

University of Pennsylvania



School of Engineering & Applied Science Graduate Studies

School of Engineering & Applied Science

world-class faculty

Renowned scientist-engineers recognized as national and international authorities in their fields.

break-through research

Creating the new knowledge that leads to new solutions, new ideas, and new technologies.

ivy league excellence

A degree with immediate name recognition that opens up a world of career possibilities.

outstanding research facilities

New buildings for computer science and biotechnology. Plans for a new nanotechnology building. State-of-the-art computer labs. Twelve interdisciplinary laboratories, centers, and institutes.

strategic location

All of Penn's twelve schools, fifty research centers and a hundred institutes within easy walking distance on our urban campus situated in the Greater Philadelphia region: an international center for engineering and scientific research and development.

up-to-the minute curricula

Grounded in the latest research findings and designed to be responsive to students' career goals and the needs of today's fast-moving, high-tech world.

outstanding students

Self-motivated learners of the highest caliber from across the nation and across the world.

fast-track career connections

From our Career Services Center and worldwide alumni, professional, and academic networks to on-campus recruiting by more than 500 companies.

The M.S.E. Program provides highly-qualified students with the firm theoretical foundation and interdisciplinary skills that are essential for career advancement in the rapidly-changing field of chemical and biomolecular engineering.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN Bioengineering

Penn's Department of Bioengineering, one of the first in the nation, knows no boundaries. What distinguishes our program from those of our peers is our collaborative research environment that spans the University's Schools of Engineering, Medicine, Veterinary Medicine, Dental Medicine, and Arts & Sciences. Our bioengineering program is consistently ranked as one of the best in the nation.

The Master of Science in Engineering (M.S.E.) Program in Bioengineering (BE) is innovative, unique, and nationally recognized for its excellence. We are at the fore in preparing students for leadership careers in which they will influence the direction of industrial, public, and non-profit organizations in solving problems important to biology and medical research as well as clinical, proactive, and population studies. Our flexible curriculum allows students to focus on an area of bioengineering that is of particular interest to them. Graduates of our program are in high demand in every field that requires advanced understanding of bioengineering principles. They are found in companies, organizations, and government agencies, or pursuing doctoral studies at Penn and other major universities.

The M.S.E. Program, grounded in the intersection of engineering, life sciences, and medicine, provides students with the firm theoretical foundation and interdisciplinary skills that are essential for career advancement in the rapidly-changing field of bioengineering.

Applicants must have a strong background in Engineering and Biology.

CURRICULUM

The program requires 10 graduate course units (CUs) and offers a Master's thesis option and a non-thesis option.

Thesis option:

- 1 Math course
- 2 Biological science courses
- 2 Bioengineering graduate electives
- 1 Technical elective course from any science or engineering discipline
- 2 Science & Engineering Electives
- 2 Master's Thesis Research Credits

Non-thesis option:

- 1 Math course
- 2 Biological science courses
- 2 Bioengineering graduate electives
- 1 Technical elective course from any science or engineering discipline
- 4 Science and Engineering electives

Students will focus on an area of bioengineering that interests them. The program director will be available to assist students plan their course of study and guide them to find a research mentor if applicable in the research that leads to their thesis if applicable and the successful completion of the program. It is expected that the requirements of the program be completed within twelve months.

AREAS OF CONCENTRATION

- Cell and Tissue Engineering
- Biomedical Imaging
- Biofluid Mechanics
- Injury Biomechanics
- Neuroengineering
- Orthopaedic Bioengineering
- Theoretical & Computational Bioengineering

PROGRAM HIGHLIGHTS

Access to resources available through Penn Bioengineering's thirteen research laboratories as well as affiliated laboratories on campus and in the Penn hospitals

FACULTY DIRECTOR

JOHN C. SCHOTLAND, M.D., PhD
Associate Professor of Bioengineering

John C. Schotland is trained as a biophysicist and physician. He is the author of more than 70 publications and patents in the fields of optical physics and biomedical imaging. Dr. Schotland has licensed several patents to business startups and biotechnology companies. He serves on the faculty of the Departments of Bioengineering and Electrical and Systems Engineering.

MASTER OF

Biotechnology

The Master of Biotechnology program provides students with the science and engineering training needed for success in the critical and dynamic industries of biotechnology and pharmaceuticals. This innovative and interdisciplinary program draws courses from the sciences, engineering, medicine, and business/entrepreneurship. Applying advances in molecular biology in human and animal health, agriculture, environment, and specialty biochemical manufacturing, Biotechnology is an interdisciplinary field that works at the frontiers between biology, engineering, medicine and plant science. Biotechnology impacts scientific and technological areas such as: Recombinant DNA; Clinical Diagnostics; Medical Therapy; Bioinformatics; and Biomaterials Production.

CURRICULUM

Students take a total of eleven courses to complete the degree requirements. Six are chosen from the program's Core Categories:

- Biochemistry
- Cell & Molecular Biology
- Engineering Biotechnology
- Laboratory Skills
- Statistics
- Core Elective

The remaining five courses comprise the Track Electives, and are based on the five program Tracks, which provide students flexibility to tailor their degree to their background, interests and career goals:

- Molecular Biotechnology (molecular biology and genetic engineering)
- Biopharmaceutical/Engineering Biotechnology (drug discovery, drug delivery and biopharmaceutical manufacturing)
- Computational Biology/Bioinformatics (analysis of genomic and proteomic databases as well as structural biology)
- Biomedical Technologies (clinical issues such as biomaterial, tissue engineering, device design, and imaging)
- MB/MBA Dual Degree with the Wharton School* (core training in the science of biotechnology along with an MBA)

Students may begin in either the fall or spring term, and on either a full-or part-time basis. Full-time students can comfortably complete the program's required eleven courses in three academic terms.

*Note: Acceptance into the MB/MBA is dependent on first being accepted into the MBA which requires a separate application through the Wharton School. The MB/MBA dual degree program is a 2-year full-time program.

