>
<td>503</td>
<td>Introduction to Elasticity</td>
<td>Theory of stress, theory of strain, stress-strain relations, equations of elasticity, two-dimensional elasticity, selected problems.</td>
</tr>
<tr>
<td>504</td>
<td>Stress-Strain Behavior of Soils</td>
<td>Experimental techniques for determination of soil strength and stress-strain behavior, methods of analyzing and presenting test results, compositional and environmental factors affecting stress-strain, volume change, pore pressure, and strength behavior of sands, clays, and compacted soils, relation between drained and undrained behavior, effects of 3-D stress conditions. Prerequisites: CE 366, CE 367 or equivalent.</td>
</tr>
<tr>
<td>506</td>
<td>Advanced Structural Systems</td>
<td></td>
</tr>
<tr>
<td>511</td>
<td>Applied Plastic Design and Limit Analysis</td>
<td>Basic hypothesis, simple cases of plastic collapse, effect of end-fixity, rectangular portal frames, methods of plastic design, deflections, shear and axial load, applications to design.</td>
</tr>
<tr>
<td>514</td>
<td>Advanced Vibrations and Structural Dynamics</td>
<td>Free and forced vibrations of single degree of freedom systems under a variety of time dependent loads. Damping in structures. Unit impulse response</td>
</tr>
</tbody>
</table>

516 Prestressed Concrete

Basic concepts, materials, flexural analysis, partial prestressing, beam design, shear and torsion, losses of prestress force, composite beams, deflections, introduction to slabs and axially loaded members. Prerequisite: CE 403.

517 Infrastructure Evaluation and Service Life Extension

518 Experimental Techniques for Graduate Students

524 Matrix and Computer Methods in Structural Analysis

Analysis of indeterminate structures by the force and displacement methods. Development of the stiffness and flexibility matrices for structures. Extensive computer use. Prerequisite: CE 312.

525 Nondestructive Evaluation and Condition Assessment of Structures


526 Introduction to Finite Elements

529 Computational Fluid Mechanics

534 Disaster – Mitigating Design

538 Introduction to Environmental Engineering
<table>
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<tr>
<th>Course Code</th>
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<th>Description</th>
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</thead>
<tbody>
<tr>
<td>541</td>
<td>Environmental Engineering Chemistry</td>
<td>Expands topics from the field of chemistry and adapts them to an environmental engineering context. Environmental: application of fundamental chemistry principles to water and water treatment process, combustion processes, and the fate and transport of pollutants in ground and surface water and the atmosphere. Chemical equilibria, stoichiometry, kinetics, sorption, basic concepts from organic chemistry, aerobic, anaerobic biotic reactions, nitrogen cycle, phosphorous cycle, and carbon cycle.</td>
</tr>
<tr>
<td>542</td>
<td>Environmental Chemistry Laboratory</td>
<td>Hands-on experience with common environmental testing methods. Emphasis on water, wastewater, ground and surface water testing, used to evaluate surface and groundwater pollution, support environmental modeling, and evaluate water and waste treatment design and operations. Includes tests for Ph, acidity, alkalinity, hardness. Field trip to local wastewater or water treatment facility.</td>
</tr>
<tr>
<td>555</td>
<td>Environmental Law and Policy</td>
<td>Designed to impart a thorough understanding of the major environmental laws and implementing regulations. Covers methods used to implement federal environmental enforcement strategies, interrelations of major regulatory programs, current prospects for policy changes. Also: the Superfund and Community Right-to-Know Acts, Resource Conservation and Recovery Act, Occupational Safety and Health Act, and related permit and enforcement regulations and procedures.</td>
</tr>
</tbody>
</table>
| 556        | Sustainable Development Principles and Practice  | Introduction to the principles of sustainable development and sustainability. Current practices are presented using case histories from both national and international experience. Student will be exposed to policy and ethical aspects from both a technical and...
non-technical perspective. Outside speakers will present current issues related to the implementation of principles in practice nationally and internationally.

560 Case Studies in Geotechnical and Geo-environmental Engineering

Focuses on techniques and procedures used to obtain design data and complete actual geotechnical and geo-environmental designs of facilities located within the region. Presents as short design projects a series of case histories covering broad aspects of design, including shallow foundations, deep foundations, ground improvement, slope stability, geotechnical or environmental design in karst terrain, design of waste containment liner systems, design of petroleum contamination remediation systems, and completing environmental site assessments or audits. Students will submit brief reports on their analysis and proposed design. Prerequisites: CE 366, CE 468.

562 Seepage and Slope Stability

563 Applied Hydrology

Hydrologic cycle, precipitation, runoff, hydrologic data sources, frequency analysis, peak flow determination at ungaged sites, hydrographs, hydrologic routing, effects of urbanization, storm water management facility, GIS in hydrology, computer applications for hydrologic analysis.

564 Surface Water Quality

This course will focus on the physical, chemical, biological, and hydrological characteristics of surface water system in junction to water quality modeling and management issues. Reaction kinetics and material balances will be investigated for use in modeling contaminant movement in the environment. Specific attention will be given to typical water quality problem domains in stream and river systems, lake and reservoir systems. Mixing in lakes and rivers, stratification, sediment transport, dissolved oxygen and pathogens, eutrophication, and the fate and transport of toxics in these systems will be discussed. Prerequisites: ENGR 331; ENGR 538

565 Water Resources

The course covers the fundamentals of
<table>
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<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>570</td>
<td>Innovative Infrastructure Management</td>
<td>Introduction to innovative infrastructure management applications and the available tools and technologies. Covers physical infrastructure management using computer available technologies; physical infrastructure using computer assisted decision tools—highways, sewers, and underground systems; remote sensing technologies; energy management systems; assessment tools for environmental issues; and economic assessments—case studies. Case studies presented using Arc View and other Geographic Information System (GIS) tools.</td>
</tr>
<tr>
<td>571</td>
<td>Pavement Theory &amp; Design</td>
<td>Basic mechanics, theory and design principles for highway and airport pavement structures. Emphasis will be paced on mechanistic-empirical structural pavement design. Contents include traffic characterization, materials selection and testing procedures, environmental consideration, mechanics of rigid and flexible pavements, also pavement performance modeling and reliability. Prerequisite: MATH 122.</td>
</tr>
<tr>
<td>572</td>
<td>Intelligent Transportation Systems</td>
<td>Introduces some of the technologies, processes, and demonstrations that are a part of intelligent transportation system development. Some technologies reviewed include global positioning system applications, sensor and communication systems for public transit, congestion management systems, commercial vehicle inspection management systems, and emergency/accident response improvements. Review of Geographic Information System technology applications for transportation planning, land use planning, impact assessment, and public communication, including specific application case studies. Presents new pavement design criteria developed under the Strategic Highway Research Program, along with improved pavement management system.</td>
</tr>
</tbody>
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leveraging condition index technics. A review of the current status of the federal smart vehicle program and its implications on transportation in the future, including environmental benefits.

573 Traffic Engineering and Flow Theory

Various components of traffic systems, traffic flow characteristics, traffic data collection and traffic control of urban streets and freeways. Traffic operations of arterial streets and networks, optimal signal timing design, and capacity analysis using theoretical analysis, experimental techniques, and computer simulation. Traffic flow theory at micro-, meso- and macro-scopic levels will also be addressed.

574 Forensic Engineering-
Scientific Failure Investigation

575 Introduction to Systems Analysis

Introduces a scientific approach to decision making, usually under conditions requiring the allocation of scarce resources. Provides several of the most useful and realistic mathematical models available for solving engineering management problems, including linear programming, transportation and assignment models, deterministic economic order quantity inventory models, and network models. Same as CMGT 575.

576 Systems Design

Detailed system design by individual and student groups with projects selected from transportation, water resources, energy problems, policy planning, and the like. Prerequisite: Senior or graduate standing.

577 Econometrics

578 Transportation Systems Management and Operations

579 Harbors and Coastal Engineering

Design of seawalls, breakwaters, revetments, and jetties.

581 Practical Construction Law

A series of lectures on various topics in construction from the perspectives of an owner, the project architect and the contractor. Lectures follow a detailed topical outline, updated each year by the instructor. Analysis of "real world" practical cases in a lecture and open discussion format. Introduction to various construction law and litigation topics, contact clauses and topics. Develop a non-theoretical, practical course, using "real world" examples and case studies to supplement the mission of the Department of Civil Engineering, which mission is to provide a balanced education to students, strong in scientific, engineering, humanistic, and social bases, so that they may attain a leadership role in their profession and use their knowledge and skill for the enhancement of human welfare and the environment.

582 Value Engineering

The course introduces the concept of value engineering (VE) and demonstrates its application and technique. The VE process identifies opportunities to remove unnecessary costs while assuring quality, reliability, and performance. The course includes techniques used in VE such as: creativity, weighted evaluation, design-to-cost, life-cycle costing, FAST diagramming, and human relations.

583 Engineering Entrepreneurship, Sustainability, and Lean Methods

Engineering Entrepreneurship builds on the technical foundations established in the engineering program and focuses on the engineer as the catalyst for innovation and creating new ventures. It includes concepts and themes related to business planning, strategy, entrepreneurship, and critical thinking. It will explore the application of sustainability and lean methods to new and existing endeavors through case studies, business analysis, and student presentations. Classic and modern market analysis systems will be introduced along with business planning and finance, and exposure to the spectrum of corporate activities in the entrepreneurial and research and development environment.
585 Graduate Research Methods

586 Advanced Cementitious Material

587 Estimating and Bidding
In-depth analysis of the procedures for developing a detailed estimate of the general contractor and subcontractor for construction of building projects. Examines external sources that impact on the estimated costs. Determining the monitoring procedures for control of costs by subcontractors, suppliers, and vendors. Utilization of the estimate in the purchase budget, internal cost control, and determination of tax liabilities. Study of federal regulations impacting construction costs, safety requirements, insurance, and bonding costs. Use of the estimate in the interrelation between the architect/engineer and the contractor. Quantitative estimates included in class projects.

588 Construction Operational Management
Introduces mid-level administration and management techniques in the construction industry to maximize the understanding and participation of new managers in management procedures. Major managerial functions including planning, organizing, staffing, directing, and controlling. Specialized issues include leadership, motivation, communication, contract documents, construction schedules, change orders, claims, ethics, cost controls, interrelation within a corporate structure, working relationships with the legal, accounting, and other construction related professions.

589 Construction Scheduling Techniques
Examines the different types of schedules used in the construction process including bar chart, Critical Path Method (CPM), Project Evaluation and Review Technique (PERT). Develops an understanding of the forward and backward passes for both the Arrow Diagram Method (ADM) and the Precedence Diagram Method (PDM). Analysis cost and resource loaded schedules. Introduces advantages/disadvantages of different delay analysis techniques.
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<tr>
<td>590</td>
<td>Construction Operational Analysis</td>
<td>The course provides students with an introduction to different types of construction equipment and their application, equipment economics, productivity measures, probability theory and statistics, and performance improvement. The course primarily focuses on modeling and simulation of field operations using discrete event simulation, including use of specialized software. Activity cycle diagrams will be used extensively to describe processes and their elements, activities and resources. Verification and validation of simulation models will be discussed. Analytical skills gained from this course will allow students to better understand and design construction operations.</td>
</tr>
<tr>
<td>591</td>
<td>Engineering Hydrogeology and Groundwater Flow</td>
<td>Introduces the practical and theoretical aspects of groundwater occurrence and flow. The geology, hydrology, and geochemistry of groundwater. Practical analytical tools, including flow net theory and use; aquifer test data collection and interpretation; construction dewatering; water supply well design; environmental contaminant transport. Federal and state regulations that pertain to groundwater development and quality.</td>
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<tr>
<td>594</td>
<td>Construction Law, Operations and Project Delivery</td>
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<tr>
<td>596</td>
<td>Water and Wastewater Treatment Engineering</td>
<td>This course provides a survey of engineering approaches to treatment of water with an emphasis on fundamental principals and models. Theory and conceptual design of systems for treating municipal drinking water and wastewater are discussed. Physical, and chemical processes are presented, including sedimentation, filtration, disinfection, coagulation, and biological treatment.</td>
</tr>
<tr>
<td>598</td>
<td>Hazardous Waste Treatment</td>
<td>Reviews the various methods currently available or being developed for treating hazardous wastes. Incineration, bioremediation, chemical treatment, and separation processes. Examples of multiphase hazardous waste treatment applications illustrate uses and limitations of alternative methods for treating hazardous wastes.</td>
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<tr>
<td>599</td>
<td>Transportation</td>
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</table>
Safety
Engineering

603 Inelastic Stress Analysis
Visco-elastic Behavior. Non-linear Visco-elastic Behavior in 1-D and 3-D. 1-D Plasticity and Visco plasticity. 3-D Non-Hardening Plasticity Theory. 3-D Plasticity with Strain and Strain-Rate Hardening. Application of Linear Visco-elasticity, Non-Linear Visco-elasticity and Plasticity Principles in the Analysis of Simple Structural Elements.

604 Constitutive Modeling of Frictional Materials
Brief overview of 3-D soil behavior, simple, hyperbolic, and rigid-plastic constitutive models for soils, Cam Clay model, stress-dilatancy theory, models for elastic behavior, general framework of work-hardening plasticity theory, associated versus non-associated plastic flow, double hardening and single hardening models, incrementalization procedure, large stress reversals, and rotational kinematic hardening models. Prerequisite: CE 504 or permission of instructor.

