Table of Contents

2023-2024 Engineering Graduate Bulletin

2023-24 Engineering Graduate Bulletin
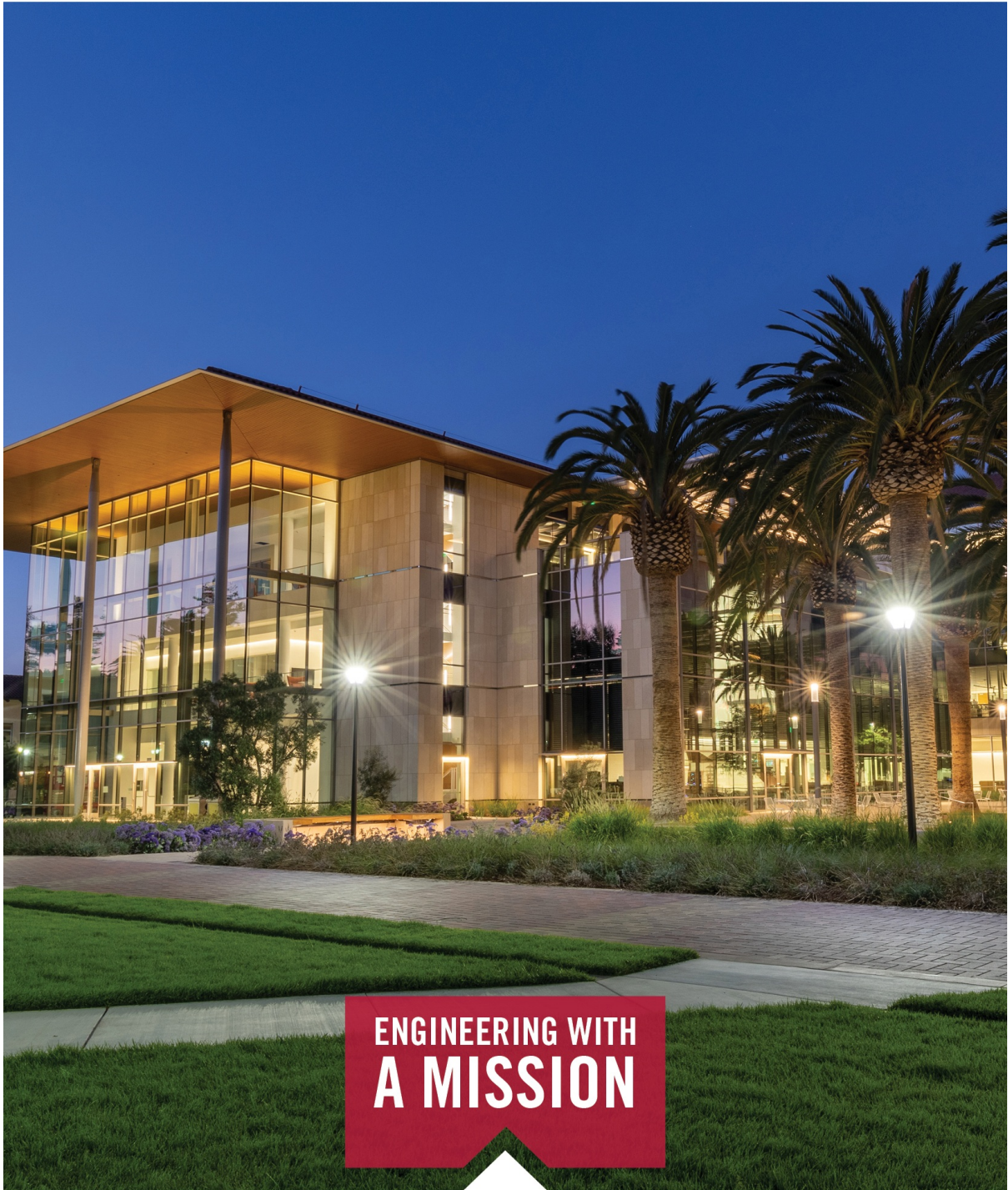
ENGINEERING WITH
A MISSION

Santa Clara
University
School of Engineering

Letter from the Dean

On behalf of the School of Engineering faculty and staff, I welcome you to a new year in your graduate school journey. Some of you are continuing the engineering education path that you started with us as an undergraduate. Some might be seeking to change the trajectory of your engineering career. Still, some of you might be boldly changing the very field in which you seek to contribute your talents.

At Santa Clara University we are ready to help you on your graduate journey, wherever it started and wherever it will take you. Santa Clara University is committed to providing you a graduate education that combines rigorous instruction in fundamentals with the art of engineering practice. A Santa Clara graduate education will not only advance your technical knowledge and skills, but will also lead you to become a life-long learner, giving you a critical advantage in today's rapidly changing and competitive workplaces that drive engineering innovation. Your graduate education will empower you to truly use your intellect and creativity to their fullest expression as an engineer.

The Santa Clara graduate engineering program aims to produce not only outstanding engineers, but also engineering leaders of uncompromising dedication, integrity, and conscience, who will be strong leaders in an increasingly complex global environment. As the Jesuit University in Silicon Valley, SCU is proud to be a vital and unique part of the limitless innovative force that is the heart of the Valley. Similar to the way the Silicon Valley pioneers of the past were driven to explore, to innovate, and to improve society through advances in engineering, the quest continues today, not only in the Valley, but in the mind of every engineer who wants to make a difference. At Santa Clara University, you will find a community of teachers and scholars who will stimulate your imagination, expand your knowledge, and nurture your conscience and compassion so that you can take your place in a profession that can and will create a more just, humane, prosperous, and sustainable world.

The School of Engineering at Santa Clara University is now in its 111th year helping students turn their dreams into reality. We stand ready as we continue another century of engineering excellence to help you in your journey. Welcome!

Sincerely,

Elaine P. Scott, Ph.D.

Dean, School of Engineering

Engineering at Santa Clara

The undergraduate programs leading to the Bachelor of Science degree in Civil, Electrical, and Mechanical Engineering were first offered at Santa Clara University in 1912. The programs were later accredited by the Accreditation Board for Engineering and Technology in 1937. Since that time, the following degree programs have been added: Bachelor of Science in Bioengineering, Computer Science and Engineering, Electrical and Computer Engineering, General Engineering, and Web Design and Engineering; Master of Science in Aerospace Engineering, Applied Mathematics, Bioengineering, Civil Engineering, Computer Science and Engineering, Electrical and Computer Engineering, Engineering Management and Leadership, Mechanical Engineering, Power Systems and Sustainable Energy, and Robotics and Automation; Engineer's degree in Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering; and Doctor of Philosophy in Bioengineering, Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering. In addition, the School of Engineering offers a variety of certificate programs, as well as an Open University program.

SCHOOL OF ENGINEERING MISSION STATEMENT

The Santa Clara University School of Engineering's mission is to prepare diverse students for professional excellence, responsible citizenship, and service to society. The engineering school does this through:

- Distinctive academic programs that are designed to produce engineers who approach their profession with competence, conscience, and compassion
- Broadly educated faculty who model and encourage the notion of lifelong learning
- Scholarly activities that create new knowledge and advance the state of the art of technology
- Interactions with professional societies and companies in Silicon Valley and beyond
- Service activities that benefit our diverse constituencies and humanity in general

SCHOOL OF ENGINEERING VISION

Grounded in the Jesuit approach to education, the School of Engineering's vision is to educate the whole person to solve society's most complex problems. Our vision is an engineering community that inspires and develops engineering leaders of competence, conscience, and compassion—entrepreneurial thinkers who will build a more just, humane, and sustainable world.

2023-2024 Graduate Academic Calendar

Click here to see the most up-to-date Graduate Academic Calendar.

Chapter 1: Santa Clara University

Located in the heart of California's Silicon Valley, Santa Clara University is a comprehensive Jesuit, Catholic university with more than 8,900 students. Founded in 1851 by the Society of Jesus, California's oldest operating higher education institution offers a rigorous undergraduate curriculum in arts and sciences, business, and engineering, plus nationally recognized graduate and professional programs in business, law, engineering, education, counseling psychology, pastoral ministries, and theology. The University boasts a diverse community of scholars offering a values-oriented curriculum characterized by small class sizes and a dedication to educating students for competence, conscience, and compassion. The traditions of Jesuit education--educating the whole person for a life of service--run deep in all of its curricular and co-curricular programs.