FACULTY DIRECTOR

SCOTT L. DIAMOND, PhD
 Director, Biotechnology Program;
 B.S., Chemical Engineering, Cornell University, 1986; PhD, Chemical Engineering, Rice University, 1990;
 Director, Penn Center for Molecular Discovery; Associate Director, Institute for Medicine and Engineering

Professor Scott L. Diamond is trained as a chemical engineer and specializes in cardiovascular therapeutic technologies. He is the author of more than 90 publications and patents in the fields of gene therapy, drug delivery, thrombolytics, thrombosis, and endothelial mechanobiology. He is an established Investigator of the American Heart Association and recipient of the NSF National Young Investigator Award and an NIH FIRST Award. Dr. Diamond has licensed numerous patents to business start-ups and related biotechnology interests. He serves on the faculty of the Departments of Chemical and Biomolecular Engineering, Bioengineering, Pharmacology, and the Wharton School.

STUDENTS

Biotechnology students have diverse backgrounds and goals. Some enter straight from their bachelor's degree, others after several years of industry experience. They come from numerous disciplines, from biology to business to pharmacy. Graduates represent a broad range of knowledge and expertise. Students come from near and far, including numerous internationals from all corners of the world. The richness of this diversity provides an incredible educational experience for all, and enables a robust network of future colleagues who actively share their knowledge and opportunities with each other.

OPPORTUNITIES

Penn is home to numerous world-class interdisciplinary institutes, centers and laboratories. Coupled with a wealth of biotechnology and pharmaceutical companies in the surrounding area, students have a myriad of opportunities for practical experience. Each semester, nearly 20% of our students are engaged in an internship or independent study on or off campus. Many students seek post-graduation employment right here in the region. They work in positions that include research, management, and consulting. Other graduates advance into PhD study in biotechnology or a related discipline, medical school, or law school.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN

Chemical and Biomolecular Engineering

The nation's first degree program in Chemical Engineering began here at Penn in 1893. We have been defining the frontiers of the field.

The Department of Chemical Engineering officially changed its name to the Department of Chemical and Biomolecular Engineering in 2002. Our new name reflects our visionary approach to the rapidly-changing field of chemical engineering: research and development that is grounded in the interface of chemical engineering and biological processes at the molecular level.

Our innovative Master of Science in Engineering (M.S.E.) Program in Chemical and Biomolecular Engineering (CBE) is known for its success in preparing students for leadership roles in the oil, chemical, pharmaceutical, and electronics industries.

Graduates of our program are found in companies such as Merck, Bristol-Myers-Squibb, General Electric, United Technologies, Bridgestone Americas, Exxon Mobile, Honeywell, Rohm & Haas, and many more.

CURRICULUM

You must complete a total of ten graduate course units: six required courses and four electives.

Required core courses:

- Applied Engineering Mathematics I, II or Numerical Methods and Modeling
- Advanced Thermodynamics
- Kinetics and Reactor Design
- Transport Processes I-II

Elective courses in the following areas of study:

- Chemical and Biomolecular Engineering
- Engineering
- Physical and Biological Sciences

Areas of concentration:

- Fluid Mechanics
- Thermodynamics
- Control
- Design
- Bioengineering
- Polymer Engineering
- Heat Transfer
- Computer Applications

Thesis option:

You may substitute a thesis for two elective courses.

Students whose undergraduate degrees are not in chemical engineering must take the following undergraduate core courses during their first year:

- Thermodynamics of Fluids
- Fluid Mechanics
- Heat and Mass Transport
- Separation Processes
- Chemical Reactor Design

PROGRAM HIGHLIGHTS

Access to resources available through CBE's many research laboratories such as the Advanced Chemical Technologies Laboratory and affiliated laboratories on campus including the Vogelos Laboratories of the Institute for Advanced Science and Technology along with Skirkanich Hall, the new home of Bioengineering

FACULTY DIRECTOR

RAYMOND J. GORTE, PhD
 Chair, Graduate Group in Chemical and Biomolecular Engineering;
 Russell Pearce and Elizabeth Crimian Heuer Professor of Chemical and Biomolecular Engineering

Dr. Gorte is an internationally-known researcher whose work on fuel cells has been acclaimed in the scientific community and featured on NPR Science Friday, Reuters, and MSNBC. He is also well-known for his research on zeolite acidity and for metal-support effects, especially with ceria-supported precious metals, used in automotive emissions control. He is author of more than 250 publications in refereed journals and is currently focusing his studies on ceria-based catalysts and anodes for solid-oxide fuel cells.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN

Computer Graphics and Game Technology

The game, film, and video industries need highly-skilled professionals to meet the growing demand for more interactive entertainment and computer-animated special effects. Penn offers a unique academic program for multi-skilled professionals that blends art with computer science and technology. The Master's Program in Computer Graphics & Game Technology (CGGT) is exciting, innovative, and nationally recognized for its success in preparing students for leadership careers as designers, technical animators and directors and game programmers. Our curriculum gives students first-hand experience in the latest graphics and animation technologies, interactive media design principles, product development methodologies, and entrepreneurship.

The CGGT Program prepares students for leadership careers in the fields of interactive entertainment, computer-animated films and visual effects. Our alumni are found in major game, film, and video companies such as Disney, DreamWorks Animation, Electronic Arts, Acclaim, and Crystal Dynamics.

CURRICULUM

You must complete a total of ten course units.

Requirements:

- 2 Creative Arts and Design
- 4 Computer Science, Systems, and Technology
- 1 Product Design, Development and Production
- 1 Business and Entrepreneurship
- 1 Elective course in any of the areas above

Dual MCIT/CGGT degree:

Applicants who do not have an undergraduate degree in computer science must first complete the six core courses required for the Master's Program in Computer and Information Technology (MCIT) prior to admission to the CGGT Master's Program.

PROGRAM HIGHLIGHTS

- Access to Penns Center for Human Modeling and Simulation, internationally recognized for cutting-edge research in 3D computer graphics, human simulation and the behavioral animation of embodied intelligent agents.
- A major advantage of our program is that students have access to Penn's Center for Human Modeling and Simulation, internationally recognized for cutting-edge research in 3D computer graphics, human simulation and the behavioral animation of embodied intelligent agents.