611 Management Information Systems and GIS in Civil Engineering
Information technology in various aspects of civil engineering. Overview of design and implementation of management information systems including geographic information systems and global positioning systems. File structures and access methods, relational database, database modeling, design and user interface, E-R diagram, information storage and retrieval, query languages ANSI SQL, normalization process, concurrency control, transaction processing, distributed, WEB-based and multi-tiered database systems. Applications of GIS and GPS in transportation and environmental engineering will also be emphasized.

614 Earthquake Engineering and Seismic Design
615  Soil Dynamics and Geotechnical Earthquake Engineering

Introduction to seismology, seismic hazard analysis. Soil properties under dynamic conditions. Wave propagation. Ground response analysis, soil structure interaction, machine foundations. Local site effects, liquefaction. Special topics.

622  Variational Methods in Engineering

Variational approach to mechanics, calculus of variations. Hamilton's principle and Lagrange's equations of motion, Hamilton-Jacobi theory. Applications; theory of small oscillations, dynamical theory of thick plates, geometric theory of propagation. Prerequisite: Permission of instructor.

630  Pavement Theory and Design Principles

670  Risk and Reliability in CE Systems

Explores fundamental and advanced risk and reliability applied to civil engineering systems. Topics covered include hazard and failure consequences, definition and quantification of risk, risk aversion and risk acceptance, modeling uncertainty, probabilistic risk assessment, assessment of consequences and likelihood of failure, system reliability, maintainability. Projects will explore risk and reliability in structural systems, geotechnical, transportation, environmental systems, and construction processes.

675  Advanced Operations Research

Decision-making under uncertainty by application of quantitative techniques from operations research and management science (ORMS). Focus on the modeling and stochastic side of ORMS, with multidisciplinary applications in engineering. Multi-criteria decision making, stochastic network optimization and dynamic programming, system modeling and simulation, and stochastic processes. Students will gain necessary knowledge and skills to solve real world problems.

714  Passive and Active Control of Large Structural Systems

Introduction to energy management in structural systems. Basic concepts of seismic isolation, mechanical behavior of elastomeric and sliding isolation systems. Design concepts of isolation systems for buildings and bridges, code provisions. Theory and applications of active structural control and energy dissipation systems in large structures.
Current methods of structural control, practical considerations, implementation issues. Case studies.

**Theoretical Hydrodynamics**

Basic equations, boundary and initial conditions. Three-and two-dimensional potential flow theory. Free streamline theory. Infinitesimal waves in deep water, higher order theory; shallow water waves.

**Advanced Geotechnical and Structural Systems**

Designed to provide students with advanced knowledge related to theories and practices of geotechnical, foundation, and structural systems, emphasizing: analysis and design of the group pile foundation, drilled shaft foundation, and underground structures (culverts, pipelines, etc.); reinforced concrete design of earth structures (spread footings, mat foundations, cantilever walls, etc.); and geotechnical and foundation stabilization and improvement methods. Also designed for hands-on experience in utilizing state-of-the-art computer programs currently used in design practice for the analysis and design of geotechnical, foundation, and structural systems under static as well as dynamic loadings (foundation vibration, earthquake, etc.).

**CENT**

**Traffic Flow and Traffic Engineering**

Various components of traffic systems, traffic flow characteristics, traffic data collection and traffic control of urban streets and freeways. Traffic operations of arterial streets and networks, optimal signal timing design, and capacity analysis using theoretical analysis, experimental techniques, and computer simulation. Traffic flow theory at micro-, meso- and macro-sopic levels will also be addressed.

**Reinforced Concrete Design**

**Pavement Asset Management**

**Web Design and Programming**

**Computer Programming & Appl.**

**Project Managing project resources and a project**
Management budget are key components of a Project Management and Control System. In this course students learn and demonstrate an ability to manage key resources of a project. The course focuses on effective project/program management approaches and techniques which are typical to private sector engineering projects and major government system acquisitions. The dynamic aspects of project management are treated, including such topics as requirements assessment, program planning, configuration management, scheduling techniques, integrated logistics support, life cycle management, test and evaluation, standards of conduct and project team management.

552 Decision Analysis

553 Risk Management

554 Organization Theory & Behavior Develops the competencies and knowledge that one needs to be an effective professional, leader, or manager. Now, more than ever, the keys to an organization's effectiveness and competitiveness are its employees. Technology, financial capital, physical assets, and access to proprietary information are increasingly recognized as being little more than short-term sources of competitive advantage. Long-term competitive advantage comes from the rich array of individual and team-based competencies capable of being put into action by an organization's employees, managers, and leaders. Emphasizes seven competencies: managing self, managing communication, managing diversity, managing ethics, managing across cultures, managing teams, and managing change.

566 Geotechnical Engineering & Lab

568 Hydraulics & Envir. Engr. Lab

570 Pavement Asset Management

573 Traffic Flow Theory &
Engineering Management Program

Director: Jeffrey E. Giangiuli, MSE

Adjunct Associate Professors: Alan B. Carr; Jeffrey E. Fernandez; Larry D. Ferreiro; Jeffrey E. Giangiuli; Boyd A. Jones; Michael P. Kushner; William Newnam; Donald Purcell; Matthew D. Sermon; Richard C. Thompson, Jr., Ph.D.

Mission

The Engineering Management Program offers students the opportunity to earn a Certificate in Engineering Management or a Master of Science degree. The Engineering Management Program curriculum enhances management performance, develops managerial skills, and promotes the use of technology and engineering techniques to resolve the production, operations, regulatory, and financial issues facing today's professional in business, industry and government. It is designed to provide the student with knowledge of the theory and practice of management as it specifically pertains to engineering and technology-oriented organizations and activities. The program is oriented to the management of engineering processes within the broader context of a company or agency enterprise.

Master of Science (Engineering Management)

The Master of Science curriculum enhances management performance and develops managerial skills. It is designed to provide the student with knowledge of the theory and practice of management as it specifically pertains to engineering and technology-oriented organizations and activities. The program is oriented to the management of engineering processes within the broader context of a company or agency enterprise. Three tracks are offered to allow the student to focus on their career preference:

Engineering Management and Organization
This track was developed to provide a graduate-level foundation for the practice of managing engineering organizations. It is appropriate for those that will assume leadership positions in technically oriented organizations.

**Project and Systems Engineering Management**

This track was developed to provide a graduate level foundation for the practice of managing projects associated with development and life cycle management of a product. It is appropriate for project managers and system engineers in management roles or those that will be in those positions.

**Technology Management**

This track was developed to provide a graduate-level foundation for the practice of managing technology development, and implementation of sustainment activities. It is appropriate for those that will assume leadership positions in technology development or sustainment organizations.

Each track has seven core courses that give the foundation for engineering management and electives that allow students to focus their degree to their personal career plan. Nine semester hours (three courses) are used to tailor the degree program to the student's specific needs.

The Master of Science (Engineering Management) degree program requires completion of 30 semester credit hours. The School of Engineering offers a wide range of specialties relating to mechanical engineering, civil engineering, electrical engineering, computer science, and biomedical engineering. Elective courses up to six credits may be transferred from accredited educational institutions into the program. Our partnership with the Nuclear Power Directorate allows transfer of 12 credits for completion of the U.S. Navy Officer Nuclear Power School Program.

As listed in CUA Announcements - Graduate Studies, a maximum of 6 credit hours of studies may be transferred from another institution. No course with a grade of less than B (3.0) is transferrable. Grades earned in transferred courses are not included in computing the required GPA of 3.0. Up to 9 credit hours may be transferred from the Defense Acquisition University (DAU). Specific restrictions are addressed on the DAU Partnership page.

Other substitutes may be appropriate depending on the student's educational objectives.

The engineering management master's degree program results in an engineering/scientific degree, rather than a business degree; therefore the program candidate should have an engineering, physical science or mathematics degree with appropriate technical or engineering experience. (Depending on experience, candidates without mathematics-based degree may be accepted for the program. Prerequisites may be required.)

A minimum of 30 semester credit hours is required, but a thesis is not required. All M.S. candidates for graduation must have earned at least a 3.0 cumulative grade point average in courses leading to the degree. For more information go to http://engineering.cua.edu/engrmgmt.

**Certificate of Engineering Management**

http://announcements.cua.edu/2015-2016/graduate/engineering.cfm
Four Professional Certificates are available:

**Engineering Management Professional Certificate**

This program is designed to provide specialized graduate-level education and to further professional continuing education for those persons who will assume major administrative positions in industry or government organizations.

**Program Management Professional Certificate**

This program is designed to provide specialized graduate-level education and to further professional continuing education or certification (beyond or prior to Project Management Institute certification) for those who will act as program or product managers in industry and government.

**Systems Engineering Professional Certificate**

This program is designed to provide specialized graduate-level education and to further professional continuing education or certification (beyond or prior to International Council on Systems Engineering (INCOSE) certification) for those persons who will act as the technical/systems engineering lead in major programs, organizations or functions in industry or government.

**Management of Information Technology Professional Certificate**

This program is designed to provide specialized graduate-level education and to further professional continuing education or certification for those persons who will be responsible for management of information technology resources in industry and government.

These certificate programs provide an understanding of the core engineering management theory and tools that underpin technical management practices.

The Engineering Management Professional Certificate is awarded upon successful completion of 15 semester credit hours (five courses) of key program courses. To meet student needs one course could be substituted by an appropriate elective course from the CUA School of Engineering or an approved transferred course. For a course to be transferred, students must have earned a grade of B or better. The certificate is awarded after completion with a grade of C or better in all CUA courses counted toward the certificate requirements.

**Courses Offered**

A full listing of graduate courses offered by the department is found below. Consult Cardinal Station for additional information about courses and to determine course offerings by semester.

**Course Catalog for Engineering Management**

**CMGT**

505 Decision Analysis

Introduces decision analysis, a quantitative decision making technique for systematic evaluation of alternative courses of action
under conditions of uncertainty. Complex decision problems are divided into separable components for analysis. The decision maker's perceptions of options, future states of nature, probabilities and utilities for various options are determined explicitly. Topics include the fundamentals of probability theory, decision trees, expected monetary values, utility theory, sampling, and risk sharing.

508 Technology Management

This course describes the guiding principles and critical issues of knowledge and technology management, and provides the tools to design and implement a successful technology strategy as part of the overall strategy of the organization. It discusses topics essential for the management of public and private sector high technology organizations and issues relevant to their survival. Examples of these issues include: development and application of knowledge, integration of technology and business strategy, development of competencies and capabilities to stay in the forefront of technology in the global marketplace, response to change, specific human resource and organizational factors involved in management of knowledge and technology, forecasting and technology selection, and the influence of the internal and external environment.

510 Information Systems for Managers

Presents an in-depth orientation for current and future managers. Addresses the organizational foundations of systems, their strategic role, and the organizational and management changes driving electronic commerce and electronic business in the digital organization. Explores the technical foundation for understanding (IS) and how information technologies (IT) work together with the Internet to create a new infrastructure for the digital integration of the organization. Focuses on the role of IS in capturing and distributing organizational knowledge and in enhancing management decision making and the process of redesigning the organization using IS.

515 Software Project Management

Focuses on the competencies essential for successful software project management, in the areas of product, project, and people management skills. Product skills include assessing and tailoring processes, evaluating alternative processes and
becoming aware of process standards, defining the product, managing requirements and subcontractors, performing initial assessments, selecting methods and tools, tracking product quality, and understanding development activities. Project skills include building a work breakdown structure, documenting plans, estimating cost and effort, managing risks, monitoring development, scheduling, selecting metrics and project management tools, and tracking progress and process. People skills include appraising performance, handling intellectual property, effective meetings, interaction and communication, leadership, managing change, negotiating successfully, planning careers, presenting effectively, recruiting, selecting a team, and team building.

547 Managerial Engineering Economics
Examines decision-making based on comparisons of the economic worth of alternative courses of action with respect to their costs and/or incomes or benefits. The early part of the course focuses on the conventional mathematics of money and interest; i.e., the time value of money. It stresses the concepts of Present Worth, Equivalent Annual Worth, and Rate-of-Return calculations. This mathematics framework is then applied to consideration of specific decision problems of private sector capital investment choices, asset replacement, and analysis of public projects. Presents the overlapping aspects of accounting, finance, and investment analysis, including the related aspects of depreciation, inflation, risk management, and sensitivity analysis.

561 Engineering Ergonomics
A systematic design approach to the human-task-environmental system to increase productivity and decrease risk of injury and system failure. The course focuses on identifying ergonomic problems and developing design solutions to address those problems. Topics include anthropometry, work design, manual materials handling, cumulative trauma disorders, information processing, and designing for unique populations.

562 Engineering Risk Management
Provides engineering and construction managers with an understanding of predicting, identifying, assessing, managing and communicating risk for engineering projects. Entails a fundamental
review of probability and statistics practices so that they may be applied toward the study of risk, risk identification, risk assessment, risk evaluation, and risk management. Examines definitions, arguments and approaches from a variety of sources. To reinforce lectures, uses real world engineering examples from the defense, energy, and information technology industries where managers are forced to manage risk. Technical skills learned will encompass risk-based priority modeling, economic monetary value analysis, Bayesian revision, utility analysis, safety analysis, risk assessment, and risk management.