The University was established as Santa Clara College on the site of the Mission Santa Clara de Asís, the eighth of the original 21 California missions. The college originally operated as a preparatory school and did not offer collegiate courses until 1853. Following the Civil War, enrollment increased, and by 1875 the size of the student body was 275. One-third of the students were enrolled in the collegiate division; the remainder attended the college's preparatory and high school departments.

Santa Clara experienced slow and steady growth during its first 60 years, becoming the University of Santa Clara in 1912, when the schools of engineering and law were added. In 1925, the high school was separated from the University and took the name of Bellarmine College Preparatory in 1928. The Leavey School of Business opened in 1926, and within a decade, became one of the first business schools in the country to receive national accreditation.

For 110 years, Santa Clara was an all-male school. In the fall of 1961, women were accepted as undergraduates, and Santa Clara became the first coeducational Catholic university in California. The decision resulted in an admissions explosion—from 1,500 students to more than 5,000. The size of the faculty tripled, and the University began the largest building program in school history, building eight residence halls, a student union, and an athletic stadium. In 1985, the University adopted "Santa Clara University" as its official name.

University Vision, Mission, and Fundamental Values

Santa Clara University has adopted three directional statements to describe the kind of university it aspires to become (Strategic Vision), its core purpose and the constituencies it serves (University Mission), and the beliefs that guide its actions (Fundamental Values).

Strategic Vision

Santa Clara University will educate citizens and leaders of competence, conscience, and compassion, and cultivate knowledge and faith to build a more humane, just, and sustainable world.

University Mission

The University pursues its vision by creating an academic community that educates the whole person within the Jesuit, Catholic tradition, making student learning our central focus, continuously improving our curriculum and co-curriculum, strengthening our scholarship and creative work, and serving the communities of which we are a part in Silicon Valley and around the world.

Student learning takes place at the undergraduate and graduate level in an educational environment that integrates rigorous inquiry and scholarship, creative imagination, reflective engagement with society, and a commitment to fashioning a more humane and just world.

As an academic community, we expand the boundaries of knowledge and insight through teaching, research, artistic expression, and other forms of scholarship. It is primarily through discovering, communicating, and applying knowledge that we exercise our institutional responsibility as a voice of reason and conscience in society.

We offer challenging academic programs and demonstrate a commitment to the development of:

- Undergraduate students who seek an education with a strong humanistic orientation in a primarily residential setting
- Graduate students, many of them working professionals in Silicon Valley, who seek advanced degree programs that prepare them to make significant contributions to their fields

In addition to these core programs, we also provide a variety of continuing education and professional development opportunities for non-matriculated students.

Fundamental Values

The University is committed to these core values, which guide us in carrying out our mission and realizing our vision:

Academic Excellence. We seek an uncompromising standard of excellence in teaching, learning, creativity, and scholarship within and across disciplines.

Search for Truth, Goodness, and Beauty. We prize scholarship and creative work that advance human understanding, improve teaching and learning, and add to the betterment of society by illuminating the most significant problems of the day and exploring the enduring mysteries of life. In this search, our commitment to academic freedom is unwavering.

Engaged Learning. We strive to integrate academic reflection and direct experience in the classroom and the community, especially to understand and improve the lives of those with the least education, power, and wealth.

Commitment to Students. As teachers and scholars, mentors and facilitators, we endeavor to educate the whole person. We nurture and challenge students—intellectually, spiritually, aesthetically, morally, socially, and physically—preparing them for leadership and service to the common good in their professional, civic, and personal lives.

Service to Others. We promote throughout the University a culture of service—service not only to those who study and work at Santa Clara but also to society in general and to its most disadvantaged members as we work with and for others to build a more humane, just, faith-filled, and sustainable world.

Community and Diversity. We cherish our diverse and inclusive community of students, faculty, staff, administrators, and alumni, a community that is enriched by people of different backgrounds, respectful of the dignity of all its members, enlivened by open communication, and caring and just toward others.

Jesuit Distinctiveness. We treasure our Jesuit heritage and tradition, which incorporates all of these core values. This tradition gives expression to our Jesuit educational mission and Catholic identity while also welcoming and respecting other religious and philosophical traditions, promoting the dialogue between faith and culture, and valuing opportunities to deepen religious beliefs.

Academic Programs

Santa Clara University offers undergraduate degrees leading to the bachelor of arts (B.A.), bachelor of science (B.S.), and bachelor of science in commerce. The College of Arts and Sciences offers the B.A. degree and the B.S. degree in 33 subject areas and includes the graduate program in pastoral ministries, through which it offers the master of arts (M.A.) degree in catechetic, pastoral liturgy, spirituality, and liturgical music. The Leavey School of Business offers the B.S. degree in commerce with majors in subject areas. The School of Engineering offers a B.S. degree with majors in seven subject areas. A variety of interdisciplinary and discipline-based minors are also offered for undergraduates.

The School of Law offers programs leading to the degrees of juris doctor (J.D.) and master of laws (LL.M.). J.D. students may earn certificates of specialization in high technology law, international law, and public interest and social justice law. LL.M students may earn master of laws in intellectual property or U.S. law. A broad curriculum also includes business and commercial law, taxation, criminal law and trial advocacy, environmental law, estate planning, labor law, health law, legal writing and research, as well as opportunities for externships, clinical work, and professional skill development.

The Leavey School of Business offers graduate programs leading to the master of business administration (MBA) degree with coursework in accounting, economics, finance, management, marketing, and operations management and information systems (OMIS). The MBA can be done part-time on campus and online. The business school also offers graduate programs leading to the master of science in information systems (MSIS), business analytics, online in marketing, or finance & analytics. We also offer a 4+1 degree aimed at seniors for our MS programs in information systems, business analytics, and finance & analytics. In conjunction with the law school, the business school also offers joint degree programs leading to a J.D./MBA and J.D./MSIS.

The School of Engineering offers graduate programs leading to the master of science (M.S.) degree in aerospace engineering; applied mathematics; bioengineering; civil engineering; computer science and engineering; electrical and computer engineering; engineering management and leadership; mechanical engineering; robotics and automation and power systems and sustainable energy; and the engineer's degree in computer science and engineering, electrical and computer engineering, and mechanical engineering. The engineering school also offers a doctor of philosophy (Ph.D.) degree in bioengineering, computer science and engineering, electrical and computer engineering, and mechanical engineering.

The two departments in the School of Education and Counseling Psychology offer credential and graduate programs. The Department of Education focuses on preparing teachers and administrators for public and Catholic schools. It offers programs in teacher preparation leading to credentials (e.g., California preliminary multiple-subject and single-subject teaching credentials, and California Clear credential) and the master of arts in teaching (MAT) degree. Its programs in educational administration prepare public K–12 administrators for credentials (e.g., the Preliminary California Administrative Services credential and the California Clear Administrative Services credential), and Catholic school leaders through the certificate program in Catholic School Leadership. The department also offers an M.A. program in interdisciplinary education (with emphasis in curriculum and instruction; science, technology, environmental education, and mathematics [STEEM]; and educational administration). The Departments of Education and Counseling Psychology jointly offer the certificate program in Alternative and Correctional Education. The Department of Counseling Psychology offers two degree programs: M.A. in counseling psychology and M.A. in counseling. The M.A. in counseling psychology can lead to state licensure for marriage and family therapists and/or licensed professional clinical counselors. The department includes emphasis programs in health, correctional, and Latinx counseling.

The Jesuit School of Theology (JST) is one of only two Jesuit theological centers in the United States operated by the Society of Jesus, as the order of Catholic priests is known. It is one of only two Jesuit theological centers in the country that offer three ecclesiastical degrees certified by the Vatican Congregation for Catholic Education, and it also offers four advanced theological degrees certified by the Association of Theological Schools. In addition, JST offers a spiritual renewal program for clergy, religious, and lay people, and conducts an annual Instituto Hispano that offers a certificate program to advance Hispanic leadership in the pastoral life of the church.

Centers of Distinction

Santa Clara University has three Centers of Distinction that serve as major points of interaction between the University and local and global communities. Each center focuses on a theme that is central to Santa Clara's distinctive mission as a Jesuit university and offers an educational environment integrating rigorous inquiry and

scholarship, creative imagination, reflective engagement with society, and a commitment to fashioning a more humane and just world. Each center engages faculty and students from different disciplines as well as experts and leaders from the community through speakers, conferences, workshops, and experiential learning opportunities.