FACULTY DIRECTOR

STEPHEN LANE, PhD
Director, Computer Graphics and Gaming Technology Master's Program; Lecturer in Computer and Information Science

Dr. Lane is an accomplished researcher, educator and entrepreneur with over 18 years of experience designing, developing and commercializing advanced 3D graphics and animation technology for use in interactive entertainment, computer games, virtual reality and distributed simulation and training applications. Dr. Lane's responsibilities have ranged from basic technology development to computer hardware and software design, project management and business development. Dr. Lane also has an active research agenda with interests in the areas of robotics, physically based character animation, embodied intelligent agents and virtual reality user interfaces—specifically the intersection of control theory, artificial intelligence and computer animation meet. Drawing on his background and experiences in the game and simulation industries, Dr. Lane currently teaches courses on computer animation, advanced topics in computer graphics and animation and computer game design and development.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN

Computer and Information Science

Information technology is revolutionizing not only business, science, and our personal lives but also our understanding of nature, mind, and society. A revolution that began in 1946. Here. At Penn. Birthplace of ENIAC: the world's first electronic, large-scale, general-purpose digital computer.

The MSE Program in Computer and Information Science, ranked as one of the nation's top programs, prepares students to be tomorrow's innovators, leaders, and visionaries in this rapidly-expanding field. Our multi-disciplinary program allows you to pursue your own career interests. From telecommunications, computational linguistics, and bio-informatics to Artificial Intelligence, software engineering, and financial management. They can be found in major companies such as Microsoft, Lockheed Martin, Oracle, and UBS Securities Japan Ltd. or pursuing doctoral degrees at major research universities such as Penn and Drexel.

CURRICULUM

You must complete a total of ten courses: four core courses and six electives.

Core courses cover the following fields:

- Software Foundations
- Computer Architecture
- Analysis of Algorithms
- Software Systems
- Theory of Computation

Financial curriculum:

For course requirements, go to:
www.cis.upenn.edu/grad/financial.shtml

Software engineering curriculum:

For course requirements, go to:
www.cis.upenn.edu/grad/software.shtml

Sample elective courses include:

- Systems Analysis and Design*
- Simulation and Dynamic Competitive Strategy*
- Decision Support Systems*
- Information Systems: Representation & Discovery*
- Dynamic Programming & Stochastic Models*
- Corporate Finance*
- Probability*
- Engineering Entrepreneurship
- Information & Community Technology for Education & Development

*Enrollment must be pre-approved by The Wharton School.

PROGRAM HIGHLIGHTS

Access to interdisciplinary institutes, laboratories and centers such as the Institute for Research in Cognitive Science and the Center for Bioinformatics

FACULTY DIRECTOR

RAJEEV ALUR, PhD
Chair, Graduate Group in Computer & Information Science; Zinman Family Professor of Computer & Information Science

Dr. Alur's areas of research include formal modeling and analysis of reactive systems, hybrid systems, model checking, software verification, logics and automata, and design automation for embedded software.

Author/co-author of more than 150 publications, invited lecturer at more than 40 symposia and workshops, and holder of six patents, Dr. Alur has chaired/co-chaired numerous scientific meetings such as the International Conference on Computer-Aided Verification, the International Conference on Hybrid Systems: Computation and Control; and the IEEE Symposium on Logic in Computer Science. He currently serves as chair of the ACM Special Interest Group on Embedded Systems.

His many honors include the National Science Foundation's CAREER (1997) and ITR (2001) awards, Alfred P. Sloan Faculty Fellowship (1999), and designation as a highly-cited scientist by the Institute for Scientific Information (2005).

MASTER OF**Computer and Information Technology**

designed for students and professionals with minimal or no prior computing experience

The Master's Program in Computer And Information Technology (MCIT) is a new and already widely-hailed program specifically designed for students and professionals with minimal or no prior computing experience. Information technology is revolutionizing our fast-paced, high-tech global society...changing the way we live, work, and do business; creating new fields, new industries, new careers unheard of ten—even five—years ago.

Our MCIT program gives you the expertise you need to understand and to succeed in today's highly innovative and competitive workplace. IT graduates can be found in major companies such as Microsoft, GlaxoSmithKline, GE Capital, and Lehman Brothers, or pursuing doctoral degrees at major research universities such as Penn and Drexel.

The MCIT Program prepares students and industry professionals who want to begin/advance a career in information technology or prepare for doctoral studies in computer science.

CURRICULUM

You must complete a total of ten courses: six core courses and four elective courses selected from Computer Information Technology and Computer Information Systems course offerings.

Required core courses include:

- Programming Languages & Techniques I-II
- Mathematical Foundations of Computer Science
- Introduction to Computer Architecture
- Digital System Organization & Design
- Theory of Computation

Sample elective courses include:

- Internet and Web Systems
- Software Systems
- Database and Information Systems
- Computer and Network Security
- Introduction to Bioinformatics

Upon successful completion of the MCIT program, you may apply to our MSE Program in Computer and Information Science. Six additional graduate courses are required for the MSE-CIS degree.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN**Electrical Engineering**

Interconnections between electrical and systems engineering are creating a fresh vision of knowledge, its uses, and its users. Proof of this exciting synergy is evident in the recent merger of Penn's electrical engineering and systems engineering departments.

The M.S.E. Program in Electrical Engineering gives you the theoretical foundation and the interdisciplinary skills needed to deal with the new ideas and new applications that are the hallmarks of 21st Century Electrosience.

A major advantage is that our MSE Program allows you to tailor your education to your own interest and goals. from Electromagnetics and Photonics, sensors and MEMS to VLSI and Nanotechnology. A telling measure of our success is the success of our graduates. They are found in major companies such as Alcatel/Lucent or Pursuing Doctoral Degrees.

CURRICULUM

You must complete a total of ten graduate course units: seven courses in the broad area of Electrical Engineering from the department's offerings, and three electives.

Graduate courses for EE students in the ESE department cover a wide range of topics including:

- electromagnetics and photonics
- VLSI
- MEMS and nanotechnology
- systems and control
- communications and signal processing

Thesis option:

You may substitute a thesis for two elective courses.