564 Strategic Standardization
A survey course, intended for graduate engineering and law students. Provides students with a broad understanding of the interdisciplinary issues associated with standardization, which is a difficult concept to define. From a broad perspective, the term covers every product, material, and service in commerce, anywhere in the world; it is one of the most critical components associated with the development of the global economy and all of its individual parts.

570 Project Management
Managing project resources and a project budget are key components of a Project Management and Control System. In this course students are required to use a simulation program to learn and demonstrate an ability to manage key resources of a project. The course focuses on effective project/program management approaches and techniques which are typical to private sector engineering projects and major government system acquisitions. The dynamic aspects of project management are treated, including such topics as requirements assessment, program planning, contract administration, manufacturing management, configuration management, scheduling techniques, integrated logistics support, life cycle management, test and evaluation, standards of conduct and project team management.

572 Organizational Theory and Behavior
Develops the competencies and knowledge that one needs to be an effective professional, leader, or manager. Now, more than ever, the keys to an organization's effectiveness and
competitiveness are its employees. Technology, financial capital, physical assets, and access to proprietary information are increasingly recognized as being little more than short-term sources of competitive advantage. Long-term competitive advantage comes from the rich array of individual and team-based competencies capable of being put into action by an organization's employees, managers, and leaders. Emphasizes seven competencies: managing self, managing communication, managing diversity, managing ethics, managing across cultures, managing teams, and managing change.

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<tr>
<td>573</td>
<td>Planning and Control of Organizations</td>
<td>Reviews and analyzes the theory and application of the basic components of the managerial control process. Includes introduction to such managerial concepts as cost and profit analysis, planning and scheduling of activities, cost concepts, budget decision techniques, budget control activities, capital and operating budgeting, and the cost of capital. Emphasizes coordination, control, and interaction between decision theory and the instruments of policy implementation in formal organizations.</td>
</tr>
<tr>
<td>574</td>
<td>Strategic Management</td>
<td>Integrates all of the learning from the Engineering Management program to serve as a capstone business course, and focuses it particularly on the perspectives and problems of the firm's Chief Executive Officer and other senior strategic managers. Focuses on strategic competitiveness, business-level and corporate-level strategy formulation, strategy implementation, and competitive rivalry and competitive dynamics. Includes case studies to illustrate the concepts and their applications.</td>
</tr>
<tr>
<td>575</td>
<td>Introduction to Systems Analysis</td>
<td>Introduces a scientific approach to decision making, usually under conditions requiring the allocation of scarce resources. Provides several of the most useful and realistic mathematical models available for solving engineering management problems including linear programming, transportation and assignment models, deterministic economic order quantity inventory models, and network models. Same as CE 575.</td>
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<tr>
<td>580</td>
<td>Introduction to Systems Analysis</td>
<td>This course will develop the student's understanding of the basics of systems</td>
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</table>
Engineering Management engineering management through the life cycle of a system, the evolution of systems engineering and how it relates to program management, and to recognize its application in real situations and develop technical management solutions based on systems engineering principles. The course will consist of lecture, discussion, practical exercises, case studies, independent research and student presentations. Class discussion will require each student to participate in the presentation of the course material by sharing their understanding and interpretation.

594 Independent Project Directed Studies

Class Locations
Engineering Management classes are held at the Crystal City Crowne Plaza Hotel or on the CUA campus in northeast DC. The degrees offered at off campus sites have been approved by the governing board of CUA and are equivalent to those given on campus. The State Council of Higher Education for Virginia (SCHEV) has certified the CUA School of Engineering to operate in Virginia.

Department of Electrical Engineering and Computer Science

Professors Mohammed Arozullah; Nader Namazi; Charles C. Nguyen; Philip A. Regalia

Professors Emeriti Andrew G. Favret; George E. McDuffie; Robert Meister

Associate Professors Lin-Ching Chang; Hang Liu; Scott Mathews; Ozlem Kilic, Chair

Assistant Professors Georges Nehmetallah; Erion Plaku; Patricio Simari

Clinical Assistant Professors Ujjal Bhowmik

Lecturers Charles Campbell Jr.; Vincent Cassella; Aysegul Cuhadar; Vinh Dang; Said Ganjalizadeh; Robert Kamocsai; Vadim Knyazev; Francis Linehan; Quang Nguyen; Sridava Rao; Kevin Russo; Lawrence Schuette; Hanney Shaban; Randy Swisher; David Tremper

The faculty is actively engaged in several research areas including computer graphic display of medical images, Web-based communication, ATM-based high-speed networks, computer and satellite communications, interaction of electromagnetic radiation with biological systems, image microoptical devices, image motion detection and estimation, communication intelligence, information visualization, biomedical imaging, computational intelligence and image understanding. A majority of the research projects is funded by industries and government agencies such as NASA, the Navy, the Army, NIH, and NSF.

Admission

Students pursuing degree programs should apply for regular admission. The minimum requirement for regular admission to the M.S. program is a bachelor's degree in engineering, science or mathematics from an accredited institution. Students lacking certain requirements for regular admission to the M.S. program can apply for a provisional admission. Performance of provisional students will be reviewed after two semesters of graduate study for possible transfer to regular admission. The minimum requirements for regular admission to the M.S. program in computer science is a bachelor's degree with undergraduate background in computer science that includes the equivalent of the following topics: data structures, computer organization and assembly language, programming languages, theoretical computer science, and discrete structures. A student will be provisionally admitted to the M.S. program if he or she has one or more deficiencies. The deficiency courses must be successfully completed before the provisional status is converted to regular status. Admission to the doctoral degree programs is based upon academic performance at the bachelor and master's levels. For other admission requirements, please refer to Admission under Special Regulations.

M.S. Program

Two options are available in the M.S. program. The nonthesis option requires 30 semester credit hours of approved coursework. The thesis option requires a minimum of 24 semester credit hours of approved coursework plus a thesis comprising six semester credit hours of master's thesis guidance. The approved coursework must include at least 18 semester credit hours of approved electrical engineering courses. The remaining courses must be in engineering and science disciplines and approved by the graduate coordinator of the department.

The M.S. degree program in computer science has two options, the thesis option and the nonthesis option. For both options, each student must submit a program of study to the department for approval upon entering the program. The program of study must contain a minimum of 30 semester credit hours of approved graduate-level courses comprising at least 18 semester credit hours of core courses and 12 semester credit hours of elective courses.
The core courses must be selected from courses in four areas of concentration: computer science foundations, computer systems, software systems, and computing methodologies, such that at least three semester credit hours are chosen from each of the above areas of concentration.

**Doctoral Degree Program**

The program of studies is individually tailored to meet the needs of the student and to fit with the department research areas and facilities. Students must pass a comprehensive examination in three major areas after completing all required coursework.

The Ph.D. degree requires a minimum of 54 semester hours of formal graduate coursework beyond the bachelor's degree. The major includes at least nine semester credit hours at the 600-700 levels in three areas. Additional areas that must meet minimum requirements are chosen in consultation with the adviser. For additional degree requirements, see Degree Requirements.

**Courses Offered**

A full listing of graduate courses offered by the department is found below. Consult [Cardinal Station](http://announcements.cua.edu) for additional information about courses and to determine course offerings by semester.

**Course Catalog for Electrical Engineering**

**CSC**

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<th>502 Engineering and Computer Science Management</th>
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This course is intended to provide students with an opportunity to merge the fundamentals of executive business analysis and decision making with their knowledge of computer science. The course will cover a brief historical view of the evolution of I/T innovation from the personal computer through today’s cloud computing with a strong focus on the executive decisions that helped drive this innovation. Students will complete deep dives into past successes and failures within the I/T industry and will come to understand the importance of business strategy, project management and ROI analysis as it relates directly to I/T investments. They will look at current industry trends and will have an opportunity to drive research that can change/alter the future landscape of several technology areas. Prerequisites: Juniors, Seniors and Graduate students who have a firm understanding of technology, computer architecture, programming fundamentals, operating systems, relational databases and networking.
504 Compiler Construction
An in-depth study of the programming languages compilation process. The course encompasses various topics about programming languages including language structures, grammars, and parsing techniques. The course also studies the building blocks of a modern compiler, and the various stages of the compilation process from the language parsing to code generation and optimization. Prerequisite: CSC 306 or permission

507 Unix System Programming
Principles of object-oriented software development. Use of observer, strategy, composite, factory, and state patterns to build a framework for network protocol software. Discussion and implementation of several Client/Server communications methods: TCP sockets, Messages, and shared memory. Other topics include remote procedure calls (RPC) and multithreaded programming. Prerequisite: CSC 306

508 X Window Programming
An overview of the X Window System, explaining the network-transparent aspect of this windowing system, followed by the very basics needed to create an X Window Application: establishing a connection to the X server, creating windows, drawing, color, selecting fonts, and manipulating events. Explores the C language xlib interface to graphics, window manager, and events through several programming assignments. The advantage of using a toolkit, using the C language interface to several public domain toolkits with emphasis on Tcl/Tk or the Hush C++ API to Tcl/Tk, and a C++ GUI framework.

509 Web Design & Programming
This course provides the conceptual foundation for the logical structures necessary to develop web pages and websites. Topics include logic structures, control structures, variables, design contemplations, I/O operations, and other web programming considerations. Student will learn the basics of creating web pages and combining these into a functional website as a group assignment. A brief introduction to several web-based programming languages and tools, such as XHTML, CSS, JavaScript, Java Applets, XML, XSLT, DOM, Perl, CGI, Apache, Java Servlets, JSP, PHP, ASP.NET, MYSQL,
JDBC, and HTTP is provided. Student will also learn the necessary skills to build, maintain, and host web pages and websites. Other topics include Web server platform and architecture, client-side and server-side programming concepts, static and dynamic web pages, database and data warehousing, data access techniques, and security issues in web design. This course does not require any prior web design or programming knowledge.

511 Computational Complexity
Examination of computer algorithms from the point of view of computational complexity. Topics include polynomial algorithms, FFT and GCD; algorithms for vector and parallel machines, pipelines, and systolic arrays; NP completeness. Prerequisite: CSC 210.

513 Fundamentals of Computer Graphics
This course covers the fundamental concepts and algorithms for computer graphics, including representations for images, curves, surfaces, transformations, and projections, interpolation, clipping, visibility, ray tracing, shading, photon mapping, texture mapping, animation, and special effects. Students should have background in linear algebra and strong programming skills.

514 Introduction to Hardware Accelerated Computing
The past few years the High Performance Computing (HPC) community has witnessed a surge in the use of hardware acceleration, such as graphics processor units (GPU), field programmable gate arrays (FPGA), digital signal processors (DSP), cell processors, etc. This coincides at a time when conventional microprocessors are unable to keep up with Moore's Law, and become costly due to their increasing power requirements. This course is an introduction to hardware accelerated computational techniques and provides an introduction to FPGA and GPU-programming. Students are expected to have a strong understanding of programming in C, C++ or equivalent programming language. This course will enable students develop a solid understanding of the interaction between software and hardware, and gain hand-on experience in high performance computing. Prerequisite: CSC 113, EE 326.
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<tr>
<td>515</td>
<td>Mobile Programming</td>
<td>Description: This course will teach fundamental programming principles with a focus on the mobile environment such as iOS and Android. The course will emphasize practical application of numerous academic concepts. Students should already have a familiarity with C and Java, an understanding of basic object-oriented programming, studied basic algorithms and data structures. Hands-on programming will be a big part of this course. Prerequisite: &quot;Permission of Instructor&quot;</td>
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<td>519</td>
<td>Digital System Design</td>
<td>Comprises both lectures and labs, introduces the most important aspects of real-world digital design. Emphasis on practical, hands-on experience in building a system of medium complexity. Design synthesis highlights modern ASIC devices. Staff.</td>
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<td>520</td>
<td>Topics in Computer Science</td>
<td>An individual topic from the area of computer science, investigated in detail with students examining accepted and proposed ideas relative to the topic. Sample topics include, but are not limited to, software testing, issues in large-scale software development, current issues in artificial intelligence, issues in safety-critical software, issues in business-oriented software, database design and advanced analysis of algorithms. May be repeated for credit with different topics. Prerequisite: Permission of instructor.</td>
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<td>521</td>
<td>Programmable Logic Devices and HDL Design</td>
<td>This course covers the concepts, structure and programming characteristics of programmable logic devices (PLDs) such as Field-Programmable Gate Arrays (FPGAs). Hardware Description Languages (HDLs) are used to create designs that are tested on FPGA devices. In this course, students will learn how to design and implement general-purpose hardware components, such as computer arithmetic units and microprocessor data/control paths. Students will also learn how to design specialized hardware from different fields such as digital signal and image processing using techniques that are based on high-level environments, such as Matlab and Simulink, targeting FPGA devices. Prerequisites EE / CSC 326 or instructor's permission.</td>
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<td>522</td>
<td>Operating Systems</td>
<td>A study of the major concept areas of operating systems. Topics include operating systems structure, process and thread scheduling, process synchronization, deadlock management, memory management, file-systems, protection, I/O traffic controls and evaluation models. Prerequisite: 306 or Permission of Instructor.</td>
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<td>524</td>
<td>Secure Programming</td>
<td>Introduction to Software Security, risk assessment, buffer overflows, design for security, security testing and auditing, security issues of open source and closed source software, guiding principles of software security, selection of appropriate technologies, access control, race conditions, trust management, input validation, and database security. Prereq: CSC123</td>
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<td>525</td>
<td>Embedded Systems Programming</td>
<td>CSC 525 Embedded Systems Programming gives an overview of embedded systems, including the concepts, design considerations and software development for an embedded computer system. The course will strive to cover embedded system design/development concepts, real world considerations in embedded system design and use, and platform-based Embedded System Design. At the end of this course, students will be able to develop the hardware and software required for designing an embedded system SoC on Xilinx FPGAs. Many of the concepts learnt during the lectures will be demonstrated in the lab exercises and final project. Use of platform based design for embedded systems is the current trend in embedded systems design, which will be helpful in industry as well as academic research. Prerequisites: CSC390 or CSC391 or permission</td>
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<td>526</td>
<td>Computer and Network Security</td>
<td>This course will introduce the application of cryptographic concepts in the practical implementation of network security practices and techniques. The issues here are: What are the risks and vulnerabilities of computer, Internet, and multimedia data? What are the countermeasures to fight these back? How does cryptographic technique enforce protection? What is digital signature? What is steganography and</td>
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how is it used for authentication and counterfeit detection? What the different network security technologies are as applied to electronic mail, e-commerce, web transaction, and IP networks?