Miller Center for Social Entrepreneurship

The mission of the Miller Center for Social Entrepreneurship is to accelerate entrepreneurship to end global poverty for the next generation. We fuse the entrepreneurial spirit of Silicon Valley with the University's Jesuit heritage of service to the poor and protection of the planet, catalyzing innovative, sustainable solutions to poverty, and guided by the UN Sustainable Development Goals. Through an array of programs, including our signature Global Social Benefit Institute (GSBI™) accelerator program and award-winning Global Social Benefit Fellowship (GSBF), the Center engages an international network of social enterprises, investment capital, and technical resources to build the capacity of the global social entrepreneurship movement. As a Center of Distinction at Santa Clara University, we offer faculty and students real-world case studies, distinctive curricula, and unique opportunities for research, fellowships, and internships --- advancing the University's vision of creating a more just, humane, and sustainable world with a uniquely Silicon Valley flavor. More information can be found at the Miller Center for Social Entrepreneurship website.

Ignatian Center for Jesuit Education

The Ignatian Center for Jesuit Education promotes and enhances the distinctively Jesuit, Catholic tradition of education at Santa Clara University, with a view toward serving students, faculty, staff, and through them the larger community, both local and global. The Ignatian Center achieves this mission chiefly through four signature programs:

- The Bannan Forum provides year-long thematic programs, including academic events and scholarly activities that further the Jesuit, Catholic character of the University.
- Arrupe Engagement, a community-based learning program, places over 1,200 students each year with community partners, frequently in connection with an academic course.
- Thriving Neighbors extends the community-based learning experience by engaging teaching, scholarship, and sustainable development that links Santa Clara University with the predominantly Latino Greater Washington community in San Jose, CA.
- The Immersion programs offer students, during academic breaks, the opportunity to experience local, domestic, and international communities with little access to wealth, power, and privilege.
- The Ignatian Spirituality offers experiences grounded in the Ignatian practices that support faith development and growth to members of the community to encounter the spiritual sources of the Jesuit tradition.

Through these four programs, the Ignatian Center aspires to be recognized throughout Silicon Valley and beyond as providing leadership for the integration of faith, justice, and intellectual life.

Markkula Center for Applied Ethics

The Markkula Center for Applied Ethics brings the traditions of ethical thinking to bear on real-world problems. Our mission is to engage individuals and organizations in making choices that respect and care for others. Beyond a full range of events, grants, and fellowships for the Santa Clara University community, the Center serves professionals in business, education, health care, government, journalism, and the social sector--providing training, programs, and roundtables that explore the ethical challenges in the field. In addition, we focus on ethical issues in leadership, technology, and the internet. Through our website and international collaborations, we also bring ethical decision-making resources to the wider world.

Faculty

Santa Clara University's emphasis on a community of scholars and integrated education attracts faculty members who are as committed to students' intellectual and moral development as they are pursuing their own scholarship. The University's 584 full-time faculty members are distinguished teachers and scholars. Examples of awards received by SCU faculty include: Fulbright, National Science Foundation, National Institutes of Health, and National Endowment for the Arts. Additionally, our faculty are acclaimed authors, scientists and theorists in their fields.

Alumni

Santa Clara University has over 100,000 alumni living around the world--in all 50 states and more than 100 countries. More than half of the alumni live in the San Francisco Bay Area, where many are leaders in business, law, engineering, academia, and public service. These graduates connect with one another and the current campus community by engaging with over 45 different groups organized around identity, industry, and location.

Campus

The University is located on a 106-acre campus in the city of Santa Clara near the southern end of the San Francisco Bay in one of the world's great cultural centers. More than 50 buildings on campus house 15 student residences, a main library, a law library, two student centers, the de Saisset Museum, extensive performing arts and athletic facilities, and a recreation and fitness center.

Santa Clara's campus has the advantage of being located in Silicon Valley—a region known for its extraordinary visionaries, who have designed and created some of the most significant scientific and technological advances of our age. Silicon Valley is more than a location—it is a mindset and home to more than 3 million residents and 6,600 science- and technology-related companies, (not including San Francisco, which is located just an hour away).

Santa Clara's campus is well known for its beauty and Mission-style architecture. Opened in 2013, the brick-paved Abby Sobrato Mall leads visitors from the University's main entrance to the heart of campus—the Mission Santa Clara de Asís. The rose gardens and palm and olive trees of the Mission Gardens surround the historic Mission Church, which was restored in 1928. The adjacent Adobe Lodge is the oldest building on campus. In 1981, it was restored to its 1822 decor.

Academic Facilities

Amid all this beauty and history are modern, world-class academic facilities. Students study and thrive in places such as the Joanne E. Harrington Learning Commons, Sobrato Family Technology Center and Orradre Library where individuals and groups can study in an inviting, light-filled, and open environment. Notably, the library features an Automated Retrieval System, a high-density storage area where up to 900,000 books and other publications can be stored and retrieved using robotic-assisted technology.

Another example of Santa Clara's excellent academic facilities is Lucas Hall, home of the Leavey School of Business. This modern 85,000-square-foot building houses classrooms, meeting rooms, offices, study spaces, and a café. Classrooms are equipped with state-of-the-art videoconferencing equipment as well as a multiplatform system to record faculty lectures for later review by students. Vari Hall (formerly Arts and Sciences) adjacent to Lucas Hall is home to the Markkula Center for Applied Ethics as well as academic departments, classrooms, and a 2,200-square-foot digital television studio—among the best found on any campus nationwide.

Located near Varsi Hall is the Schott Admission and Enrollment Services Building, a welcome center for campus visitors and home to several University departments. Opened in 2012, the lobby of this LEED Gold equivalent structure includes technology-infused exhibits that illustrate Santa Clara's Jesuit mission. Among other green features on campus are two solar-powered houses built in 2007 and 2009 for the U.S. Department of Energy's Solar Decathlon. Both homes now serve as laboratories for solar and sustainability technologies.

University Library & Learning Commons

The Santa Clara University Library & Learning Commons is a central hub for students to study and collaborate. The Learning Commons has a mix of both individual and group seating, group study rooms, computer labs, outside patios, as well as a cafe on the first floor. Throughout the year, the University Library hosts events, art exhibits, and late-night hours. Library staff are available to support student research. You can contact library staff in person at the Library Help Desk, by making an appointment online, or through our 24/7 chat service, "Ask a Librarian." The Library's Archives & Special Collections provides access to rare books, manuscripts, historic photos, and artifacts.

Library resources, which can be accessed within the Learning Commons and remotely, include an online catalog (OSCAR), over 250 general and subject-specific databases, research guides for many subjects and classes, and interlibrary loan programs. The library's collection includes books, ebooks, magazines, newspapers and journals, streaming videos, and more.

Schott Admission and Enrollment Services Building

Located near Vari Hall is the Schott Admission and Enrollment Services Building, a welcome center for campus visitors and home to several University departments. Opened in 2012, the lobby of this LEED Gold equivalent structure includes technology-infused exhibits that illustrate Santa Clara's Jesuit mission.

Among other green features on campus are two solar-powered homes built in 2007 and 2009 for the U.S. Department of Energy's Solar Decathlon. Both homes now serve as laboratories for solar and sustainability technologies.

Sobrato Campus for Discovery and Innovation

Opened in the Fall of 2021, this 270,000 square-foot building is the home to the School of Engineering and many of the science departments of the College of Arts and Sciences. The building has classrooms, Innovation Zone, teaching and research labs, engineering and science shops, faculty and staff offices, collaboration spaces, and a cafe. The Miller Center for Social Entrepreneurship and the Frugal Innovation Hub are also located in this state-of-the art building. The central landscaped courtyard and rooftop terraces provide excellent places for gathering.

Student Life

The Robert F. Benson Memorial Center serves as a hub for campus life. The Benson Memorial Center offers dining services and houses the campus bookstore, student and administrative offices, lounges, and meeting rooms. The University's main dining hall, The Marketplace, resembles an upscale food court with numerous stations and options. For a more informal experience, The Bronco is the Benson Center's late-night venue, serving beverages and pub-style food.

Another hotspot for student life, the Paul L. Locatelli, S.J., Student Activity Center includes a 6,000-square-foot gathering hall with a high ceiling that can accommodate dances and concerts as well as pre- and post-game activities. Designed with environmental sensitivity, the building is energy efficient and has daytime lighting controls and motion sensors to maximize the use of natural light.