PROGRAM HIGHLIGHTS

Access to Electrical and Systems Engineering's fifteen research laboratories such as the renowned General Robotics, Automation, Sensing and Perception (GRASP) Laboratory; The Ackoff Center for Advancement of Systems Approaches; The Distributed Systems Laboratory; The Microfabrication Laboratory; and The Multimedia And Networking Laboratory

FACULTY DIRECTOR

DANIEL D. LEE, PhD
Chair, Graduate Chair in Electrical and Systems Engineering; Associate Professor of Electrical and Systems Engineering; Bioengineering

Dr. Lee is a visionary researcher and dedicated educator who follows in Penn's tradition of putting knowledge to use for society.

His research focuses on understanding the general principles that biological systems use to process and organize information, and on applying that information to build better artificial sensorimotor systems. His current projects include: learning applied to ground robots, legged locomotion, and robocup soccer 4-legged team. He also leads Penn's robot team in the Annual Robocup Competition.

Invited lecturer at national and international colloquia, symposia, and workshops and holder of three patents, Dr. Lee is author of sixty publications and refereed conference proceedings.

In Recognition Of His Outstanding Research, He Has Been Awarded the NSF Career Award, The National Academy Of Engineering Frontiers Of Engineering Award, And The University Of Pennsylvania Research Foundation Award.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN**Integrated Product Design**

The University of Pennsylvania's Integrated Product Design program builds the skills to rethink, reinterpret, redesign and reconstruct a wide range of products and their complementary business models. The program draws on the strengths of three internationally recognized schools within the University: the School of Engineering & Applied Science, The Wharton School, and the School of Design.

The graduate courses that make up the program adopt an interdisciplinary point of view, and are taught by professors from all three schools. Collaborative team projects and student-driven independent projects complement the core courses to give students both a solid grasp of the fundamentals and a deep understanding of the nuances of these fields.

The program is designed to cultivate professionals that possess both a breadth of knowledge and a depth of expertise in a specialty, in order to effectively bridge the domains of technology, manufacturing, business, aesthetics, and human-product interaction. The guiding philosophy of the program is not only to teach students to create products, but to understand and address the social, environmental and experiential contexts of those products, so that product design can be harnessed as a force for the greater good.

COURSES INCLUDE

- Creativity in Engineering & ID
- Product Design
- Design of Mechatronic Systems
- Design for Manufacturability
- Industrial Design
- Furniture Design
- Marketing Research
- Applied Probability Models in Marketing
- Operations Strategy and Process Management
- Master's Thesis

DEGREE REQUIREMENTS

A Masters of Science in Engineering in Integrated Product Design requires ten courses, including the three course Master's Thesis. Students who do not have the requisite background in the three core areas, Engineering, Design Arts and Marketing and Finance, may be required to enroll in additional background courses.

Prior to the matriculation in the Integrated Product Design M.S.E. degree program, candidates must have completed an undergraduate degree in one of the three areas: business, design arts, or engineering from a recognized program and obtained a minimum grade point average of 3.0 out of 4.0.

<http://www.me.upenn.edu/ipd/>

FACULTY DIRECTOR

MARK YIM, PhD
Associate Professor; Gabel Family
Term Junior Professor; Undergraduate
Curriculum Chair

Research Interests:

- Modular reconfigurable robots and locomotion, PolyBot.
- MEMS and batch fabrication techniques. brute force digital time optimal control.

Education:

- Stanford University, PhD Mechanical Eng.
- Stanford University, MS Mechanical Eng.
- Johns Hopkins University, BS Engineering Mechanics

MASTER'S DESIGN THESIS

The Master's Design Thesis is a 3 CU research and studio project, expected to be achieved in 3 semesters. The project is an opportunity to manifest a synthesis of art, technology and business strategy, and to push the envelope of design possibility in the context of user need and market forces. The project will involve the development of a product from concept, user need, marketing analysis, design implementation to prototype and feasibility testing. The thesis project is supervised by a faculty member in SEAS, Wharton, or Design, or an external sponsor with approval by the program Director.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN**Materials Science and Engineering**

Penn is a pacesetter. We were one of the first universities to establish a center for materials research in the 1960's. By remaining at the forefront of technology innovations, this center, the Laboratory for Research on the Structure of Matter, has grown to be one of the largest in the nation.

We're still setting the pace. Opening up new fields in materials science. Preparing tomorrow's leaders. Putting our knowledge to practical use in today's high-tech society.

The M.S.E. Program in Materials Science and Engineering prepares students to be leaders, innovators, and visionaries in the materials revolution that is being driven by discoveries that cross the boundaries of physics, chemistry, and biology, such as in the growing field of nano-bioscience.

Our program, grounded in the latest research findings, provides a rigorous in-depth education in the fundamentals and applications of technologically relevant materials. A major advantage of our multidisciplinary program is that you can tailor your education to your own professional and career goals. From ceramics, polymers, and metals to nanostructured and soft materials.

A telling measure of our success is the success of our graduates. They are to be found in leadership positions in industries that range from electronics, manufacturing, and communications to transportation and energy, or pursuing doctoral degrees at Penn and other top-ranked research universities.

CURRICULUM

You must complete a minimum of ten graduate courses:

- Five required courses in materials science
- Five approved elective courses selected from the graduate curricula in engineering, physical sciences or business.

Thesis masters:

You may substitute a thesis for three electives.

www.seas.upenn.edu/mse/grad/index.html

PROGRAM HIGHLIGHTS

- Access to research and resources of Penn's renowned interdisciplinary centers: Laboratory for Research on the Structure of Matter designated as an NSF Materials Science Research and Engineering Center, Nano Science and Engineering Center (Nano/Bio Interface Center), Nano Technology Institute, the Penn Regional Nanotechnology Facility, and the Institute for Medicine and Engineering
- Ready access to National Laboratories and their facilities, including synchrotron radiation and neutron sources

FACULTY DIRECTOR

RUSSELL J. COMPOSTO, PhD
Chair, Graduate Group in Materials Science and Engineering; Professor of Materials Science and Engineering; Chemical and Biomolecular Engineering and Bioengineering

Dr. Composto's areas of research include polymer surfaces and interfaces, cell/organic interfaces, polymer based nanocomposites, polymer coating and adhesion, wetting and phase separation in polymer blends, and SAM/peptide tethered surfaces. He is the director of The Composto Polymer Research Group which is affiliated with the Laboratory for Nanoscience and Molecular Engineering at Interfaces. Author/co-author of over a 100 publications in refereed journals and conference proceedings, Dr. Composto is a Fellow of the American Physical Society (APS) and vice-chair elect of the Polymer Division of APS.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN

Mechanical Engineering and Applied Mechanics

“The icon of mechanical engineering at Penn today is just as likely to be a cell, a nanotube, or a surgical robot, as a gear or an engine.” What distinguishes our graduate program in Mechanical Engineering and Applied Mechanics from those of peers is that we know no boundaries in exploring the connections between engineering and fields such as science, the life sciences, and business.