Prerequisite: CSC 323

527 Fundamentals of Neural Networks

530 Introduction to Data Analysis

This course introduces the computational methods for data analysis. Topics include signal processing, frequency filtering, feature extraction, principal component analysis, linear discriminant analysis, statistical tests, and current big data analysis approaches. Students will learn how to apply the data analysis techniques to data scientific research, starting from raw data filtering, going through feature selection and extraction, and finally concluding with data model construction and statistical inference.

This course requires the background in probability, statistics, and linear algebra.

531 Data Communications Networks

This course deals with basic principles of networking. More specifically it covers the following topics: Network Architectures and Protocols. OSI model and TCP/IP protocol suite. Transmission media. Protocols at the physical, data link, network and transport layers. Multiplexing, error and congestion control. Circuit and packet switching. Local and metropolitan area networks. ATM and frame relay. Network security and distributed applications. Prerequisite: EE 413 or equivalent.

532 System Simulation

Modeling and simulation of continuous and discrete systems, simulation languages, digital simulation techniques, Monte Carlo method, queuing models, design of simulation experiments and analysis of results, applications. Prerequisite: Permission of instructor.

533 Optimization

A survey of mathematical programming, combinatorial optimization, and weak optimization. Studies practicalities, convergence and efficiency of different optimization methods. Introduces contemporary methods such as Simulated Annealing and Genetic Algorithms. Considers applications in computer science, engineering, and business. Suitable for computer science,
mathematics, engineering, and business majors. Prerequisites: CSC 124, MATH 122.

534 Communication and Computer Network Simulation

This course deals with simulation modeling, design and performance evaluation of communication and computer networks. It includes simulation of network elements and overall networks. Simulated network elements include point-to-point, multicast and broadcast links, wireless, satellite and radio links, queuing systems, circuit and packet switches and routers. Simulated overall networks include Local Area Networks (LAN), Internet, packet switched networks, Asynchronous Transfer Mode (ATM) and wireless networks. Development of simulation models for audio and video traffic sources and flow and congestion control algorithms are presented. Methods of presentation, analysis, interpretation and use of simulation results for design purposes are discussed. The course uses OPNET simulation software packages to provide hands-on experience in simulation. Prerequisite: CSC 531 or permission of instructor.

541 Database Systems

Principles of database system including database design, implementation, and management. Topics may include review of database language, data modeling, database security, advanced database concept, database connectivity with the internet and modern database management. Prerequisite: Permission of instructor.

542 Artificial Intelligence

Topics may include state space search, heuristic search, knowledge representation techniques, expert systems, automated reasoning, definitions of intelligence, computer problem solving, game playing, pattern recognition, theorem proving, semantic information, processing, evolutionary systems, and heuristic programming. Prerequisite: Instructor's permission.

551 Pattern Recognition

This course provides a broad introduction to pattern recognition. Topics include: Bayesian decision theory, density estimation, linear classifiers, nearest neighbor rules, decision trees, artificial neural networks, dimensionality
reduction, feature extraction and feature selection, clustering. The course is directed towards advanced undergraduate and beginning graduate students. Prerequisite: background in probability, statistics, and linear algebra or permission of instructor.

564 Advanced Software Engineering

Examines the software development cycle with respect to the system life cycle. Topics include software size and cost estimation, relative effort and time distribution across software development phases, products of the major activities of the software development process, the various management techniques currently in use, and process models of software development. Review of the desired attributes of the software product (portability, reusability, maintainability, etc.) from the perspectives of benefits of the attribute and techniques for achieving the attribute. Prerequisites: CSC 370, CSC 280.

565 Information Security

Principles of Infosec, security planning, risk management, security technology, physical security, implementing information security, legal, ethical, and professional issues in infosec, security and personnel, information security maintenance etc. Prerequisite: Senior standing

569 Computer Security and Privacy

Importance of computer security and its effect on individual privacy. Topics include computers and their impact on privacy, data banks, physical security, administrative security, and computer systems and network security. Not open to students who completed this course under earlier numbering (597). Prerequisite: Junior standing.

575 Human-Computer Interface

576 Introduction to Robotics

Covers basic concepts in robotics such as robot arm kinematics, robot arm dynamics, trajectory planning, and control. Transformation between joint space and Cartesian space. Coordinate frames and homogeneous coordinate transformation. Solution of inverse kinematic problem and robot workspace. Differential motion and manipulator Jacobian matrix. Introduction to the control problem of robot manipulators.
Prerequisite: Senior Engineering or Graduate Students

581 Cryptography and Steganography

Introductory concepts of cryptography and steganography; Classical and modern cryptographic algorithms - the underlying mathematics and analysis; Number theory; Cryptographic protocols in computer and data security applications; Fundamentals of information hiding - Techniques and applications.
Prerequisite: CSC565

582 Computer Graphics and Game Programming

The course will study the makeup of a 3D game engine, surveying the computational aspects required in the production of its individual components. The engine of choice will be the jMonkeyEngine 3D game engine, an open-source, cross-platform, Java-based engine. The students will program a novel game of their own design using the engine while learning about the computational techniques involved in the programming of game engine components in general. Prerequisites: programming ability in C++ or C#, and understanding of basic linear algebra concepts such as vector and matrix.

583 Geometry Processing in Computer Graphics and Vision

611 Logic for Computing Scientists

Topics may include propositional logic, syntax and semantics, proof theory vs. model theory, soundness, consistency and completeness, first order logic, logical theories, automated theorem proving, ground resolution, pattern matching unification and resolution, Dijkstra's logic, proof obligation, and program proving. Prerequisite: CSC 312

612 Analysis of Algorithms

An advanced study in computer algorithms that delves deeply into a selected problem: linear programming (simplex, revised simplex, complementary slackness, Khachian's ellipsoid, etc) and duality; in addition, the course also covers suffix trees, minimum spanning trees, Bellman-Ford and Dijkstra's shortest paths algorithms, and computational geometry. Prerequisites: CSC 311 or Permission of Instructor.
613 Combinatorial Algorithms and Intractability
Topics may include combinatorial algorithms, nondeterministic algorithms, classes P and NP, NP-hard and NP-complete problems, and intractability, and design techniques for fast combinatorial algorithms. Prerequisite: CSC 311

620 Digital Forensics Technology
The primary objective of this course is to provide a broad understanding of the technologies and tools used to perform digital forensics for the detection and prevention of computer crimes. Various techniques of forensic evidence acquisition, detection, and classification will be introduced. Core principles of a few forensically-oriented data processing technologies such as compression, watermarking, steganography, steganalysis, cryptanalysis, and multiresolutional analysis will be studied. The course will also include different modalities of data such as binary, text, audio, image, and video, as applicable to different modalities of forensics such as hardware, software, computer, network, and memory.

621 Computer Networks
Topics may include physical layer basics; network protocol algorithms; error handling; flow control; multihop routing; network reliability, timing, and security; data compression; cryptography fundamentals; advanced network protocols and infrastructure; applications of high-performance networks to distributed systems; and high-performance computing and multimedia domains. Prerequisite: CSC 323 or instructor's permission.

623 Real-Time Systems
This course provides a theoretical and practical study of real-time systems, applications, and operating systems. It studies real-time applications, real-time systems, uni-processor scheduling, resource access control, multi-processor and distributed scheduling, and specific attributes of real-time network protocols and operating systems. Prerequisites: CSC 306 or permission of instructor.

633 Software Requirements & Specifications
Topics may include an examination of the definitional phase of software development; a survey of requirements and specification issues and techniques; and an analysis of specification representations and techniques emphasizing important application
635 Software Verification, Validation, and Testing
Topics may include an examination of the test phase of software development; test planning; requirements-based and code-based testing techniques; tools; reliability models; and statistical testing.

636 Distributed Computing
Topics may include the principles underlying the design and implementation of distributed client-server software components; technologies for developing distributed software components, such as sockets, database connections, dynamic type inspection, security, events, and dynamically building function calls; and an introduction to middleware for programming distributed asynchronous systems, including an introduction to events, call-backs, and connections. Prerequisite: CSC 306 or equivalent.

641 Data Mining
Introduction to data mining techniques, including data preprocessing, data mining primitives, association rules, decision trees, cluster analysis, classification and machine learning, data visualization, and data warehousing. Applications from a wide variety of domains will be studied. Prerequisite: CSC 541 or Permission of instructor.

650 Intelligent Multimedia
Lecture Digital watermarking in multimedia applications, copyright protection, authentication, tracking, digital asset management, access control, information hiding in multimedia. Prerequisite: EE 634 or Instructor's permission.

651 Multimedia Processing and Information Retrieval
This course covers topics including multimedia systems, multimedia applications, image compression and processing, video compression and processing, content-based image retrieval, and content-based video indexing and retrieval. Prerequisite: EE 634 or Permission of instructor.

671 Cyber-Security Laws, Ethics and Policies
Enforcement, review, and analysis of computer and network crimes, Electronics Communications Privacy Act, HIPPA, SOX, critical infrastructure protection, computer espionage and foreign intelligence collection, direct and covet action in peace time, military action in time of war, and international
675 Visual Intelligence and Computer Vision

681 Security Architecture and Analysis
This course focuses on the analytical approach to system security and survivability. Topics may include Security Architectures, analysis and tradeoffs of different architectures, survivable system analysis, intrusion detection, vulnerability assessment, computer forensics, security protocols, firewalls, and VPNs.

691 Advanced Computer Architecture
An overview of advanced processor architectures, I/O subsystems, multiprocessor architectures and high performance networking. Advanced Pipelining and instruction level parallelism, memory hierarchy design, storage subsystems, interconnection networks, Multiprocessors. Prerequisite: CSC 391.

693 Advanced Topics in Cyber Security
An overview of advanced and emerging cyber security topics relevant to the current cyber security environment. Cyber security topics, for the current security environment in government and industry on a global basis, will be the focus of this class. Topics include, but not limited to, cloud computing, Homeland Security, big data, and more. This class does not guarantee to repeat the same topics as class topics are based on the current cyber security environment. Prerequisites: CSC 565, Information Security.

728 Visualization
The course focuses on visualization of scientific data. Both visualization principles and practical design issues are addressed. The course introduces the visualization pipeline. It covers the visualization of scalar data, vector data, and tensor data. It also covers image visualization, volume visualization and finally information visualization. It discusses the effective use of
visualization in various areas of the natural sciences, and examples of application will be drawn from these areas. It emphasizes the importance of visualization in understanding observations, examining theories, and fostering new scientific hypothesis.

representation and presentation, document visualization, and dynamic exploration Permission of instructor.

775 Human-Computer Interface

The ways in which humans interact with computers will change dramatically in the coming years. This course cover advanced topics in human-computer interface (HCI): (1) models and frameworks, (2) usability engineering, (3) user interface software tools, (4) HCI for collaborative applications, (5) HCI for multimedia and hypermedia and (6) integrating real and virtual worlds.

Prerequisites: CSC 675, CSC 642 or Permission of instructor.

991 Graduate Design

Allows a graduate student to individually propose, design, implement, and document a research project under the guidance of a faculty member. The research project should allow the student to study a topic to a greater extent than would be possible in a classroom setting.

EE

502 Optical Systems and Devices

In recent years, photonics has found increasing applications in areas such as communications, image processing, sensing and displays. The objective of this course is to provide a thorough survey of this rapidly expanding and important area of electrical engineering. This course will cover the primary theories of light including ray, wave, electromagnetic and photon optics, as well as the interaction of light with matter, and the theory of semiconducting materials and their optical properties. Practical applications of photonics such as imaging systems, holography, fiber optics, laser and detectors will be covered.