For fitness-minded students, the Pat Malley Fitness and Recreation Center features a 9,500-square-foot weight training and cardiovascular exercise room, three basketball courts, a swimming pool, and other facilities to support the recreational and fitness needs of the campus community.

The campus features many locations for quiet reflection as well, such as the St. Clare Garden, which features plants and flowers arranged into five groups to portray the stages of the saint's life. For campus members who want a more hands-on relationship with nature, the Forge Garden, SCU's half-acre organic garden, serves as a campus space for

course research, service learning, and sustainable food production.

Athletics and The Arts

The importance of athletics to the University is evident everywhere on campus. Among the newest additions to Santa Clara's athletics facilities are the Stephen Schott Stadium, home field for the men's baseball team, and the state-of-the-art Stevens Soccer Training Center, funded by a gift from Mary and Mark Stevens. The gift also allowed Santa Clara to upgrade the stands in Stevens Stadium (formerly Buck Shaw Stadium), home to the men's and women's soccer programs, and build a plaza to celebrate Bronco sports---its past, present, and future. The plaza celebrates the history of Santa Clara University football as well as the legacy and future of men's and women's soccer at SCU. Bellomy Field, 4.7 acres of well-lit and turfed outdoor playing fields, provides space for club and intramural sports, such as rugby and field hockey. Adjacent to Bellomy Field is the well-appointed women's softball field, which opened in 2013. The Leavey Event Center houses the University's premier basketball facility. Over the years, the Leavey Event Center has hosted nine West Coast Conference Basketball Championships.

The University recognizes the arts as an important part of life at Santa Clara University. The Edward M. Dowd Art and Art History Building opened in 2016, housing an integrated fine arts program that is a destination and a center for inspiration, innovation, and engagement in the arts and art history in Silicon Valley. An important arts destination in the Bay Area, the Department of Art and Art History's gallery exhibits artwork from a diverse group of established and emerging artists and provides a dynamic teaching and learning resource for faculty, staff, students and the community. The de Saisset Museum, the University's accredited museum of art and history, presents changing art exhibitions throughout the year and serves as the caretaker of the University's California History Collection, which includes artifacts from the Native American, Mission, and early Santa Clara College periods.

SCU•Presents represents the University's commitment to the performing arts on campus, which includes performances at venues such as the Louis B. Mayer Theatre, the Fess Parker Studio Theatre, and the Music Recital Hall. The Mayer Theatre is Santa Clara University's premier theatrical venue, housing 500 intimate seats in either a flexible proscenium or thrust-stage setting. The Fess Parker Studio Theatre has no fixed stage or seating. Its black box design, complete with movable catwalks, provides flexibility in an experimental setting. The 250-seat Music Recital Hall provides a contemporary setting where students, faculty, and guest artists offer a variety of performances.

Chapter 2: Academic Programs and Requirements

General Information

More than 800 students attend Santa Clara University's Graduate Engineering Programs each quarter. The School of Engineering offers a large variety of programs to meet the needs of these engineering professionals.

Through the coursework, projects and research required in a student's degree program and the Enrichment Experience required for all M.S. students, Engineering graduate students will achieve the following objectives:

1. Academic competence

Graduate students will demonstrate broad content knowledge and the ability to integrate and apply concepts from their course of study to professional situations.

2. Creative and collaborative learning

Graduate students will demonstrate an ability to collaborate in creative ways, and communicate effectively with professionals and others in their discipline.

3. Professional development

Graduate students will exhibit professionalism, consistent with the University's Jesuit mission that includes attention to ethics, integrity, and responsible engagement with their communities–both locally and globally.

B.S./M.S. Program

The School of Engineering's B.S/M.S. program provides a way for current SCU undergraduate students to begin taking courses required for a master's degree before completing the requirements for a bachelor's degree. Students typically complete the requirements for their master's degree within a year of completing their bachelor's. This is an excellent way to save time and open up more career possibilities early on. The degree is offered in Aerospace Engineering, Bioengineering, Computer Science and Engineering, Electrical and Computer Engineering, Engineering Management and Leadership**, Mechanical Engineering, Robotics and Automation, and Power Systems and Sustainable Energy. This program is also open to students in the College of Arts and Sciences who are majoring in mathematics, biology, computer science, or engineering physics. Students in the College of Arts and Sciences interested in a the B.S./M.S. program in Civil, Environmental, and Sustainable Engineering should consult the CESE department chapter of the graduate bulletin for details.

For B.S./M.S. applicants, the application fee and GRE General Test requirement are waived. Admission into the B.S./M.S. program is based on a minimum GPA of 3.0 in the major. Upon notification of acceptance into the B.S./M.S. program, students may begin taking graduate-level courses in their senior year. A maximum of 20 eligible units can be transferred into the graduate program.

> *Please Note: Undergraduate students will be charged the current undergraduate tuition rate while enrolled in graduate courses as an undergraduate. Once students have been matriculated into the master's degree program, current graduate tuition rates will be charged.*

**For more information on the engineering management and leadership option, please see Chapter 13.

Certificate Programs

Certificate programs are designed to provide intensive background in a focused area at the graduate level. With 16-20 required units for completion, each certificate is designed to be completed in a much shorter period of time than an advanced degree. Santa Clara's certificate programs are appropriate for students working in industry who wish to update their skills or for those interested in changing their career path. All units applied toward the certificate program must be earned within a two-year period. Students enrolled in the certificate program should only take courses that will satisfy their certificate completion. Any course substitutions or waivers must be pre-approved by the certificate advisor.

All Santa Clara University courses applied toward the completion of a certificate program earn graduate credit that may also be applied toward a graduate degree, subject to the requirements of the degree program (16-20 units can be transferred to the MS program depending on the certificate requirements). Students who wish to continue for such a degree must submit a separate application and satisfy all normal admission requirements. The general Graduate Record Examination (GRE) test requirement for graduate admission to the master's degree program will be waived for students who have been formally admitted to and who have completed a certificate program with a GPA of 3.5 or better.

Certificate programs are offered in Frugal Innovation, Renewable Energy, Digital System Design, Integrated Circuit Design and Technology, Digital Signal Processing and Machine Learning, Digital Signal Processing Theory, Fundamentals of Electrical and Computer Engineering, RF and Applied Electromagnetics, Design and Manufacturing, Dynamics and Controls, Mechanics and Materials, Mechatronics Systems Engineering, and Thermofluids and Energy, For more specific information on each certificate, please see Chapter 18.

> Please Note: Santa Clara University does not issue F-1 visas to applicants who wish to enter directly into the certificate program.

Master of Science Program

The master's program is designed to extend the technical breadth and depth of an engineer's knowledge. Students in this program must complete a program of studies approved by the faculty advisor in the major department. The program must include a minimum of 46 quarter units, and a 3.0 cumulative GPA (B average) must be earned in all coursework taken at Santa Clara. Residence requirements of the University are met by completing 36 quarter units of the graduate program at Santa Clara. MS students have six years to complete their Master's degree.

Students have the option to write a thesis as part of their master's degree. Students who choose this option are responsible for obtaining an advisor for their thesis work. The maximum number of units awarded for the master's thesis is nine. Please note that the thesis option is not available in the Engineering Management and Leadership Program.

The School of Engineering offers Master's programs in Applied Mathematics, Aerospace Engineering, Bioengineering, Civil Engineering, Computer Science and Engineering, Electrical and Computer Engineering, Engineering Management and Leadership, Mechanical Engineering, Robotics and Automation and Power Systems and Sustainable Energy. The coursework requirements for the degree are determined by each of the major departments. In order to graduate, students must complete the required coursework for the program to which they are admitted and must have a cumulative GPA of 3.0 in all coursework listed on their approved program of study. In addition to this requirement, Engineering Management and Leadership degree candidates must earn a 3.0 GPA in those courses applied to their technical stem and a 3.0 GPA in their engineering management course stem.

Please note: Only classes with assigned grades of C- or higher will count toward the completion of the M.S degree. The grades of all courses completed during the M.S. program are used to compile final cumulative grade point average (GPA)

Note that the number of engineering management courses accepted for other degrees in the graduate engineering program is restricted to six units in computer science engineering, electrical and computer engineering, and most options of mechanical engineering.