The Master of Mechanical Engineering and Applied Mechanics (MEAM) is innovative, unique, and nationally recognized for its excellence. We are at the forefront in preparing students for leadership careers by providing opportunities to work in emerging and interdisciplinary areas that are fueling exciting advances in technology.

Established in 1872, the Mechanical Engineering and Applied Mechanics program continues its tradition of excellence in research and education. The M.S.E. degree program is managed by a Graduate Group which, in addition to Mechanical Engineering faculty, consists of prominent faculty members from diverse disciplines such as Material Science, Bioengineering, Chemical Engineering, Electrical and Systems Engineering, Computer and Information Science, School of Design, and the Wharton School. The Graduate Group structure provides an ideal environment for interdisciplinary research and education tailored to meet the complex technological challenges of this millennium.

Graduates of our program are in high demand in every field that requires advanced understanding of mechanical engineering principles. They are to be found in industry, laboratory facilities, and government agencies, or pursuing doctoral studies at Penn and other major universities.

CURRICULUM

Students are required to complete 10 courses.

The program requirements include:

- 5 MEAM core courses
- 2 engineering mathematics courses
- 3 electives
- Seminar requirement (full-time students only).

Thesis option:

You may substitute research for up to three MEAM core courses.

Areas of concentration:

- Design and Manufacturing
- Mechanical Systems: Robotics, and Microelectromechanical Systems (MEMS)
- Heat Transfer and Fluid Mechanics with applications in energy production, material processing, and the electronics industry
- Mechanics of Materials
- Biomechanics

Opportunities are also available for students to customize their program with the guidance and approval of their academic advisor

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN

Robotics

The MSE Program in Robotics is a new and unique program administered by Penn’s General Robotics, Automation, Sensing and Perception (GRASP) Laboratory, recognized as one of the nation’s premier research centers.

Multi-disciplinary in scope, the program provides an ideal foundation for what today’s experts in robotics and intelligent systems need to know — from artificial intelligence, computer vision, control systems, dynamics, and machine learning to design, programming and prototyping of robotic systems.

Grounded in up-to-the minute research findings, the MSE program in Robotics offers you an ideal foundation for a successful career in robotics, defense, aerospace, and automotive industries; government agencies; or academe.

CURRICULUM

You must complete a total of ten courses: four core and six electives.

Core courses cover the following fields:

- Robotics and Animation
- Control Systems Design
- Computer Vision
- Machine Learning

Sample elective courses include:

- Learning in Robotics
- Vision and Learning
- Hybrid Systems
- Motion Planning
- Mechatronics
- Biomechanics

Thesis option:

You may substitute a thesis for two elective courses.

PROGRAM HIGHLIGHTS

- Opportunities for research projects in robotics and related fields in the world-famous GRASP Lab
- Participation in exciting competitions such as the international Robocup soccer tournament
- Weekly GRASP seminars
- Professional networking with peers in industry and academe

FACULTY DIRECTOR

GEORGE J. PAPPAS, PhD
Director, GRASP Laboratory;
Professor of Electrical and
Systems Engineering

Dr. George J. Pappas’s research focuses on the interface of control theory with computer science. His principal research interests are hybrid systems, embedded systems, hierarchical and distributed control systems, with applications to unmanned aerial vehicles, flight management systems, distributed robotics, and biomolecular networks.

Author of numerous scholarly publications, Dr. Pappas has been awarded, among other honors, the National Science Foundation Presidential Early Career Award for Science and Engineering and the National Science Foundation Career Award.

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN Systems Engineering

“Smart” buildings and highways. Environmental monitoring. Sensor networks. Hybrid systems. These are but a few of the many ways in which electrical and systems engineering are converging, especially at Penn. Proof of this exciting synergy is evident in the recent merger of our Electrical and Systems Engineering Departments. The M.S.E. Program in Systems Engineering (SE), grounded in the intersection of electrical and systems engineering, is best positioned to give students the in-depth theoretical foundation and interdisciplinary skills required by the growing complexity of technological systems.

Our flexible curriculum allows you to tailor your studies to your personal interests and goals. From signal processing, optimization, simulation, control and cybernetics to complex adaptive systems, stochastic processes and decision sciences.

Our graduates are found in leadership positions in major companies like Lockheed-Martin or pursuing doctoral degrees at Penn or other major research universities.

The M.S.E. Program is designed for highly-qualified students who will become leaders in the increasingly complex field of systems engineering. Entering students generally have baccalaureate degrees in the engineering, mathematical, physical or economic sciences. Students with degrees in other fields who have expertise in quantitative and computer analyses also enter the program.

CURRICULUM

You must complete a total of ten graduate course units: four required core courses, two ESE courses, one SEAS course and three electives in SEAS, SAS or Wharton.

Required core courses:

- Introduction to Probability and Statistics
- Economic Systems Analysis
- Simulation Modeling and Analysis
- Introduction to Optimization Theory

Thesis option:

You may substitute a thesis for two elective courses.

SE/TCOM dual-degree program:

You may pursue two degrees simultaneously: the Master of Science in Engineering (Systems Engineering) and the Master's in Telecommunication and Networking. You must meet the requirements for each degree but certain courses may count toward both degrees..

MASTER OF SCIENCE IN ENGINEERING PROGRAM IN Telecommunications and Networking

As telecommunications becomes both more complex and more influential in the way we work, live, and do business, the demand of corporate, nonprofit and government sectors for qualified professionals is rapidly increasing.