504 Introduction to Fourier Optics

Students will be introduced to the principles of linear systems and Fourier theory applied to the analysis of optical propagation, diffraction, coherent and incoherent image formation. Topics will include two-dimensional signals and
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<tr>
<td>514</td>
<td><strong>Introduction to Hardware Accelerated Computing</strong></td>
<td>The past few years the High Performance Computing (HPC) community has witnessed a surge in the use of hardware acceleration, such as graphics processor units (GPU), field programmable gate arrays (FPGA), digital signal processors (DSP), cell processors, etc. This coincides at a time when conventional microprocessors are unable to keep up with Moore’s Law, and become costly due to their increasing power requirements. This course is an introduction to hardware accelerated computational techniques and provides an introduction to FPGA and GPU-programming. Students are expected to have a strong understanding of programming in C, C++ or equivalent programming language. This course will enable students develop a solid understanding of the interaction between software and hardware, and gain hand-on experience in high performance computing.</td>
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<td>515</td>
<td><strong>Advanced Digital Signal Processing</strong></td>
<td>This course examines the properties of signals and systems, sampling, data acquisition, Discrete-Time Fourier Transform (DTFT), Discrete Fourier Transform (DFT), Z-transform theory, spectral analysis, digital filter design and discrete transforms. Practical applications of digital signal processing will be emphasized with a number of hands on MATLAB Programming exercises.</td>
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<tr>
<td>516</td>
<td><strong>Power Systems</strong></td>
<td>This is an introductory course in the field of electric power systems and electromechanical energy conversion. This course discusses not only traditional power systems but also new uses for electric power in transportation systems. Electric power has become increasingly important as a way of transmitting and transforming energy for industrial as well as military applications. Electric power systems is an indispensable tool for alternative energy systems, including systems, diffraction theory, and the simplifying approximations to diffraction in the Fresnel and Fraunhofer regimes. Transforming properties of lenses will be studied along with the concepts of spatial filtering and aperture coding in image formation. Prerequisites: EE342</td>
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wind and solar, geothermal and their integration with the power grid. Prerequisite: ENGR 212, EE 321/322, EE 342.

519 Digital System Design Comprises both lectures and labs, introduces the most important aspects of real-world digital design. Emphasis on practical, hands-on experience in building a system of medium complexity. Design synthesis highlights modern ASIC devices. Staff.

521 Programmable Logic Devices and HDL Design This course covers the concepts, structure and programming characteristics of programmable logic devices (PLDs) such as Field-Programmable Gate Arrays (FPGAs). Hardware Description Languages (HDLs) are used to create designs that are tested on FPGA devices. In this course, students will learn how to design and implement general-purpose hardware components, such as computer arithmetic units and microprocessor data/control paths. Students will also learn how to design specialized hardware from different fields such as digital signal and image processing using techniques that are based on high-level environments, such as Matlab and Simulink, targeting FPGA devices. Pre-requisites EE / CSC 326 or instructor's permission.

522 Linear System Analysis Basic concepts in linear systems; linear spaces and linear operators; state variable approach; observability and controllability of continuous systems; stability of linear systems; design of state feedback, state estimators, and compensators. Analysis and design of composite systems.

524 Secure Programming Introduction to Software Security, risk assessment, buffer overflows, design for security, security testing and auditing, security issues of open source and closed source software, guiding principles of software security, selection of appropriate technologies, access control, race conditions, trust management, input validation, and database security. Pre-req: CSC123

526 Computer and Network Security This course will introduce the application of cryptographic concepts in the practical implementation of network security
practices and techniques. The issues here are: What are the risks and vulnerabilities of computer, Internet, and multimedia data? What are the countermeasures to fight these back? How does cryptographic technique enforce protection? What is digital signature? What is steganography and how is it used for authentication and counterfeit detection? What the different network security technologies are as applied to electronic mail, e-commerce, web transaction, and IP networks?

Prerequisite: CSC 323

527 Fundamentals of Neural Networks

Introduces basic concepts of neural networks using the general framework of parallel distributed processing. Deals with architecture, principles of operation, training algorithms and applications of a number of neural networks. Each part of the course includes computer exercises using MATLAB performed by the student to demonstrate and reinforce the concepts learned in the class.

530 Parallel and Heterogeneous Computing

This course is designed to provide an introduction to the field of parallel computation. Topics chosen for discussion will show students how to develop effective parallel programs with MPI, Pthreads, and OpenMP. An Introduction to Parallel Programming explains how to design, debug, and evaluate the performance of distributed and shared-memory programs. Parallel algorithm design and analysis as well as parallel programming languages will be examined in the context of specific parallel systems and models.

531 Data Communications Networks

This course deals with basic principles of networking. More specifically it covers the following topics: Network Architectures and Protocols. OSI model and TCP/IP protocol suite. Transmission media. Protocols at the physical, data link, network and transport layers. Multiplexing, error and congestion control. Circuit and packet switching. Local and metropolitan area networks. ATM and frame relay. Network security and distributed applications. Prerequisite: EE 413 or equivalent.

534 Communication and Computer Network

Deals with simulation modeling and performance evaluation of communication networks. Presents simulation of network

http://announcements.cua.edu/2015-2016/graduate/engineering.cfm
Simulation elements and overall networks. Simulated network elements include point-to-point, multicast and broadcast links, satellite and radio links, queueing systems, and circuit and packet switches. Simulated overall networks include Local Area Networks (LAN), packet switched (X.25) networks, and Asynchronous Transfer Mode (ATM) based Broadband Integrated Services Digital Networks (BISDN), mobile radio and packet video networks. Development of simulation models for audio and video traffic sources and flow and congestion control algorithms. Discussion of methods of presentation, analysis, and interpretation of simulation outputs. Course will use OPNET software packages to provide hands-on experience. Prerequisite: EE 413 or permission of instructor.

540 Introduction to Antenna Systems
EE540 - Introduction to Antenna Systems - A review of Electromagnetics is given with an emphasis on concepts needed for antenna theory (i.e., Vector Potentials, Free Space Green's functions, etc.) Basic concepts such as directivity, gain, bandwidth, beamwidth, polarization, and aperture size are defined and discussed. Antennas are presented from a circuit theory perspective. Case studies of dipole and loop antennas are developed to illustrate the analytical techniques. Radiation from apertures is also presented. Antenna arrays are treated and basic concepts such as scanning, amplitude distributions, grating lobes, and beam squint are introduced. The uniform and binomial distributions are treated in depth. The course concludes with a discussion of measurement techniques. Prerequisite: EE342

541 Electromagnetic Theory
Theory of electromagnetic field equations and their application to wave propagation in waveguides and resonant structures. Discussion includes partially filled waveguides, corrugated guide, and other structures. Prerequisite: EE 342 or equivalent.

542 Antennas and Propagation for Wireless Communications
This course addresses issues related to wireless communications from a perspective of antennas and propagation. The electromagnetic theory and communications components of wireless communication systems are linked together for analyzing and designing such
systems. The important role of antennas in setting up cellular communication systems is studied and critical propagation issues in the design of such systems are presented. Topics that will be discussed in the course include cellular communications history and principles, basic concepts in electromagnetic wave theory, reflection, transmission and polarization, antennas and radiation, Fresnel Theory, line-of-sight, models for radio propagation, flat earth, terrain roughness, diffraction theory, propagation in presence of buildings, fading, diversity, link budgets, system design issues. Prerequisite: EE 342.

543 Remote Sensing

This course addresses the theory and principles of passive and active remote sensing at different frequencies. The course emphasis is on electromagnetic phenomena rather than image processing techniques for the remotely captured data. Topics include wave propagation and scattering from targets and natural surfaces, basic antenna systems, radiometry and the radar equation. Effects of different media and boundaries such as rough surfaces on wave characteristics (e.g. dispersion, reflection, refraction, attenuation) are discussed. Prerequisite: EE342

544 RF and Microwave Circuits

This course is an introduction to the analysis and design of RF and microwave circuits from the perspective of distributed circuit theory. Fundamental concepts of impedance matching, network theory, S-parameters, coupled line theory, and system noise are discussed in relation to the design of passive and active components used in wireless communication circuits and mixed-signal circuits. Topics covered in the course include transmission lines, impedance matching, filters, power dividers, couplers, resonators, oscillators, mixers, active microwave transistor amplifiers, and design techniques for optimizing system gain, bandwidth, noise figure, and input/output impedance. Industry-standard microwave CAD tools will be used to analyze and design circuits. Students will fabricate several circuits in planar microstrip and learn how to characterize circuit performance on
network/spectrum analyzer instruments to complete the design learning cycle. Prerequisites: EE342 or equivalent

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>545</td>
<td>High Resolution Radar Signal Processing</td>
<td>Introduction to lasers, including interaction of radiation and atomic systems, resonators, oscillation criteria. Discusses specific systems of gas, solid, and semiconductor type. Brief discussion of topics. Electro-optics, modulation, and detection. Prerequisite: EE 441 or equivalent.</td>
</tr>
<tr>
<td>546</td>
<td>Electrical Properties of Materials</td>
<td>Introduction to lasers, including interaction of radiation and atomic systems, resonators, oscillation criteria. Discusses specific systems of gas, solid, and semiconductor type. Brief discussion of topics. Electro-optics, modulation, and detection. Prerequisite: EE 441 or equivalent.</td>
</tr>
<tr>
<td>548</td>
<td>Optical Signal and Image Processing</td>
<td>Fundamentals of waves, wave interference, multiple beam interference, Fraunhofer and Fresnel diffraction and transverse waves. Fourier transform techniques are used to describe light propagation through homogeneous media (lenses, gratings, holograms). Topics: scalar diffraction theory, the lens as a Fourier transforming element, coherent and incoherent imaging and holography.</td>
</tr>
<tr>
<td>549</td>
<td>Parallel Programming for large-scale Computational Problems</td>
<td>This course will cover light generation, modulation and detection technologies. Main emphasis will be on semiconductor optoelectronic materials and devices. Basic principles of operation of lasers and detectors will be discussed. Polarization and absorption modulation of light based on ferroelectric and semiconductor materials will be described. A brief summary of potential applications to communications and sensing systems will be included.</td>
</tr>
<tr>
<td>550</td>
<td>Semiconductor Optoelectronics - Materials and Devices</td>
<td>This course will cover light generation, modulation and detection technologies. Main emphasis will be on semiconductor optoelectronic materials and devices. Basic principles of operation of lasers and detectors will be discussed. Polarization and absorption modulation of light based on ferroelectric and semiconductor materials will be described. A brief summary of potential applications to communications and sensing systems will be included.</td>
</tr>
<tr>
<td>561</td>
<td>Random Signal Theory</td>
<td>Mathematical techniques for analysis and measurement of random signals and processes needed as a foundation for work in radar/sonar, communication theory, or detection, and estimation. Probability; random variables; correlation functions and power spectra stationarity, ergodicity; linear and nonlinear systems with random inputs. Prerequisite: MATH 309.</td>
</tr>
<tr>
<td>Course Code</td>
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<tr>
<td>563</td>
<td>Fundamentals of Acoustics</td>
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<tr>
<td>565</td>
<td>Information Security</td>
<td>Principles of Infosec, security planning, risk management, security technology, physical security, implementing information security, legal, ethical, and professional issues in infosec, security and personnel, information security maintenance etc.</td>
</tr>
<tr>
<td>569</td>
<td>Computer Security and Privacy</td>
<td>Importance of computer security and its effect on individual privacy. Topics include computers and their impact on privacy, data banks, physical security, administrative security, and computer systems and network security. Not open to students who completed this course under earlier numbering (597).</td>
</tr>
<tr>
<td>572</td>
<td>Basics of Information Coding and Transmission</td>
<td></td>
</tr>
<tr>
<td>576</td>
<td>Introduction to Robotics</td>
<td>Covers basic concepts in robotics such as robot arm kinematics, robot arm dynamics, trajectory planning, and control. Transformation between joint space and Cartesian space. Coordinate frames and homogeneous coordinate transformation. Solution of inverse kinematic problem and robot workspace. Differential motion and manipulator Jacobian matrix. Introduction to the control problem of robot manipulators.</td>
</tr>
<tr>
<td>581</td>
<td>Cryptography and Steganography</td>
<td>Introductory concepts of cryptography and steganography; Classical and modern cryptographic algorithms - the underlying mathematics and analysis; Number theory; Cryptographic protocols in computer and data security applications; Fundamentals of information hiding - Techniques and applications.</td>
</tr>
<tr>
<td>Course Code</td>
<td>Course Title</td>
<td>Description</td>
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<tr>
<td>617</td>
<td>Adaptive Signal Processing</td>
<td>This course is concerned with the theory of adaptive signal processing. Topics include adaptive systems, adaptive linear combiner, theory of adaptation with stationary signals, searching the performance surface, LMS algorithm, z-Transform in adaptive signal processing, adaptive algorithms and structures, adaptive modeling and system identification, inverse adaptive modeling, deconvolution, and equalization, and adaptive interference canceling. This course is accompanied with MATLAB computer projects.</td>
</tr>
<tr>
<td>618</td>
<td>Optimum Signal Processing</td>
<td>This course examines the properties of linear model, least-squares estimation (recursive and batch), Singular-Value Decomposition (SVD), Best Linear Unbiased Estimation (BLUE), likelihood, Maximum-Likelihood (ML) estimation, multivariate Gaussian random variables, mean-squares estimation of random parameters, Maximum a Posteriori (MAP) estimation of random parameters, Expectation-Maximization (EM) algorithm. Practical applications will be emphasized with a number of hands on MATLAB Programming exercises.</td>
</tr>
<tr>
<td>621</td>
<td>Fundamentals of Kalman Filtering and Smoothing</td>
<td>Lecture covers the basic problem of state estimation (prediction, Kalman filtering, smoothing), the steady-state Kalman filtering to the linearized variable model, and the state estimation for the not-so-basic state estimation. The state estimation also discussed for the nonlinear model. Computer projects. Prerequisite: EE561.</td>
</tr>
</tbody>
</table>
| 627        | Neural Networks and Bioinformatics              | Introduces basic concepts of neural networks using the general framework of parallel distributed processing. Deals with architecture, principles of operation, training algorithms and applications of a number of neural networks. Emphasizes designing networks from first principles to
solve engineering problems. Application of neural networks to several engineering problems, including pattern classification, data and image compression, robotics, target tracking, and signal processing.