Graduate Minor in Science, Technology, and Society (STS)

The graduate minor in science, technology, and society (STS) is designed to help students gain a deeper understanding of the influence that engineering has on society (and vice versa). Knowledge of this kind has become essential in an increasingly complex and interconnected world, in which purely technical expertise often needs to be supplemented by additional skills. In order to successfully operate in such an environment, engineers must (at the very least) have the ability to communicate clearly, function on interdisciplinary and diverse teams, and make ethically and socially responsible decisions. The minor consists of a Core and a set of electives and requires a minimum of 12 units of coursework. It is open to all students who are pursuing a master's degree in engineering.

For more comprehensive information, please see Chapter 17.

Engineer's Degree Program

The program leading to the engineer's degree is particularly designed for the education of the practicing engineer. It is offered in the computer science and engineering, electrical and computer engineering, and mechanical engineering departments. The degree is granted on completion of an approved academic program and a record of acceptable technical achievement in the student's field of engineering. The academic program consists of a minimum of 46 quarter units beyond the master's degree and a cumulative GPA of 3.0. Courses are selected to advance competence in specific areas relating to the engineering professional's work. Evidence of technical achievement must include a paper principally written by the student and accepted for publication by a recognized engineering journal prior to the granting of the degree. A letter from the journal accepting the paper must be submitted to the department chairperson. In certain cases, the department may accept publication in the proceedings of an appropriate conference.

Admission to the program will generally be granted to those students who demonstrate superior ability in meeting the requirements for their master's degree. Normally, the master's degree is earned in the same field as that in which the engineer's degree is sought. Students who have earned a master's degree from Santa Clara University must file a new application (by the deadline) to continue work toward the engineer's degree. A program of studies for the engineer's degree should be developed with the assistance of an advisor and submitted during the first term of enrollment.

Doctor of Philosophy Program

The Doctor of Philosophy (Ph.D.) degree is sought by those engineers who wish to engage in research and discover new knowledge in a specific area within their field. The work for the degree consists of engineering research, the preparation of a thesis based on that research, and a program of advanced studies in engineering, mathematics, and

related physical sciences. The student's work is directed by the degree-conferring department, subject to the general supervision of the School of Engineering. The school grants Ph.D.s in bioengineering, computer science and engineering, electrical and computer engineering, and mechanical engineering.

Preliminary Examination

The preliminary examination shall be written and/or oral and shall include subject matter deemed by the major department to represent sufficient preparation in depth and breadth for advanced study in the major.

Students currently studying at Santa Clara University for a master's degree who are accepted for the Ph.D. program and who are at an advanced stage of the M.S. program may, with the approval of their academic advisor, take the preliminary examination before completing the M.S. degree requirements.

Students who have completed the M.S. degree requirements and have been accepted for the Ph.D. program should take the preliminary examination as soon as possible but not more than one and one-half years after beginning the program.

Only those students who pass the preliminary examination shall be allowed to continue in the doctoral program. The preliminary examination may be repeated only once and only at the discretion of the thesis advisor.

Thesis Advisor

It is the student's responsibility to obtain consent from a full-time faculty member in the student's major department to serve as his/her prospective thesis advisor.

It is strongly recommended that Ph.D. students find a thesis advisor before taking the preliminary examination. After passing the preliminary examination, Ph.D. students should have a thesis advisor before the beginning of the next quarter following the preliminary examination. Students currently pursuing a master's degree at the time of their preliminary examination should have a thesis advisor as soon as possible after being accepted as a Ph.D. student.

The student and the thesis advisor jointly develop a complete program of studies for coursework and research. The complete program of studies (and any subsequent changes) must be filed with Engineering Graduate Programs and approved by the student's doctoral committee. Until this approval is obtained, there is no guarantee that courses taken will be counted toward the Ph.D. course requirements.

Doctoral Committee

After passing the Ph.D. preliminary exam, a student requests that the thesis advisor form a doctoral committee. The committee consists of at least five members, each of which must have earned a doctoral degree in a relevant field of engineering or a related discipline. The committee must include the student's thesis advisor, at least two other current faculty members of the student's major department at Santa Clara University, and at least one member who is not in the major department. The committee reviews the student's program of study, conducts an oral comprehensive exam, conducts the dissertation defense, and reviews the thesis. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, dissertation defense, and thesis itself meet with the approval of all committee members.

Residence

The Ph.D. degree is granted on the basis of academic achievement. The student is expected to complete a minimum of 72 units of graduate credit beyond the master's degree with an overall GPA of 3.0 or better. Please note: Only classes with assigned grades of C- or higher will count toward the completion of the Ph.D. degree. Of these, 36 quarter units may be earned through coursework, independent study and directed research, and 36 through the thesis. Deviation from this distribution must be approved by the student's doctoral committee and must not be more than six units. All Ph.D. thesis units are graded on a Pass/No Pass basis.

Comprehensive Examinations and Admission to Candidacy

After completion of the formal coursework approved by the doctoral committee, the student shall present his/her research proposal for comprehensive oral examinations on the subject of his/her research work. The student should make arrangements for the comprehensive examinations through the doctoral committee. A student who passes the comprehensive examinations is considered a degree candidate.

The comprehensive examinations normally must be completed within four years from the time the student is admitted to the doctoral program. These examinations may be repeated once, in whole or in part, at the discretion of the doctoral committee.

Thesis Research and Defense

The period following the comprehensive examination is devoted to research for the thesis, although such research may begin earlier. After successfully completing the thesis research, the student must pass an oral examination on his/her research, conducted by the doctoral committee and whomever they appoint as examiners. The thesis must be made available to all examiners one month prior to the examination. The oral examination shall consist of a presentation of the results of the thesis and the defense. This examination is open to all faculty members of Santa Clara University, but only members of the doctoral committee may vote.

Thesis and Publication

At least one month before the degree is conferred, the candidate must submit one copy of the final version of the thesis to the department and one copy to the University Library. The thesis will not be considered as accepted until approved by the doctoral committee and one or more refereed articles based on it are accepted for publication in a professional or scientific journal approved by the doctoral committee. The quality of the refereed journal must be established by satisfying one of two criteria: (1) the refereed journal should have an impact factor of at least 1.0 or (2) prior to submitting the candidate's work to a refereed journal, written approvals of the journal's quality should be obtained from the candidate's advisor, the doctoral committee, the department chair, and the dean's office. This written approval must be kept in the candidate's file.

Time Limit for Completing Degrees

All requirements for the doctoral degree must be completed within eight years following initial enrollment in the Ph.D. program. Extensions will be allowed only in unusual circumstances and must be recommended in writing by the student's doctoral committee. Extensions will be allowed only if approved by the Dean of Engineering in consultation with the Graduate Program Leadership Council.

Non-Enrollment Period

Ph.D. students are required to enroll in at least one unit for the fall, winter, spring quarters and their final graduating quarter. Those who do not wish to enroll must submit a leave of absence or a withdrawal request on their workday student portal. Leave of absence or withdrawal request must be submitted by the end of the first week of the quarter. Please note the request is not guaranteed.

> Please Note: Students who miss one or more quarters and fail to submit the appropriate requests will be discontinued automatically and will have to reapply to the Ph.D. program.

Additional Graduation Requirements

The requirements for the doctoral degree in the School of Engineering have been made to establish the structure in which the degree may be earned. The student's Ph.D. committee looks at the proposed research and the prior background of the student to determine whether or not there are specific courses that must be added as requirements. The University reserves the right to evaluate the undertakings and the accomplishments of the degree candidate in total and award or withhold the degree as a result of its deliberations.

The Industrial Track

In addition to our regular Ph.D. program, Graduate Engineering Programs also offers an "industrial track" for working professionals as an option to facilitate the collaboration between academia and industry. Details are as follows:

1. The topic of the research should be coordinated with the needs of the candidate's employer and must be agreed upon by all parties. This topic must have a component that is publishable and is presentable in open forums. If necessary, a collaborative research agreement will be enacted to indicate the rights of the School and the industrial partner.

2. As a part of the application process, candidates must submit a letter of support from their employer. This letter should contain a pledge of financial support and must identify a co-advisor within the company. The co-advisor shares responsibilities for guiding the candidate's research with a full- time faculty advisor. This person is also expected to be a member of the doctoral committee.

3. Students who opt for this "industrial track" are responsible for meeting all other requirements for the Ph.D. The awarded degree will be the same for all students, regardless of the track that they choose to pursue.

Open University Program

Engineers who wish to update their skills or learn new technologies without pursuing a specific degree may enroll in the School of Engineering's Open University program.