Penn's Telecommunications and Networking Program is at the forefront in preparing leaders who will shape the future of this dynamic field. The Telecommunications and Networking (TCOM) Program at Penn is unique, innovative, and best positioned to offer working professionals and students the in-depth theoretical foundation and interdisciplinary skills required by the growing complexity of the field.

Our TCOM curriculum has two major advantages. One is the multidisciplinary approach of its faculty: scientist-engineers from Penn Engineering and business experts from the Wharton School. The other is flexibility in course selection and scheduling. TCOM graduates are found in leadership positions in major companies such as Cisco and Microsoft or pursuing doctoral degrees in telecommunications and networking and related fields.

The TCOM Program is designed for highly-qualified students whose goal is to expand their professional skills, prepare for doctoral studies, or advance their careers. Applicants should have a strong background in mathematical analysis.

Penn's TCOM Program is outstanding in the quality of its interdisciplinary leadership. The program faculty are nationally recognized as authorities in their fields. They are scientist-engineers from the Departments of Electrical & Systems Engineering and Computer & Information Science; business experts from the Wharton School; and leaders from industry. Innovators in the lab and in the classroom, the TCOM faculty have garnered a host of awards for their work. They include chaired professors, IEEE and ACM Fellows, editors of scholarly journals, recipients of NSF Career Awards and Lindback and Warren Awards for distinguished teaching. They are in high demand as consultants and advisors by major corporations and government agencies. Their discovery-oriented, problem-solving approach to the rapidly-evolving field of telecommunications and networking is mirrored in the rigor, breadth, and relevance of their teaching.

CURRICULUM

You must complete a total of ten graduate course units: three required core courses and seven elective focus courses.

Core courses are in the following areas:

- Basic Networking
- Advanced Networking
- Choice of three TCOM electives

Five electives:

Choice of any remaining TCOM elective course(s) or relevant SEAS or Wharton course(s)

Thesis option:

You may substitute a thesis for two elective courses.

Dual-degree program:

You may pursue two Master's degrees simultaneously: one in Telecommunication and Networking and another in Computer and Information Science, Computer and Information Technology, or Systems Engineering. You must meet the requirements for each degree but certain courses may count toward both degrees.

PROGRAM HIGHLIGHTS

- Course advising, teaching, thesis supervision and mentoring by eminent Penn Engineering and Wharton faculty
- Strong ties to industry through adjunct faculty drawn from companies such as AT&T Labs, Lucent Technologies, Telcordia, and Agere
- Class schedules responsive to the time constraints of working professionals and part-time students
- Hands-on experience with utilities provided with UNIX and Linux workstations, as well as additional software packages and languages
- Access to our renowned research laboratories including a distributed systems laboratory; a general robotics, automation, sensing, and perception lab, a multimedia and network laboratory; and a telecommunications laboratory
- A multidisciplinary approach that mirrors the teamwork concept prevalent in today's business world
- Industrial and business networking that offers opportunities for internships and employment

FACULTY DIRECTOR

SALEEM KASSAM, PhD
Solomon & Sylvia Charp Professor of Electrical Engineering.

Current research interests are in Communications Systems, Wireless Channels, Blind Signal Separation, Channel Equalization, and in High-Resolution Imaging Arrays. Applications of this research include wireless communications, data transmission, image analysis, radar & sonar, medical applications including ultrasound imaging and brain activity monitoring.

PhD PROGRAM IN**Bioengineering**

Bioengineering employs engineering principles of analysis and design to solve problems in medicine and biology. Penn's PhD in Bioengineering builds a solid foundation in science and develops powerful methods for understanding basic physiological processes. Its fundamental goal is to present a broad, flexible curriculum that gives students experience in a wide range of subject areas and intellectual approaches.

Focusing on biological and medical sciences, the program combines the resources of Penn's School of Engineering, School of Medicine, School of Arts and Sciences, School of Veterinary Medicine, School of Dental Medicine, School of Nursing, and the University Hospitals. This unique composition gives students the opportunity to work in emerging and interdisciplinary areas relevant to Bioengineering.

The Bioengineering Department is pioneering in a wide range of research areas by enabling students to work, develop, and lead in bioengineering research and practice. It has consistently been ranked as one of the nation's best in preparing students for careers. Graduates function creatively and independently in many fields related to biomedical technology, including academia, medicine, government, and industry.

COURSE REQUIREMENTS

All doctoral students are required to take the following:

- 2 courses in biomedical science. Many students take one course in cell biology and one in systems physiology to broaden their biological background and emphasize the quantitative aspects of living systems.
- 5 course units in bioengineering fundamentals devoted to analytical methods, modeling, and experimental methods and data analysis.
- 2 course units in mathematics.
- Bioengineering research rotation. A minimum of 1 is required.
- Bioengineering seminar. A minimum of 2 semesters is required, usually in the first year.
- Thesis Research, balance of University requirements.

Total: 9 courses, 1 rotation, and 2 seminars

TYPICAL PhD TIMELINE

- Most students will complete the required lab rotations and choose an advisor by Spring of their first year.
- Students will complete the Qualifying Exam over the summer of their first year and no later than November of the fall semester of the second year.
- Students will form a thesis committee together with their advisor during their second year of study.
- Students will complete the thesis proposal during the fall of the third year of the program.
- During subsequent years, it is expected that students make continuing progress with their research towards their doctoral dissertation.
- Most students will complete the program in 5 or 6 years.

PROGRAM HIGHLIGHTS

Along with offering advising, seminars, and informal meetings with the Department Chair and Graduate Group Chair to solicit student input and exchange information, the department strongly supports the Graduate Association of Bioengineers (GABE). GABE is a student-run association that represents the entire graduate student community in BE and organizes both social and professional Bioengineering events, sometimes in collaboration with the student chapter of BMES (Biomedical Engineering Society).

Joint PhD degree programs offer an exciting opportunity to match the aspects of research excellence and clinical care in specialized fields of human health (MD/PhD), veterinary medicine (VMD/PhD), and dental medicine (DMD/PhD).