628 Computational and Molecular Imaging

This course is designed to provide students with a comprehensive foundation of computational and molecular imaging and applications, recognizing the cross-disciplinary nature of the subject. It should be an informative exploration of tomographic imaging, image computation, and molecular characterization, with an emphasis on the strategic frontier between informatics and biomedicine.

631 Broadband Integrated Services Digital Networks

Broadband services and principles of BISDN. BISDN architecture and protocol reference model. Functions of the BISDN layers: ATM and ATM Adaptation layers, physical layer for BISDN (cell based, SONET/SDH, FDDI and DWDM based). ATM switching. User-Network Interface specifications: physical and ATM layers specifications and Signaling for point-to-point, point-to multipoint and multipoint-to-multipoint connections. Congestion control, analytical and simulation modeling and performance evaluation. ATM switching, Wireless ATM. Applications: circuit and LAN Emulation, IP, Multiprotocol and MPLS over ATM. Prerequisite: EE 531 or equivalent.

634 Digital Image Processing

This course deals with the fundamentals of the major topics of digital image processing. The topics used in the course include the two-dimensional systems and mathematical preliminaries, image sampling and quantization, image transforms, stochastic models, image enhancement, filtering, restoration, reconstruction, and compression. This course is accompanied with computer projects. Prerequisite: Random Signal Theory, EE 561 or equivalent.

642 Electo-Optics and Photonics

Introduces electro-optics, acousto-optics, magneto optics, and photonic switching. Covers the bulk electro-optic effect, with discussion of switching, phase and amplitude modulation, optical isolation and beam deflection applications. The Faraday effect and Faraday isolators, waveguide electro-optic effects, with
Photonic Communication Network Devices

643 Photonic Communication Network Devices

Introduces the principles of operation for photonic communication devices. These include optical fibers, couplers, splitters, taps, isolators, circulators, attenuators, tunable filters, laser diodes, modulators/demodulators, photodetectors, lightwave amplifiers, wavelength converters/routers, wavelength division multiplexers/demultiplexers, optical add/drop multiplexers, optical switches, optical packet switches.

Optical Communications

644 Optical Communications


Optical Communication Networks

645 Optical Communication Networks


Optical Internet

646 Optical Internet

This course deals with the architecture and protocol stacks for transmission of application to switching, modulation, and computer logic circuits; the acousto optic effect, with application to switching, frequency modulation, beam deflection, and optical filtering; and principles of photonic switching.
TCP/IP over Optical Transport Networks (OTN). The protocols involved are: TCP/IP, Multi-protocol Label switching (MPLS), Asynchronous Transfer Mode (ATM), Point-to-point (PPP), HDLC, Frame Relay, Gigabit Ethernet, Synchronous Optical Network (SONET) and Optical Transport Network. Relevant functionalities and interaction among these protocol layers to the operation of optical internet are presented. Optimal architecture and protocol layers needed for optical internet is developed. The Integrated, Overlay and augmented architectures for TCP/IP/MPLS over OTN are presented. Technologies needed for implementation of an all-optical transport network is presented. Management and control of such networks are to be discussed. Survivability and availability models are presented. Effect of the reconfiguration time of OTN on the performance of optical internet is presented.

647 Intelligent Broadband Multimedia Networks
This course deals with building blocks, architectures, examples and applications of intelligent broadband multimedia networks. Topics to be presented are: Basic intelligent network concepts, examples of types of intelligent networks, Global, advanced and future intelligent networks, Architecture of knowledge machines and knowledge Processing systems. Examples of intelligent networks: Network based educational systems, Integrated medical systems and PC based intelligent home networks. Social and cultural impact of intelligent broadband multimedia networks.

652 Wireless Communications
Intended to give an introduction to wireless communications engineering. Includes characterization of the radio environment; link and system performances and the cellular concept. Study of the effect of the environment on the mobile systems and methods of mitigating degrading effects. Analysis of state-of-the-art wireless communication technologies and systems. Prerequisite: Permission of instructor.

656 Digital Communications
Fundamentals of digital data transmission. Performance analysis of basic digital modulation techniques. Detection of binary signals in AWGN. The matched filter and general formula for
Prerequisite: EE 561 or equivalent.

657 Spread Spectrum Communications Studies the foundations of Spread Spectrum Communications. Includes basic types of spread-spectrum modulation, generation of pseudo-noise sequences for the modulation/demodulation process, and synchronization between the transmitter and receiver. Investigates performance of spread spectrum systems in a noise or jamming environment. Considers application of spread spectrum communications to a common communication system including digital cellular telephones. Prerequisite: EE 656 or equivalent.

659 Satellite Communications This course deals with subsystems, operations and applications of satellite communication systems. Topics to be included are: Spacecraft subsystems: Telemetry, Tracking and Command subsystem, Communication subsystem, and Antennas. Satellite link design: uplink and downlink, effect of propagation impairments, examples. Efficient modulation and multiplexing techniques. Multiple access techniques: FDM/FM/FDMA, TDMA, CDMA and DAMA. Encoding for forward error correction: Linear block codes, Binary cyclic codes and convolutional codes. VSATs. Applications: satellite television, ATM over satellite. Prerequisite: EE 413 or equivalent.

### Karhunen-Loeve transformation.
Detection and estimation of signals.
Computer projects. Prerequisite: EE 561.

<table>
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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>672</td>
<td><strong>Error Control Coding</strong>&lt;br&gt;Introduction to Galois fields; linear codes and cyclic codes; BCH codes and their decoding procedures. An introduction to convolutional codes and decoding procedures. Practical applications of block codes and convolutional codes. Prerequisite: EE 561.</td>
</tr>
<tr>
<td>710</td>
<td><strong>Wavelet Theory and Applications</strong>&lt;br&gt;Introduces the basic concepts of time-scale processing as provided through wavelet analysis. Focuses on both the development and construction of orthogonal and biorthogonal wavelet filters for time-scale processing as well as issues related to their implementation. Compares wavelet analysis and standard Fourier techniques. Engineering applications include image processing, fractal waveform analysis, sonar processing, and noise reduction techniques. Includes computer simulation projects. Prerequisite: Permission of instructor.</td>
</tr>
<tr>
<td>712</td>
<td><strong>Communication Theory</strong>&lt;br&gt;Optimum receiver design; theory and implementation. Analysis of waveform communication problems in terms of its vector equivalent. Signal set notation and analysis. Fundamental concepts involving the theoretical limits of communication system performance. Analysis of time, bandwidth, and dimensionality parameters. Channel capacity and reliability functions. Effect of quantization on communication system performance. Rudimentary concepts of information and its measure. Non-AWGN channel models. Prerequisite: EE 561 or equivalent.</td>
</tr>
<tr>
<td>717</td>
<td><strong>Advances in Adaptive Signal Processing</strong>&lt;br&gt;More recent advances in adaptive signal processing are explored, including higher-order statistic methods, nonlinear filter structures including Volterra and Bussgang filters, infinite impulse response (IIR) adaptive filters, and applications to medical imaging, wireless communications, and data analysis and forensics. The course will be project oriented, with students researching recent literature on a particular theme and developing adaptive signal processing algorithms tailored to the specific theme.</td>
</tr>
</tbody>
</table>
725 Information Theory and Source Coding

Introduction to information theory from a communication system viewpoint. Source and channel encoding. Information measures for both continuous and discrete sources. The source coding theorem and channel coding systems developed. Practical methods of source and channel coding investigated.
Prerequisite: EE 561.

731 Computer Communication Networks

This course deals with analytical modeling and design of computer communication networks. Topics to be covered are: Delay models: Queueing models: Little's formula, M/M/1, M/M/m, M/M/?, M/M/m/K and M/G/1, MMPP, Fluid flow and fractal models and Network of Queues. Graph Theoretical models and routing algorithms: Bellman-Ford, Dijkstra's and Floyd-Warshall algorithms. Multiaccess Communications: The ALOHA system, carrier sense, reservation, polling and splitting algorithms. Flow control: Window flow control, and rate control schemes, delay and loss analysis of audio and video multiplexers. Call admission control.
Prerequisite: EE 531 or equivalent.

740 Numerical Methods in Electromagnetics

Investigates modern techniques in computational electromagnetics. Emphasis on applying computational methods to practical applications such as microwave circuit analysis, scattering, radiation, and optics problems.
Prerequisite: EE 541

741 Advanced Electromagnetic Scattering Phenomena

Time domain methods have several advantages over conventional frequency domain methods in the area of numerical electromagnetic solutions to scattering/radiation problems. For example, time domain methods work better for wide-band signature studies, are better suited for parallel and GPU processing. These methods are also provide better visual representations for understanding the field interactions. The material covered in this course includes direct solution of the domain integral equations using marching-on-time (MOT) methods, finite difference time domain method (FDTD), Transmission Line matrix (TLM) method, time domain finite element (TDFE) method, and time domain finite volume method (TDFV).
Electromagnetics

746 Electromagnetic Radiation and Scattering Provides an introduction to advanced electromagnetic theory with emphasis on radiation and scattering theory. Field equations derived for radiation and scattering problems and applied to simple antennas and bodies. Geometrical optics and geometrical theory of diffraction are presented for antenna problems, edge diffraction, and scattering from simple conducting bodies. Prerequisite: EE 541 or equivalent.


Materials Science and Engineering

Associate Professors Biprodas Dutta, Director; John Philip; Abhijit Sarkar
Research Ordinary Professors Lawrence Cook
Clinical Associate Professors Jandro Abot
Adjunct Assistant Professors Sugata Chowdhury
Lecturers Mrinal Dewanjee; Parshu Gyawali

The Materials Science and Engineering (MSE) program offers graduate courses leading to the degree of Master of Science, M.S. Two options are available in the M.S. program. The nonthesis option requires 30 semester credit hours of approved coursework. The thesis option requires a minimum of 24 semester credit hours of approved coursework plus a thesis comprising six semester credit hours of master's thesis guidance.

The approved coursework must include at least 18 semester credit hours of approved MSE core courses. The core courses are described in a later section. The remaining courses must be in engineering and science disciplines and approved by the director of the program. For both options, each student must submit a program of study to the program director for approval upon entering the program.
Mission

The goal of the MS program in MSE is to produce graduates who are schooled in engineering fundamentals and capable of doing advanced engineering work. To this end, the Materials Science & Engineering program is professional in nature and lead to the Master of Science degree. Major areas include metal, ceramics, glasses, physical, mechanical, structural and electrical properties of materials. Other areas of specialization are nanotechnology, lasers and semiconductor lithography. The available courses include laboratory studies, applied mathematics, engineering analysis and a variety of introductory and advanced level courses in various areas of engineering and applied science. Graduate students plan their program in consultation with the program director and pursue the Master of Science (M.S.) degree program with a specific concentration in one of the areas identified above. Maximum flexibility scope of studies is afforded by utilization of courses offered in departments of the university or other area universities through the Consortium of Universities of the Washington Metropolitan Area.

Admission

Students pursuing the MS degree in MSE should apply for regular admission. The minimum requirement for regular admission to the M.S. program is a bachelor's degree in engineering, science or mathematics from an accredited institution. For foreign students, satisfactory scores (according to CUA guidelines) in TOEFL or a similar testing agency is additionally required. Students lacking certain requirements for regular admission to the M.S. program can apply for a provisional admission. Performance of provisional students will be reviewed after two semesters of graduate study for possible transfer to regular admission. The minimum requirement for regular admission to the M.S. program in MSE is a bachelor's degree with undergraduate background in engineering, computer science, any science discipline including biology and mathematics. A student will be provisionally admitted to the M.S. program if he or she has one or more deficiencies. The deficiency courses must be successfully completed before the provisional status is converted to regular status. For other admission requirements, please refer to Admission under Special Regulations.

Courses Offered

A full listing of graduate courses offered by the department is found below. Consult Cardinal Station for additional information about courses and to determine course offerings by semester.