If a student from the Open University program is accepted into a degree program, a maximum of 16 units may apply toward the degree (if the courses are in the same discipline to which the student is accepted). The general GRE test requirement for admission to the master's degree program will be waived if the student has completed a specified set of required courses and has earned a GPA of 3.5 or higher in those courses.

Open University students who are considering enrolling in the master's program should be aware that each specialization has its own set of requirements, and that the number of "free electives" is very limited. Such students are therefore strongly encouraged to choose their classes in consultation with a faculty advisor from the very beginning.

Students should remember, however, that all coursework taken at SCU, whether as a degree-seeking or an Open University student, becomes a part of the student's academic history.

> Please Note: Santa Clara University does not issue F-1 visas to applicants who wish to enter directly into the open university program.

Chapter 3: Admissions

Applications

Applications for admission and related deadlines are available on the graduate school of engineering website:

Prospective Graduate Student Resources

Program (See Program Details Below)	Application Requirements (See Application Requirement Details Below)
B.S./M.S. Degree Program **(Current SCU Undergraduate Students)**	• Online Application (Slate) • Application Fee Waived • GRE Scores Waived
Open University	• Online Application (EngineeringCAS) • Nonrefundable Application Fee • Official Transcripts • TOEFL/IELTS/DUOLINGO (If Applicable)
Certificate	• Online Application (EngineeringCAS) • Nonrefundable Application Fee • Official Transcripts • TOEFL/IELTS/DUOLINGO (If Applicable)
Master's Degree	• Online Application (EngineeringCAS) • Nonrefundable Application Fee • Official Transcripts • GRE Waived (Except for the MS in CSE) • TOEFL/IELTS/DUOLINGO (If Applicable)
Engineer's Degree	• Online Application (EngineeringCAS) • Nonrefundable Application Fee • Official Transcripts • 3 Letters of Recommendation • Statement of Purpose • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)
Ph.D. Degree	• Online Application (EngineeringCAS) • Nonrefundable Application Fee • Official Transcripts • 3 Letters of Recommendation • Statement of Purpose • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)

Application Requirement Details

- **ONLINE APPLICATION**
    - **B.S./M.S. Degree Program (Slate):** Submit your online application using the Slate application system https://slate.scu.edu/apply/.
    - **All other programs (EngineeringCAS):** Submit your application using the EngineeringCAS application system https://engineeringcas2023.liaisoncas.com/applicant-ux/#/login.
- **NONREFUNDABLE APPLICATION FEE:**
    - All applicants to any School of Engineering program are required to submit a nonrefundable $90 application

fee.

- **OFFICIAL TRANSCRIPTS:**
  - *Domestic Applicants*
    - On the Slate application, list any degree program in which you are currently enrolled, as well as every institution you have previously attended. Upload official transcripts from **EACH** institution.
    - Request an official transcript from **EACH** degree granting institution. The official transcript must include the degree received and date of conferral. *Note: we do NOT accept transcripts sent directly from students, transcripts are ONLY ACCEPTED from the University.*
    - Acceptable transcript delivery methods include: certified electronic transcripts that are passcode protected, digitally signed, and sent from the issuing institution or its authorized agent to gradengineeradmissions@scu.edu.
  - *International Applicants*
    - Students attending a university **OUTSIDE** of the United States, must submit a transcript evaluation report from Educational Credential Evaluators (ECE) or World Education Services (WES) or SpanTran The report must include a course by course evaluation which will verify a GPA based on a 4.0 scale, and the U.S. equivalence of each educational credential. Please refer to the ECE or WES website: www.ece.org or www.wes.org To use SpanTran's evaluation service, start your evaluation request form here
    - (There is no exception to this requirement). *Please note: A copy of your original transcripts will be attached to the report and* **you do not need to send any additional transcripts.**
- **OFFICIAL GRE SCORES.** Official Graduate Record Examination (GRE) scores must be sent directly to Graduate Engineering Programs by the Educational Testing Service (ETS). Our institution code is 4851. Additionally, students can send a PDF copy of their official results to gradengineeradmissions@scu.edu. For information on the GRE, please visit the website: www.ets.org/.
  - The following programs are required to report GRE scores:
    - M.S. in Computer Science and Engineering
    - Engineer's and Ph.D. programs
- **OFFICIAL TOEFL/IELTS/DUOLINGO SCORES.** For non-U.S. citizens or students who have received a degree from a university outside of the United States international students, we will accept scores from the Test of English as a Foreign Language (TOEFL), the International English Language Testing Systems (IELTS) or Duolingo. Our institution code is 4851. Test scores over three years old will not be accepted. Additionally, students can send a PDF copy of their results to gradengineeradmissions@scu.edu. This requirement is waived for those who attended an institution within the U.S.

Program Details

B.S./M.S. Degree Program (Current undergraduate SCU students)

The B.S./M.S. degree program allows current SCU undergraduate students to begin taking courses required for a master's degree before completing the requirements for bachelor degree. This B.S./M.S. program is based on a minimum GPA of 3.0 in your major. Upon notification of acceptance into the B.S./M.S. program, students may begin taking graduate-level courses in their senior year and a maximum of 20 units can be transferred into the graduate program.

Open University

For those who want to update their skills and learn new technologies without the commitment of earning a graduate degree, Open University allows students to enroll in graduate-level classes.

- A maximum of 16 units may apply toward the degree if the courses are in the same discipline to which the student is accepted. The general GRE test requirement for admission to the master's degree program will be

waived if the student has completed a set of required courses in the department to which they are applying and has earned a GPA of 3.5 or higher.

- Note 1: Santa Clara University does not issue F-1 visas to applicants who wish to enter directly into Open University.
- Note 2: Open University students are not eligible to enroll in undergraduate classes.

Certificate Programs

Certificate programs provide an opportunity for continued learning and skills refreshment for professional practice at the graduate level.

- Depending on the certificate program, students will complete 16-18 units of coursework.
- All certificate units in the discipline may be applied toward a master's degree. Students who wish to pursue a Master's degree must submit a separate online application. The application fee will be waived for currently enrolled certificate students. The general GRE and TOEFL test requirement for graduate admission to the master's degree will be waived for students who complete a certificate with a GPA of 3.5 or higher.
- Note 1: Santa Clara University does not issue F-1 visas to applicants who wish to enter directly into the Certificate Program.

Master's Program

Our master's programs extend the breadth and depth of undergraduate knowledge leading to a professional work. Completion of the degree requires 46 units.

Ph.D. Degree

Our research-intensive Ph.D. program prepares students for careers in research and design.

Ph.D. degrees are offered in the Departments of Bioengineering, Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering. This is a full-time program. Students must complete 72 units.

Engineer's Degree Program

This unique program is designed for the practicing engineer. Completion of the program requires a minimum of 46 units beyond the master's degree.

Admission Deferrals

Any student who has been admitted and made an enrollment deposit to a degree program and wishes to defer their admission for the current academic year (the year listed in your acceptance letter) must submit a deferral form prior to the start of the quarter listed on the student's admission letter. If a student wishes to defer into the next academic year, they must submit a new application (please note: admission is not guaranteed and any previous enrollment deposit is non-refundable). Please email gradengineeradmissions@scu.edu for the deferral form.

Chapter 4: Financial Information

FINANCIAL RESPONSIBILITY

Students assume responsibility for all costs incurred as a result of enrollment at Santa Clara University. It is the student's responsibility to be aware of their student account balance, financial deadlines, refund policies, financial aid information, and maintain current valid contact information at all times to ensure receipt of all University correspondence in a timely manner. All correspondence is sent using the University's official Gmail account. Students are responsible to check their Santa Clara Gmail for important information and updates.

FINANCIAL TERMS AND CONDITIONS

Students are required to accept the financial terms and conditions outlined by the University in order to continue their enrollment at SCU. Students will be prompted to accept the terms and conditions, on an annual basis, upon their login to Workday. Students will not have access to their Student Center until they have read and agreed to the information contained on the page(s) prompted. By accepting SCU's financial terms and conditions, students are agreeing to pay and to abide by all policies and procedures.

TUITION AND FEES

Tuition, per quarter unit, for all courses...$1160

Graduate Design Center and Student Association (AGES) fee...$190\ Per quarter, for each student enrolled in School of Engineering courses; includes Association of Graduate Engineering Students (AGES) fee.

MANDATORY HEALTH INSURANCE

Annual graduate student health insurance fee $3523 \ **_Subject to change, pending approval from California Department of Insurance_**

Santa Clara University requires all degree seeking students enrolled at least half-time in their school or college to have health insurance (excluding certificate and online programs). This requirement helps to protect against unexpected high medical costs and provides access to quality health care.