POSSIBLE AREAS OF CONCENTRATION

- Bioinformatics
- Biomaterials
- Cardiovascular & Pulmonary Cell & Tissue Mechanics
- Cellular Engineering
- Cellular and Molecular Imaging
- Computational Neuroscience
- Drug & Gene Delivery
- Experimental Neuroscience
- Imaging Theory & Analysis
- Injury Biomechanics
- Medical Imaging & Imaging Instrumentation
- Molecular Engineering
- Orthopaedic Biomechanics
- Theoretical & Computational Bioengineering
- Tissue Engineering

PhD PROGRAM IN**Chemical and Biomolecular Engineering**

Penn's Chemical and Biomolecular Engineering Department is the nation's oldest continuously operating degree-granting program in Chemical Engineering. Since its inception in 1893, it has been at the forefront of defining the frontiers of the field, and today the Graduate Group in Chemical and Biomolecular Engineering ranks among the nation's finest.

The PhD in Chemical and Biomolecular Engineering is primarily a research-oriented degree for students who show promise for original contributions to the theory and practice of chemical and biomolecular engineering. The degree is crucial for those planning to teach and for those planning to embark on research careers. Doctoral candidates are expected to show superior capability for independent work and study.

Graduates pursue successful careers and provide leadership in academia and in industrial settings—not only in the traditional areas of chemicals, oil, and gas but also in fields ranging from pharmaceuticals, biotech, advanced materials, and electronics.

The department consists of 15 distinguished faculty members who maintain research programs in a wide range of areas. Among them are biomolecular engineering, catalysis and reaction engineering, systems engineering, and surface and colloid science.

COURSE REQUIREMENTS

A minimum of 20 graduate courses is required for the doctorate. At least 10 must be formal graduate courses and include the following six courses:

- Applied Engineering Mathematics I
- Applied Engineering Mathematics II or Numerical Methods and Modeling
- Advanced Thermodynamics
- Kinetics and Reactor Design
- Transport Processes I
- Transport Processes II

QUALIFYING EXAMINATIONS

Every first-year student in the PhD program must take the qualifying examination. The exam covers fundamental chemical engineering principles and may also include a research proposal. Based on the student's performance on the exam, on in-class performance, and on research progress during the spring semester, the department makes a recommendation as to whether or not the student will be welcomed into the PhD program.

PROGRAM HIGHLIGHTS

Research facilities include:

- Advanced Chemical Technologies Laboratory
- Cell Mechanics and Colloidal Self-Assembly Laboratory
- Biophysical Engineering Laboratory
- Cell Adhesion and Biophysics Laboratory
- Environmental Research Laboratory

PhD PROGRAM IN

Computer and Information Science

Penn is taking the lead in addressing the educational and research questions that surround computing and information technology. The PhD program in Computer and Information Science welcomes candidates with strong training in any of the disciplines related to modern information processing, with an emphasis on computer science and mathematics. The curriculum is designed to develop the intellectual skills essential for the rapidly changing character of research and to meet the demands of academe and industry.

Doctoral studies in the department offer rewarding exploration and research. Research opportunities span theoretical and application topics, including robotics, vision, natural-language processing, databases, formal methods, real-time systems, computer architecture, machine learning, programming languages, graphics, network security, software engineering, and bioinformatics—as well as interdisciplinary collaborations with fields such as biology, genetics, linguistics, mathematics, and electrical engineering. Students develop their own advanced study focus, working with faculty mentors on topics ranging from the core computer science discipline to diverse scholarly interactions within the School of Engineering and the University.

Research laboratories offer myriad possibilities for exploration. Presentations by outstanding leaders in their fields at departmental and laboratories' colloquia provide rigor, breadth, and relevance to the research and education experience. The University of Pennsylvania's 12 schools and 50 research centers create an academic environment whose synergy informs research and education in the department. Faculty members prepare doctoral students to be tomorrow's innovators, leaders, and visionaries.

COURSEWORK

The PhD degree requires a minimum of 20 course units. Students must take 4 seminar courses during their studies at Penn: 2 related to the dissertation research area and 2 in an unrelated area. The other 16 units are a combination of additional coursework, independent studies, thesis research, and transfer credits. Eight graduate course units—including courses for which a master's degree was awarded—may be transferred from another institution.

THE WRITTEN PRELIMINARY EXAMINATION

Doctoral students are required to pass the written preliminary examination, which tests proficiency in core areas of computer science, as well as the special-area exam which tests each candidate's analytical and presentational abilities.

The purpose of the written preliminary exam is to ensure that students pursuing the PhD degree have a graduate-level competence in the fundamentals of computer science.

PROGRAM HIGHLIGHTS

PhD PROGRAM IN

Electrical & Systems Engineering

The Department of Electrical and Systems Engineering (ESE) is a leader in electrosience, systems science, and network systems and telecommunications. Electrosience includes electromagnetics and photonics, sensors and MEMS, VLSI, and nanotechnology. Systems science covers signal processing, optimization, simulation, control and cybernetics, complex adaptive systems, stochastic processes, and decision sciences. Network systems and telecommunications is concerned with networks, communications, logistics and manufacturing, transportation, and infrastructure engineering.

The PhD program welcomes candidates with a strong background in science and engineering who are interested in pursuing an academic doctoral degree. The objective of this program is to help students develop skills needed to perform independent research and teaching in an exciting intellectual environment. The students will work with world-class faculty advisors and mentors. Our research laboratories provide ample opportunities for students to work with other students and faculty to develop cutting-edge theories and technologies in collaboration with other departments and schools within the University.

COURSE REQUIREMENTS

Doctoral students must complete a minimum of 20 course units, including graduate-level courses, independent-study courses, and research. At least 16 course units must be nonresearch graduate-level courses, including no more than 2 independent-study units. The coursework of each PhD student must be grouped into one major area of study and two minors:

Depth major: At least 5 graduate-level courses in areas supporting the student's research.

Breadth minor: At least 2 graduate-level courses distinct from the primary research area. The courses may be thematically linked in sequence or not, but both must be distinct from the primary research area. Independent studies cannot be used in this category.

Mathematics requirement: At least 2 graduate-level courses satisfying formal mathematical reasoning. Courses that satisfy this requirement include graduate courses in mathematics, engineering mathematics, statistics, or discrete mathematics. Independent studies cannot be used in this category.