Course Catalog for Engineering

MSE

501 Introduction to Materials Engineering

519 Experimental Methods in Materials Engineering
522 Mechanical Properties of Materials

542 Electrical Properties of Materials

550 X-ray Diffraction and Electron Microscopy

551 Physical Properties of Materials

562 Corrosion Engineering

571 Artificial Organ Engineering

581 Introduction to Nanotechnology

582 Industrial Processing of Materials

582 Modeling in Materials Science and Engineering

590 Glass Science

591 Composite Materials

This course emphasizing materials engineering, mechanistic aspects, manufacturing and design components is tailored for graduate students in materials science and engineering and undergraduate students of all engineering majors. Among the course topics are fiber and matrix materials; fiber-matrix interfaces; structural polymers; metal, ceramic, and carbon matrix composites; durability; thermoelastic behavior of laminated polymeric composites; statistical strength theories of continuous-fiber composites; nanocomposites; environmental effects; processing and manufacturing of laminated composites; and characterization and nondestructive evaluation. The course will include two lab sessions and one design project.
Special Topics Courses

Computational Materials Science, Transport Phenomena, Fracture and Fatigue, Welding and Joining Processes, Systems Perspectives on Industrial Ecology, Sustainable Energy: Economic and Environmental Issues, Engineering Risk-Benefit Analysis, Symmetry and Tensor Properties of Materials are some of the courses that are not listed in the Table above but will be offered as “Special Topic” courses from time to time if sufficient student interest is perceived.

Department of Mechanical Engineering

Professors Sen Nieh, Chair

Professors Emeriti Mario J. Casarella; Edward D. Jordan; Yun Chow Whang

Adjunct Professors George Mattingly, Tse-Fou Zien

Associate Professors J. Steven Brown; John A. Judge; Joseph Vignola; Zhaoyang Wang

Clinical Associate Professors Jandro Abot

Clinical Assistant Professors Diego Turo

Adjunct Associate Professors Tuan Nguyen

Assistant Professors Eric Kommer; Xiaolong Luo

Adjunct Assistant Professors Mamta Nagajaja; Adam Wolfe; Abdulkadir Yavuz

Lecturers Jeffrey Didion; William LaPlante; Kenneth Romney

The Department of Mechanical Engineering offers graduate programs leading to the degrees of Master of Science, M.S., and Doctor of Philosophy, Ph.D. The programs are:

Professional Master's Program

For recent graduates and practicing engineers interested in specialized areas to enhance their careers, the program emphasizes advances in existing and emerging technologies. Master's thesis is optional.

Master's Program (pre-doctoral)

For students interested in pursuing a Ph.D. degree, a Master's thesis is strongly recommended.
Doctoral Program

For students pursuing a Ph.D. degree, this program emphasizes strong foundations in mechanical engineering as well as advanced topics in a specialized area of concentration.

Research Areas

- Acoustics
- Active Control and Intelligent Materials/Systems
- Advanced and Non-Linear Dynamics
- Aerospace and Aeronautic Engineering
- Air Pollution Control and Indoor Air Quality
- Biofabrication & Microfluidics
- Clean Energy Power Production and Use
- Combustion and Multiphase Systems
- Composite Materials
- Computational Methods (FEM and CFD)
- Electronic Packaging and 3-D Imaging
- Heat/Mass Transfer and Thermodynamics
- HVAC and Refrigeration
- Lab-On-A-Chip
- Mechatronics and MEMS
- Nano-Mechanics and Sensors
- Robotic Mechanics
- Structural and Experimental Mechanics
- Three-Dimensional Imaging
- Vibration and Noise Reduction of Mechanical Systems

Admission

Please refer to Admission under Special Regulations.

Master's Degree Program

Candidates for graduate studies plan their program in consultation with an adviser. Maximum flexibility in scope of studies is afforded by utilization of courses offered in other departments of the university or other area universities through the Consortium of Universities of the Washington Metropolitan Area. Requirements for the master's degree programs follow those established for the school with the specification of ENGR 520 (Mathematical Analysis for Graduate Students) and one of the following two courses, ENGR 516 (Computational Methods for Graduate Students) or ENGR 518 (Experimental Techniques for Graduate Students). The department offers the following areas of specialty: 1) Energy and Environment, 2) Acoustics, Vibration and Structures and 3) Nano-mechanics and MEMS. Please refer to Degree Requirements.

Doctoral Degree Program

Requirements for the doctoral degree program follow those established for the school. Please refer to Degree Requirements. Note that the comprehensive examination is directed at assessing a student's preparation in advanced topics for doctoral research, and understanding of the research literature and a student's ability to define the frontiers of the proposed areas of investigation. The department offers two areas of specialty for doctoral study: 1) Thermal-Fluid Sciences, and 2) Mechanics, Acoustical and Nano Systems.
Courses Offered

A full listing of graduate courses offered by the department is found below. Consult Cardinal Station for additional information about courses and to determine course offerings by semester.

Course Catalog for Mechanical Engineering

**ME**

502 Introduction to Elec. Packaging and MEMS

503 Structural Mechanics

A fundamental engineering course that introduces elasticity and mechanics analyses of solid structures, whose topics include: 3-D stresses and strains; stress and strain relations; Airy's stress function; 2-D elasticity problems; stress concentrations; failure criteria; introduction to plasticity, fracture and fatigue; bending, torsion and combined loading on structural elements; strain energy and energy method; introduction to the finite element method; plates and shells; buckling.

504 Finite Element Methods

Introduction to finite element problems in solid mechanics and diffusion. Finite element model construction applying direct and variational principle formulations; Rayleigh-Ritz and Galerkin methods. General solution procedures for 1-, 2-, and 3-dimensional problems; isoparametric elements. Design process with finite elements; use of finite element computer program for analysis and design of complex systems. Substructure and reduction methods for efficient computation. Introduction to dynamic system treatment; numerical integration methods.

505 Programming & Software Tools in Mechanical Engineering

507 Mechanical Systems and Control

Mathematical modeling of dynamic systems; basic principles of feedback; the root-locus and frequency-response
Modern Control Systems

Analysis of control systems in state space, control system design via pole placement, design of state estimators, quadratic optimal control systems design. MATLAB used extensively for analysis and design problems.

Engineering Optimization Methods

Modern Control Systems

Analysis of control systems in state space, control system design via pole placement, design of state estimators, quadratic optimal control systems design. MATLAB used extensively for analysis and design problems.

Alternative Energy Engineering

ME 526 Alternative Energy is a 3-credit course offered primarily to upper-level undergraduate and beginning-level graduate students. This course: (1) reviews the status of primary energy in the United States and the world; (2) discusses energy production, use, storage, transfer, and conversion; (3) introduces and uses the concept of exergy; (4) applies thermodynamic analyses to energy systems, including ones based on renewable energy sources, which among the considered examples could be wind, solar, geothermal, ocean, tidal, biomass, and hydroelectric; and (5) time permitting, the course will include discussions of combined heating and power (CHP) systems and fuel cells.

Renewable Energy & Technology

A practical design-oriented energy systems course dealing with alternative sources of energy, such as nuclear, hydroelectric, wind, solar, geothermal, biomass, thermoelectric and thermionic.

Environmental Protection for Energy Systems

ME 529 is a 3-credit dual level course in Energy and Environment, designed for Master students and seniors in Engineering. It presents an overview of modern energy production, conversion, and usage, and their various environmental impacts. Problems and engineering solutions to air pollution, ozone depletion, global warming and climate change, indoor air quality, and HAPs resulted from stationary and mobile energy systems will be discussed. Problem-solving techniques
Based on mass/energy balance, and chemical reactions are taught for quantitative analysis and design. Prereq: ENGR 211 or graduate status.

530 Applied Energy Systems
A first course in applied energy systems and technologies, which reviews the fundamentals of thermal-fluid sciences and discusses their applications to power, propulsion, heating, cooling, refrigeration, and cryogenic systems. It is a course in applied thermodynamics that considers the important internal and external combustion heat engine cycles, heat pump cycles, and their associated applied components and systems. A comprehensive overview of energy consumption, production, and reserves in the USA and the world is also discussed. Emphasis is placed on the quantitative analysis of performance of various applied energy systems and processes, and on the tradeoffs necessary for improved effectiveness and environmental acceptability.

531 Optimal Design of Energy Systems

532 Design of Power and Propulsion Systems
A practical design-oriented course dealing with propulsion and power-producing components and systems, including internal combustion engines, fossil fuel-fired power plants, nuclear/hydroelectric power plants, gas turbine engines, nozzles and jet propulsion, spacecraft, and direct energy converters. Open-ended design and computer problems are assigned. Prerequisite: ME 311 or ME 530 or Graduate Student Status.

533 Energy Conservation and HVAC
A dual level course in applied energy systems and environmental control, which discusses energy and water conservation opportunities as it relates to heating, ventilating, and air conditioning (HVAC) systems. The course places emphasis on energy and water savings in HVAC systems in residential and commercial buildings.

534 Design of HVAC and Refrigeration
A course in applied energy systems and environmental control, which
535 Design and Optimization of Thermal Systems
This course deals with the numerical evaluation of the inevitable trade-offs associated with any thermodynamic or heat transfer system. A distinction will be made between workable and optimal systems. Several manual solutions will be required to ensure that the physics of the system and solution techniques are well understood. A primary analytical tool that will be used for system simulation and evaluation will be the engineering equation solver (EES) program. Although no computer language will be required for simulations, prior experience with windows and spreadsheets will be helpful. Optimal system analysis will include, at least, one calculus method and one search method. Applications will include power and refrigeration systems, electronics cooling, etc.

536 Thermal Environmental Engineering
Indoor air quality: standards and regulations; major indoor pollutants (sources, health effects, control strategies); air cleaning processes. Thermal comfort. Open-ended design project by students to determine comfort and IAQ requirements in residential and industrial buildings.

537 Air Pollution and Control
A practical, comprehensive course for students interested in energy systems and environmental engineering. It discusses the cause, source, and effect of various primary pollutants, such as particulates, SOx, NOx, CO, VOCs, solid waste, and nuclear waste, and secondary pollutants such as photochemical smog, 03-depleting chemicals, acid gases, and greenhouse gases, from stationary and mobile energy systems. Discussions also include the working principle, performance characteristics, and method of analysis of engineering control equipment and processes for
the above pollutants. This course emphasizes the design approach to pollution problems from an applied engineering viewpoint. Open-ended design problems will be assigned and a field trip to a local power plant will be arranged.

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<tr>
<td>539</td>
<td>Combustion and Incineration</td>
<td>This course discusses the fundamentals of combustion science and processes, and its engineering applications to combustion and incineration systems. The topics include combustion thermodynamics and chemical kinetics; characterization of fuels and chemical wastes; premixed and diffusion flames; ignition, extinction, deflagration, and detonation; environmental impacts due to combustion and incineration; modern combustion technologies and devices; incineration technologies and systems; and pollutants removal from combustors and incinerators.</td>
</tr>
<tr>
<td>541</td>
<td>Conduction and Radiation</td>
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</tr>
<tr>
<td>543</td>
<td>Heat Exchanger: Design and Analysis</td>
<td>Fundamental analysis, thermodynamic evaluation and design/modeling of both single-phase and two-phase heat exchangers. Discussion of various applications, including compact heat exchangers and high heat flux applications. Students will be required to solve open-ended design problems.</td>
</tr>
<tr>
<td>544</td>
<td>Intro to Multiphase Systems</td>
<td>Introduction to physical systems consisting of more than one phase or component. Classification of multiphase systems, technological applications. Dispersed vs. separated multiphase systems. Size distribution. Particle-fluid interaction. Multiphase system equations. Introduction to numerical modeling. Introduction to complex multiphase systems: suspensions, emulsions, and sprays.</td>
</tr>
<tr>
<td>547</td>
<td>Intermediate Thermodynamics</td>
<td>Mass, energy and entropy balances; entropy, irreversibility, and availability (exergy); equations of state and general thermodynamic relations; gas mixtures and liquid solutions; phase equilibrium and stability; applications.</td>
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548 Intermediate Heat Transfer

The course presents the fundamentals as well as applications of heat transfer for graduate students in engineering. It discusses the basic concepts, material properties, governing laws, and solution techniques for conduction, convection, and thermal radiation. Topics include 1-D/multi-D steady conduction, conduction in composites, insulation, heat transfer fins, unsteady conduction; fluid flows and forced convection, free convection, boiling and condensation, engineering correlation, heat exchanges; blackbody and shape factors, radiation properties, radiant exchange between surfaces, radiation shields, solar/space applications; combined modes of heat transfer.

549 Intermediate Fluid Mechanics


550 Combustion and Waste Management

Dual-level course in energy systems and environmental engineering. Discusses fundamental sciences and practical applications of combustion of fossil fuels, and incineration and management of wastes. Applied combustion and incineration systems, such as car and jet engines, boilers and furnaces/kilns, incinerators, waste-to-energy plants, and land-fill waste management facility will also be discussed. Prerequisite: Graduate students or ME upper classmen).

551 Infrared Systems

552 Introduction to Flight Dynamics

Aspects of fluid flow - boundary layers, laminar and turbulent flow; subsonic and supersonic flow - shock waves and Mach Number; Bernoulli's equation and dynamic pressure; air resistance - form drag and skin friction; aerodynamic lift and airfoils - stagnation point, pressure coefficient, center of pressure and pitching moments; wing characteristics - downwash and induced drag; introduction t propulsion. Prerequisite: ENGR 331 or equivalent.
554 Aerospace Design  In this course, students work on projects related to topics in aerospace engineering. Prereq: minimum GPA of 3.0, or permission by instructor.

557 Advanced Dynamics  Multiple methods for obtaining equations of motion for rigid multibody systems. Topics to be covered will include the differentiation of vectors, kinematics, mass distribution, energy functions, and formulation of the equations of motion.