Students may purchase the university sponsored Student Health Insurance Plan but are not required to if they can provide proof of other insurance coverage comparable to the Student Health Insurance Plan as outlined in the benefit and waiver requirements on our website. Students with comparable health insurance must complete the Online Waiver Form with their own insurance information. For details and deadlines on completing the waiver or on-line insurance enrollment option go to www.scu.edu/cowell and click on Student Health Insurance.

Cowell Center

Graduate students who have health insurance other than the University-sponsored Student Health Insurance Plan will be billed a $90 Cowell Center fee for each quarter they visit the Cowell Center. Graduate students enrolled in the University sponsored Student Health Insurance Plan may use the Cowell Center at any time and the Cowell Center fee is included in the cost of the insurance premium. \

Attention: F-1 and J-1 International Students

F-1 VISA STUDENTS

All F-1 visa international students, regardless of number of units, must be enrolled in the SCU-sponsored health insurance plan unless the student meets the waiver exception below. Please see Cowell website at www.scu.edu/cowell/insurance for detailed information.

- Currently an enrolled dependent on a spouse/parent/partner or employee US based and Affordable Care Act compliant plan.

J-1 VISA STUDENTS

All J-1 visa international students, regardless of number of units, will be automatically enrolled into the SCU-sponsored health insurance plan.

OTHER FEES

Non-refundable application fee, per application...$90

Non-refundable Enrollment Deposit (will be credited toward students account once enrollment is posted)...$300

Late registration fee (Only applies to students who have no enrollment before the late registration deadline. Begins one week before the start of the quarter. Dates listed on academic calendar)...$100

Course drop/swap fee (Per course. Begins one week before the start of the quarter. Dates listed on academic calendar)...$50

Tuition Late payment fee...$100

Parking permits (subject to change)\ E Permit - (per-year)...$400\ F Permit - Leavey and Loyola parking lots only- (per-year)... $260\ N Permit - after 4:30PM only - (per year) ... $200

> Note: For parking permit fee information, please go to Parking & Transportation Website

BILLING AND PAYMENT PROCEDURES

Students assume responsibility for all costs incurred as a result of enrollment at Santa Clara University and agree to abide by applicable University policies and procedures. Students may designate a third party (e.g., parent, family member, spouse) to be an Authorized Payer for the purpose of reviewing student accounts, billing information, and remitting payment on the student's behalf. However, it is ultimately the student's responsibility to make sure all financial obligations are completed by the published deadlines.

Students receive monthly bills electronically that are accessible through Workday. A billing notification will be sent to the student's SCU Gmail account and to the email address of any Authorized Payer. Students may also forward their billing statements electronically to any third party they authorize for remitting payment. Information on a student's account cannot be provided to any third-party payer unless a completed Family Educational Rights and Privacy Act (FERPA) form authorizing its release by the student is on file with the University.

Students are obligated to pay the applicable tuition and fees by the published term payment deadline. Students enrolling after the initial payment deadline may be required to pre-pay for their enrollment. **Registered students who do not formally withdraw from the University are responsible for all tuition and fees assessed to their account, as well as any penalty charges incurred for nonpayment. Nonattendance does not relieve the student of his or her obligation to pay tuition and fees.**

Additional information, including detailed instructions on Santa Clara's billing and payment procedures, is located at the website: BURSAR WEBSITE

Graduate Programs Billing Dates and Deadlines

The following dates are the initial payment deadlines for each quarter:

Fall 2023 Billing available August 1; payment due August 21

Winter 2024 Billing available December 1; payment due December 21

Spring 2024 Billing available March 1; payment due March 21

Summer 2024 Billing available May 1; payment due May 21

PAYMENT METHODS

Santa Clara University offers a variety of payment methods to assist students with their financial obligations. Please visit our Bursar's office website for additional payment information: Bursar Payment Options.

Payment by Electronic Check

A student or Authorized Payer can make online payments by processing a fund transfer directly from their personal checking or savings account through a third-party vendor's website accessible via the University Workday system or SCU Pay site. Please note that a bank may reject a fund transfer if it exceeds a specific amount. Check with your bank about daily limits to prevent returned payment transactions. Payers are able to make electronic check payments without incurring a transaction fee.

Payment by Mail

Payment for student account charges is accepted by mail utilizing the University's cash management service lock box. Please enclose a copy of the billing statement with your paper check or cashier's check made payable to Santa Clara University and mail both items to: SCU Payment Processing, P.O. Box 550, Santa Clara, CA 95052-0550.

Payment in Person

Payments for student account charges may be made in person by cashier's check, or check at the OneStop Office in the Admissions & Enrollment Services Building. There are computer kiosks located in the OneStop Office for the convenience of students and their payers who wish to make electronic payments. The University does not accept debit or credit card payments for student account charges.

International Payment by Wire Transfer

International students may submit payment quickly and securely through Workday. Authorized Payers and other third-party payers can make payments by accessing the following link: https://payment.flywire.com/pay/payment. Students are able to benefit from excellent exchange rates and payment can usually be made in the student's home currency.

Payment Plans

Students currently enrolled at SCU may be eligible to enroll in a monthly payment plan to assist with budgeting needs. There is a $40 non-refundable enrollment fee per term and students must have a US bank account to enroll in the term plan. The first payment along with the enrollment fee is due upon enrollment and all subsequent payments will be processed automatically each month thereafter. Plans are subject to rebalancing based on changes in enrollment and/or financial aid. Participants must enroll each term; there is no automatic re-enrollment. The online monthly payment plan can be accessed by logging into Workday and selecting the Make a Payment link. Information about these plans is available on the Bursar's Office website: www.scu.edu/bursar/.

DELINQUENT PAYMENTS

If all charges on a student's account have not been cleared by payment, financial aid, enrollment in the payment plan, or loan disbursement by the payment deadline, a late payment fee will be assessed to the student's account and a hold will be placed on the student's record. A hold on a student's record prevents the release of diplomas and certifications, prevents access to any registration services, and may limit access to other University services. Students who have unpaid accounts at the University or who defer payment without approval, are subject to dismissal from the University. All unpaid balances will accrue ten percent interest per annum on the balance remaining from the date of default in accordance with California state law. Delinquent student accounts may be reported to one or more of the major credit bureaus and may be forwarded to an outside collection agency or an attorney for assistance in recovering the debt owed to the University. The student is responsible for all costs incurred to collect outstanding debt, including but not limited to accrued interest, late fees, court costs, collection fees, and attorney fees. All outstanding bills and costs of collection incurred by the University must be paid in full *prior to* a student re-enrolling at the University.

BILLING DISPUTES

If a student wishes to dispute any charge on their billing statement, a written explanation should be forwarded to Santa Clara University, Bursar's Office, 500 El Camino Real, Santa Clara, CA 95053-0615. The Bursar's Office must receive written correspondence within 60 days from the billing statement date on which the item in question appeared. Communication can be made by telephone but doing so will not preserve the student's rights.

Communication should include the student's name, SCU identification number, the amount in question, and a brief explanation. Payment for the amount in question is not required while the investigation is in progress; all other items not in question must be paid by the due date. If the amount in question is found to be correct, payment must be submitted to the Bursar's Office immediately upon notification.

REFUND PAYMENTS

Refunds will be processed only for student accounts reflecting a credit balance. The refund request process will begin after the end of the late registration period. A refund will not be processed based on anticipated aid. All financial aid must be disbursed on to a student's account before a refund is processed. It is the student's responsibility to make sure that all necessary documentation is completed and submitted to the Financial Aid office so that aid can be disbursed properly and in a timely fashion. Payment received by personal check will have a 14-calendar day hold before a refund can be issued; electronic check payments require a 7-calendar day hold. Credits from overpayments on student accounts will remain on the account for future charges or refunded to the original payer. Payments by wire transfer will be returned via the same method. For information on the Tuition Refund process and policies, please visit the Bursar's Office website: REFUNDS

Fall, Winter, and Spring Quarters

Graduate students who drop courses or formally withdraw from the University during fall, winter, or spring term will receive a tuition refund in accordance with the following:

- By the end of the first week of classes – 100% tuition refund, less any applicable fees
- By the end of the second week of classes – 50% tuition refund, less any applicable fees
- By the end of the third week of classes – 25% tuition refund, less any applicable fees
- After the third week of classes – zero tuition refund

Summer

Students who drop courses or withdraw from the University during the summer session term will receive a tuition refund in accordance with the following:

- By the end of day of the second scheduled class meeting – 100% tuition refund, less any applicable fees
- By the end of day of the third scheduled class meeting – 50% tuition refund, less any applicable fees
- No tuition refund after these days

- Courses taught in an asynchronous manner meet M, W, R for tuition refund purposes.