The remaining course units may be added to the above groups or in a free-electives category.

QUALIFYING EXAMINATIONS

The qualifying examination is a written exam designed to evaluate each student's understanding of fundamentals in eight areas:

- Linear systems
- Probability
- Electromagnetics and optical fields
- Solid-state physics and devices
- Communications
- Networking
- Optimization
- VLSI and microelectronics

PROGRAM HIGHLIGHTS

PhD PROGRAM IN

Material Science & Engineering

The Department of Materials Science and Engineering is recognized as a leader and innovator in materials research and education. Faculty members and students have received many top awards in their research fields, the educational program has produced leaders both in industry and in academia, and the University is ranked among the top five in the United States.

In 1960, Penn became one of the first universities to establish a center for materials research. That center, the Laboratory for Research on the Structure of Matter (LRSM), is now one of the nation's largest and is funded as a National Science Foundation (NSF) Materials Research Science and Engineering Center. Faculty members also lead the NSF-supported Nanoscale Science and Engineering Center (NSEC), the Center on Molecular Function at the Nano/Bio Interface, and Pennsylvania's Nanotechnology Institute, which focuses on the research, development, and commercialization of real-world nanotechnology applications.

Thanks to the long tradition of support from the NSF, on-site facilities have outstanding core techniques—such as electron and scanning probe microscopy—as well as unique capabilities for structural and compositional analysis. Because of Penn's location, students have ready access to National Laboratories and their facilities, including synchrotron radiation and neutron sources.

COURSE REQUIREMENTS

Doctoral students must complete at least 10 approved courses. They take 7 of those courses during the first year: 3 core courses—Structure of Materials, Thermodynamics, Phase Transformations—and 4 others selected according to their background and area of interest. These courses can come from engineering or the physical and biological sciences. Students take 3 additional courses after the first year.

QUALIFYING EXAMINATION

To qualify for the PhD program, students who satisfy the PhD academic requirement must also pass the Oral Qualifying Examination. The examination, held at the end of May after the second semester, tests their potential in identifying and investigating significant research questions and the depth of their understanding and intellectual integration of the materials covered in the seven approved courses.

As part of the exam, students write and defend a paper based on their chosen area of focus in materials research. The paper must incorporate a thorough analysis of two or more significant research papers in the published scientific literature and include a research plan. Students should be able to debate the fundamental background, significance, and results of the research paper and the research plan, illustrate its importance in materials research, and demonstrate that they are able to integrate the knowledge gained in their coursework.

PROGRAM HIGHLIGHTS

Research interests of our faculty span all types of materials and phenomena, and joint research programs exist with many other schools and departments, including Physics, Chemistry, Electrical Engineering, Chemical Engineering, Mechanical Engineering, Bioengineering, and the Medical School.

The cornerstone of the program is flexibility, and its hallmarks are excellence and collaboration. Our graduate students hold undergraduate degrees in many majors, and students can tailor their education according to their interests and goals to create an individualized curriculum.

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PhD PROGRAM IN

Mechanical Engineering and Applied Mechanics

Established in 1872, the Mechanical Engineering and Applied Mechanics program continues its tradition of excellence in research and education. Our graduate program emphasizes fundamental concepts and their use in applications.

A distinguished and diverse faculty of thirty-one, including colleagues affiliated with other departments in the School of Engineering and Applied Science (SEAS), Medical School, and Wharton Business School, offer fundamental and advanced courses. Many of the research theses of our students are co-advised by these faculty drawn from diverse disciplines. These prepare the graduate student both for research at the doctoral level and for high level professional employment in challenging and stimulating work environments. After their graduation, many of our students have assumed leadership roles in industry and academia.

While our curriculum is geared towards giving the students a firm grasp on fundamentals in traditional subjects of mechanical engineering, our research is carried out in cutting-edge areas such as those listed in the possible areas of concentration. Many fellowship opportunities are available each admission cycle. Fellowship packages include, tuition (and fees), generous monthly stipend, and health insurance.

CURRICULUM

The Ph.D. requirements include the completion of a minimum of 20 course units of graduate level work, satisfactory performance in the Ph.D. related exams, presentation of a departmental seminar, completion of the teaching practicum, and the submission and successful defense of an original and significant dissertation. The required 20 course units may include research units.

CORE COURSE REQUIREMENTS

- 3 engineering
- 1 course in continuum mechanics
- 1 course in dynamics
- 1 course in transport processes
- 6 seminar course units

DISSERTATION

There are several steps to the final step of receiving your MEAM PhD—the dissertation. It begins with the presentation and approval of a thesis proposal. During the course of research, all students are required to present a departmental seminar on their research. After the research is complete the PhD candidate must submit their dissertation for review and must be publicly presented and defended. After one final submission, if approved, the student will be granted his doctorate.

AREAS OF CONCENTRATION

- Biomechanics
- Cell & Molecular Biomechanics
- Computational Mechanics
- Design and Manufacturing
- Dynamic Systems and Control
- Fluid Mechanics
- Micro and Nano Fluidics
- Micro Electronic Mechanical Systems
- Mechanical Systems
- Mechanics of Materials
- Micro- and Nano-mechanics
- Robotics
- Thermal Sciences and Energy Conversion

All PhD students must complete a two-semester teaching practicum.

They may work on the practicum any time during their PhD career but generally participate during their second year, assisting with one course per semester. It is expected that each student will spend about 15 hours per week on the teaching practicum. Typically, students—

- Attend seminars emphasizing teaching and communication skills
- Lead recitations
- Conduct tutorials
- Supervise undergraduate laboratory experiments
- Develop instructional material and instructional laboratories
- Grade homework, laboratory reports, and examinations

A teaching training seminar is usually conducted the day before the first day of classes of the fall semester. In addition, Penn's Center for Teaching and Learning offers workshops and teaching certificates.

Practica are assigned by the graduate coordinator and the graduate chair, taking into consideration specific requests from faculty or students. The graduate coordinator and the graduate chair make great effort to assign practica in a manner consistent with each student's research and teaching interests and with the department's teaching needs. Satisfaction of the practicum requirement is based on end-of-semester evaluations by course instructors.

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