558 Introduction to Ocean Engineering

559 Fundamentals of Ocean Acoustics

560 Introduction to Acoustics

561 Acoustics & Wave Propagation  Vibrating systems; simple, damped, and driven oscillators; strings; bars; membranes and plates. Plane, cylindrical, and spherical waves in a fluid: transmission, refraction, reflection, and absorption. Radiation from point, line, and piston sources.

563 Acoustics Media & Design  This applied course covers design and measurement related issues in acoustics. Topics include the acoustics of natural and artificial porous media like gravel, mineral wool, foams and grass. The course addresses the use and design of data acquisition systems, the design of sound absorbers materials as well as the design of apparatuses for measuring acoustic properties. Experimental topics includes, impedance tube measurements, room acoustic measurements and design topics includes, design of sound absorber materials, design of acoustic measurement apparatus: porosity, flow resistivity and tortuosity apparatus. Prerequisite: ENGR 222 or equivalent.

566 Advanced Vibrations and Structural Dynamics I  Free and forced vibrations of single degree of freedom systems under a variety of time dependent loads.

Damping in structures. Unit impulse response functions. Frequency domain analysis. Free and forced vibrations of
multi degree of freedom systems.
Modal Analysis, eigenvalues, eigenvectors. Numerical integration, time history analysis, and modal analysis of MDOF systems.
Introduction to vibration of continuous systems.

568 Experimental Vibration and Acoustics
Properties of acoustic and vibration sensors and actuators, collection of large data sets using robotically positioned transducers, automated data acquisition and signal processing. Post-processing techniques including statistical analysis, reduction of multi-dimensional data sets, and image generation. Comparison of experimental results with theoretical predictions of acoustic and vibration behavior. Prerequisite: ME 392 or graduate status.

572 Computer Controlled Mechanical Systems
Introduction to computer control. Analysis and design of multi-input multi-output digital controllers in the z-domain. Stability, controllability, and observability analysis. Parameter identification. Design and testing of various computer control systems. Prerequisite: ME 507.

573 Marine Bioacoustics

574 Orbital Mechanics and Mission Design

577 Applied Mechatronics
This course covers the fundamentals of technologies involved in mechatronics (intelligent electro-mechanical systems), and techniques to apply these technologies to mechatronic system design. Topics include: electronics (A/D, D/A converters, op-amps, filters, power devices); software program design, event-driven programming; hardware and DC stepper motors, solenoids, and robust sensing. The course will take a narrative approach, emphasizing the importance of building intuition and understanding, with focus on the integration, system design and engineering.

580 Introduction to MEMS and
Microfabrication applications, and design issues/constraints of MicroElectroMechanical Systems (MEMS). Students will gain an understanding of microfabrication techniques for MEMS including photolithography, surface and bulk micromachining, LIGA, and other processes. Transduction mechanisms for sensors and actuators (coupling between thermal, mechanical, and electrical domains) and micro-scale engineering design issues will also be discussed in detail.

581 Introduction to Microfluidics and Lab-on-a-Chip Technologies
This course presents fundamentals and applications of microfluidic technologies for lab-on-a-chip applications. The course provides a broad view of the field of microfluidics and knowledge of relevant fabrication methods and analysis techniques. Microfluidic fabrication techniques, transport processes, flow control methods, molecular separations and detection techniques will be emphasized. Students will do class projects and are expected to demonstrate mastery of basic concepts in microfluidic modeling, design, and fabrication of a microfluidic system selected in consultation with the instructor. Prerequisite: ENGR 331

582 Introduction to Mechanical Fundamentals of Electronic Systems
An introduction to mechanical fundamentals required for designing reliable electronic systems. The focus will be on the fundamental principles of semiconductor devices, circuit theory and electrical design considerations, electronic packaging technologies, effect of materials compatibility, manufacturing processes, thermal stress, mechanical stress, environmental effects on product performance, failure analysis, reliability prediction, durability and cost.

583 Mechanical Design and Optimization of Electronic Systems

584 Introduction to Nanotechnology
As nanotechnology becomes increasingly important in the 21st century, there will be increasing demand for graduates with strong
interdisciplinary education in this area. With this in mind, the objective of this course is to introduce nanotechnology and its applications. Focus will be on defining nanotechnology, presenting a history of nanotechnology development and projecting its potential impact on the 21st century, nano-materials, nano-fabrication and nano-engineering, nano-mechanics, applications of nanotechnology, challenges in research and development of nanotechnologies, and the role of mechanical engineers in the exciting field of nanotechnology.

622 Turbulence

This course presents the fundamentals of turbulence. Topics include: introduction and motivation, statistical techniques for analysis, mean flow dynamics (Reynolds decomposition), Kolmogorov's theory, instrumentation, classical turbulent flowshear layers, jets, wakes, boundary layers (pipe flow) and introduction to numerical simulation of turbulent flows. Prerequisite: ENGR 331 or equivalent.

640 Advanced Thermodynamics

Advanced topics in thermodynamics: energy and exergy analysis of open systems; entropy, irreversibility, and availability; equations of state and general thermodynamic relations; gas mixtures and liquid solutions; phase equilibrium and stability; external-field effects; low temperature thermodynamics; introduction to irreversible thermodynamics; and direct energy conversion. Prerequisites: ME 530 or Graduate Student Status.

642 Advanced Heat Transfer

Specialized topics in heat transfer. The topics will be selected based on the interest of the students. Prerequisite: ME 548.

645 Advanced Fluid Dynamics

Specialized topics in fluid mechanics. The topics will be selected based on the interest of the students. Prerequisite: ME 549.

647 Multiphase Flows

Fundamental laws, physical interactions and dimensionless parameters, governing momentum transfer equations, solution techniques, and industrial, applications of
multiphase flow processes, including gas-solid, gas liquid, and liquid-solid systems. Emphasis is primarily placed on particle-fluid interactions. Prerequisite: ME 549.

648 Heat Exchangers - Theory and Applications

Transport properties and dimensionless parameters; heat exchanger classification, heat exchanger design; UA-LMTD and -NTU methods; fouling; header design; flow regimes in two-phase heat transfer; pressure drop and heat transfer correlations for boiling and condensation. Applications include double pipe heat exchangers, shell and tube heat exchangers, compact heat exchangers, evaporators, and condensers. Prerequisites: ME 548 or Graduate Student Status.

651 Advanced Topics of Infrared Systems

This course is intended to provide a comprehensive review of Surveillance and Reconnaissance (S&R) imaging system modeling and performance prediction. The goal of S&R systems is to provide information-detection, classification and identification of objects and features based on image characteristics. Given a set of information requirements, the system designer and operator must design and operate a system in a manner that will provide the required information. They thus require the ability to model and predict the performance of S&R systems based on design attributes and measurable operating parameters. Performance is defined in terms of the ability of users to extract the desired information. System descriptions, S&R modeling history, system characteristics, and performance models are all provided. While there are many texts describing imaging systems in the realm of linear shift invariant systems, target acquisition, driving and flying, there are few texts that address the specific design and analysis techniques used with S&R imaging systems. In particular, the emphasis here is on validated prediction of human observer performance. Prerequisite: graduate student status.

654 Computational Introduction to Finite Elements. Finite
Structural Mechanics

656 Optimal Control
Linear quadratic Gaussian optimal control; linear quadratic regulator; introduction to robust control; gain margin, phase margin; H-2, H-infinity controller. Prerequisites: ME 510 or Graduate Student Status.

657 Advanced Dynamics
A more in-depth study of material covered in ME 557. Multiple methods for obtaining equations of motion for rigid multibody systems, based on Kane's method. Topics to be covered will include the differentiation of vectors, kinematics, mass distribution, energy functions, and formulation of the equations of motion. Prerequisites: Graduate Student Status.

660 Intermediate Acoustics
The course will cover issues related to linear acoustics that stem from an understanding of the acoustic wave equation. The topics include acoustic metrology, attenuation of sound, radiation and reception, wave-guides human hearing and transduction. These analytic concepts will be applied to applied topics including musical instruments, audio, and biomedical ultrasound. Prerequisite: Graduate student status.

663 Transduction in Acoustics/Vibration

664 Modal Analysis

666 Advanced Vibrations and
Structural Dynamics II

Introduction to modal analysis: natural frequencies and mode shapes. Distributed parameter systems: vibration of beams and plates. Analytical dynamics: LaGrange equations and Hamilton's principle. Prerequisites: ME 344 or Graduate Student Status.

668 Active and Passive Vibration Control


669 Nonlinear Vibration

This course includes derivation of nonlinear equations of motion for large amplitude mechanical vibrations (such as beams and plates) but focuses on the analysis of the dynamics of nonlinear oscillators (such as Duffing, Van der Pol, and Mathieu/Hill equations). Topics considered include phase-plane analysis and stability, asymptotic and perturbation methods such as Lindstedt-Poincaré, multiple scales, and Krylov-Bogoliubov-Mitropolsky, the harmonic balance method, external excitation, primary and secondary resonances; parametric excitation, Floquet theory, and multi-degree of freedom systems including nonlinear normal modes and center manifold theory.

701 Finite Element Method: Theory and Applications

The course describes the fundamentals of finite element theory. Finite Element formulations for various physical systems are derived through variational forms of energy functionals. Finite elements for elastic structures, porous materials, piezo-electric materials, fluid and thermal systems are analyzed with emphasis on interaction phenomena and coupled behaviors.

703 Advanced Problems in Vibration and Acoustics

Topics include longitudinal and transverse waves in solids: bars, plates, and cylindrical shells; dispersion and impedance. Sound radiated by vibrating structures, effect of fluid loading on structural vibrations,
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<th>Course Code</th>
<th>Course Title</th>
<th>Description</th>
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<tr>
<td>726</td>
<td>Advanced Combustion and Multiphase Systems</td>
<td>Based on the interest of the students, this course discusses in detail a few selected, advanced topics in one of the following subareas: gas-solid suspensions, fluidization, gas-liquid systems, slurry flows, coal combustion, ICEs, boilers and fuels, incineration systems, and multiphase mechanics. Emphasis is placed on training students in independent study and in grasping the forefront of the particular research field. Final project by students. Prerequisites: ME 539, 544.</td>
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<tr>
<td>728</td>
<td>Advanced Problems in Pollution Control</td>
<td>Based on the interest of the students, this course discusses in detail a few selected, advanced topics in one of the following application areas: air pollutants emission control, indoor air quality control, wastewater treatment, water quality control, soil contamination and remediation, incineration of chemical waste, and microbiological treatment of waste. Emphasis is placed on training students in independent study and in grasping the forefront of the particular research field. Final project by students. Prerequisite: ME 537.</td>
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<tr>
<td>733</td>
<td>Turbulent Flows</td>
<td>Nature of turbulence and the formulation of governing equations. Application to free shear and wall flows, statistical description of turbulence, spectral dynamics, turbulence modeling, experimental methods. Final project by students. Prerequisite: ME 645.</td>
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<tr>
<td>741</td>
<td>Advanced Problems in Thermal Science</td>
<td>Based on the interest of the students, this course discusses in detail a few selected, advanced topics in one of the following subareas: applied thermodynamics, advanced</td>
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thermodynamics, heat conduction, convective heat/mass transfer, thermal radiation, heat/mass exchangers, and heat transfer enhancement. Emphasis is placed on training of students in independent study and in grasping the forefront of the particular research field. Final project by students. Prerequisite: ME 548.

751 Advanced Problems in Vibration Control

Finite element modeling of beams, rods, plate and shells with shape memory or piezo-electric actuators. Experimental validations. Surface damping treatment and active constrained layer damping. Variable structure control and LMS control. Prerequisites: ME 507, ME 666. Drs. Baz, Chen

752 Advanced Topics in Mechanics

This course provides an introduction to the phenomena of nonlinear oscillations. Emphasis is placed on identifying the phenomena from a physical perspective, understanding their behavior, and obtaining approximate closed-form solutions that define the essential characteristics of their behavior. Results are compared to those obtained from similar linear systems. Examples are limited to single-degree-of-freedom systems, in order to enable sufficiently rigorous study of some of the most common phenomena. This course serves as an introduction to more advanced study in the nonlinear oscillations of multi-degree-of-freedom and continuous systems, nonlinear control, and chaos theory. Prerequisite: Permission of Instructor.

754 Advanced Computational Structural Analysis

Vibration of discrete systems, the eigenvalue problem, discrete systems, continuous systems, discretization of continuous systems, the finite element method, condensation methods and sub-structure synthesis. Final project by students. Prerequisite: ME 654. Prerequisite: ME 504.

756 Advanced Problems in Controls

Topics include optimal control of continuous and discrete systems, linear quadratic regulator and tracking, Riccati equations and eigenstructure of Hamiltonian, and robust control.
techniques for linear systems (H4 and H2). Adaptive control techniques with emphasis on real-time parameter estimation, mode reference adaptive and self-tuned systems. Nonlinear control analysis and design using feedback linearization and variable structure control. Final project by students. Prerequisite: ME 512.

760 Advanced Topics in Acoustics

Research oriented course focused on sound environments. This course covers ocean and atmospheric acoustics as well as architectural acoustics. This course also includes topics related to nonlinear phenomenon such as shock wave propagation and parametric arrays. Prerequisite: ME 560

761 Acoustic Imaging

Footnotes