Saturday/Sunday Courses/Off Cycle Courses

Students enrolled in a weekend course in which the first class meeting is after the first week of the term must provide written notification, to the Graduate Engineering Programs Office, of their intent to withdraw or drop any weekend/off cycle course(s). Failure to comply with this process will result in a forfeit of tuition.

The following refund schedule applies:

- Students will receive a 100% tuition refund, less any applicable fees, if written notification is received by 5 p.m. on the Tuesday immediately following the first-class meeting.
- Students will receive a 50% tuition refund, less any applicable fees, if written\ notification is received by 5 p.m. on the Tuesday immediately following the second-class meeting.

To receive tuition refunds from the Bursar's Office, course drops must be handled administratively. **Students should NOT drop a weekend/off cycle course themselves through Workday after the first week of the quarter.**

Please Note: If you withdraw or drop below half-time status you may no longer be eligible to receive financial aid or student loans. Your account will be adjusted accordingly, and the aid returned to the appropriate program. If you have received a refund for these funds, you must reimburse Santa Clara University immediately. For more information on financial aid forfeiture, please visit the Financial Aid website or make an appointment with your financial aid counselor.

One-Unit Courses

Students enrolled in a one-unit course must provide written notification to their respective Records Office of their intent to withdraw or drop any course(s). Failure to comply with this process will result in a forfeit of tuition.

The following refund schedule applies:

- Students will receive a 100% tuition refund, less any applicable fees, if written notification is received within two business days prior to the first-class meeting.
- Students will receive a 50% tuition refund, less any applicable fees, after the first-class meeting and prior to the second class meeting, unless the course has only one session, in which case no refund will be granted.

Financial Hardship

Students who withdraw from the University or drop courses due to an illness, injury, or psychological/emotional condition are eligible for a tuition refund in accordance with the schedule above. Tuition insurance may be purchased to cover tuition charges for diagnosed medical or mental health related withdrawals that occur after the first week of the term.

Santa Clara University degree students who withdraw from the University or who are administratively withdrawn from the University after the third week of the term due to a qualifying financial hardship may be eligible for an allocation from the student hardship fund for 25 percent of the tuition charges for that term. Qualifying financial hardships include (1) death, disabling injury, medical emergency, (2) loss of job by an independent student, (3) medical or other emergency involving a dependent of an independent student, and (4) student deployment for active military duty. The Vice Provost for Student Life or designee, in consultation with the Financial Aid Office, will determine qualifying financial hardships and any allocation from the student hardship fund. Students must submit a request for an allocation from the student hardship fund by the end of the applicable term.

Santa Clara reserves the right to change tuition, room and board, fees, or other costs, to modify its services, or change its programs at any time. In addition, no refunds of tuition, room and board, fees or other costs will be made because of curtailed services resulting from strikes, acts of God, civil insurrection, riots or threats thereof, changed economic conditions, national emergency, or other causes beyond the control of Santa Clara University.

TUITION INSURANCE PROTECTION

Students and families may protect themselves against financial loss due to an unexpected withdrawal from the University by purchasing tuition insurance coverage. The University has partnered with A.W.G. Dewar Inc., to provide an optional insurance plan. This plan is designed to protect from loss of funds paid for tuition should it be necessary to completely withdraw from the University during the term for diagnosed medical or mental health reasons. Plan enrollment is available annually or quarterly. Enrollment must be completed prior to the first day of the quarter. Information on the tuition insurance plan can be found at: www.collegerefund.com and available on the Bursar's Office website at: www.scu.edu/bursar/tuitionprotection.

FINANCIAL AID

Students must be enrolled at least part-time status (4 units) to receive Federal financial aid.

California State Graduate Fellowships

State graduate fellowships are awarded to California residents pursuing a recognized graduate or professional degree who intend to pursue teaching as a career and who have not completed more than four quarters of full-time graduate work as of October 1. Selection is based on state manpower needs, academic performance, and financial need. Applicants should apply using the Free Application for Federal Student Aid (FAFSA), which is available at the website: www.fafsa.ed.gov/.

Loans

Students applying for aid may find the most advantageous method of financing their education through loan programs. Among those available to students of the School of Engineering are the Federal Perkins Loan and Federal Stafford Loans through the School as Lender Program. Applicants should apply using the Free Application for Federal Student Aid (FAFSA), which is available at the website: www.fafsa.ed.gov/.

Please Note: A student must be a U.S. citizen or eligible non-citizen to qualify for federal sources of financial assistance.

Deadlines

The Financial Aid Office has established deadlines for consideration of the various programs it administers. All students requesting financial aid from the University should contact the Financial Aid Office at the earliest possible date to request specific deadline information and appropriate application materials. Files completed later than February 1 for new recipients and March 2 for current recipients will receive consideration on a funds-available basis. All financial aid deadlines are posted on the Financial Aid website: www.scu.edu/financialaid.

Veterans and Veterans' Dependents Assistance

Santa Clara University has been certified by the Department of Veterans Affairs as qualified to enroll students under applicable federal legislation and regulations, including Chapter 35 (child of a deceased or 100 percent disabled veteran, widow of any person who died in the service or died of a service-connected disability, or wife of a veteran with a 100 percent service-connected disability), Chapter 31 (rehabilitation), Chapter 30/1606 (active duty Montgomery G.I. Bill®), Chapter 33 (Post 9/11 GI Bill®), and Yellow Ribbon. Individuals interested in attending under any of the veteran assistance programs should contact the Veterans Administration and the University Office of the Registrar.

GI Bill® is a registered trademark of the U.S. Department of Veterans Affairs (VA). More information about education benefits offered by VA is available at the official U.S. government Web site at http://www.benefits.va.gov/gibill.

Teaching and Research Assistantships

The School of Engineering offers a limited number of teaching and research assistantships providing up to eight units of tuition and, in some cases, a modest stipend. For further information, students are encouraged to contact their faculty advisor or their academic department.

University-Awarded Aid

Individual graduate schools may grant their students a specific amount of financial aid, per term, in the form of Santa Clara University school scholarships. Once the amount has been determined by the school, the information is sent to the Financial Aid Office for processing. The Financial Aid Office awards the aid and sends an email notification to the student's SCU Gmail address only, informing them of their financial aid package and/or any aid revision. Students will be able to see their school scholarship award on e-campus. The award amount will also appear as "anticipated aid" on the student's account to alleviate the assessment of holds/late fees from the Bursar's Office. Generally, financial aid is disbursed to the student's account ten days before the start of classes each term. If eligible, the Bursar's Office will issue refunds to students reflecting credit balances after the first week of class.

Cancellation of Financial Aid and Return of Funds

Students who withdraw from the University and who have federal financial aid are subject to the federal regulations applicable to the return of Title IV funds. These regulations assume that a student earns his or her financial aid based on the period of time he or she remains enrolled during a term. A student is obligated to return all unearned federal financial aid funds governed under Title IV.

Unearned financial aid is the amount of disbursed Title IV that exceeds the amount of Title IV aid earned in accordance with the federal guidelines. During the first 60 percent of the term, a student earns Title IV funds in direct proportion to the length of time he or she remains enrolled. That is, the percentage of time during the term that the student remains enrolled is the percentage of disbursable aid for that period that the student has earned.

A student who withdraws after the 60 percent point of the enrollment term earns all Title IV aid disbursed for the period. The amount of tuition and other charges owed by the student plays no role in determining the amount of Title IV funds to which a withdrawn student is entitled.

All funds must be returned to federal programs before funds are returned to the state or University financial aid programs and/or the student. The return of funds allocation will be made in the following order for students who have received federal Title IV assistance:

- Unsubsidized Federal Direct Loans (other than Direct PLUS Loans)
- Subsidized Federal Direct Loans
- Federal Direct Grad PLUS Loans
- Federal PELL Grants for which a return is required
- Federal Supplemental Educational Opportunity Grants for which a return is required
- TEACH Grants for which a return is required
- Iraq and Afghanistan Grants for which a return is required

Chapter 5: Academic Information

Engineering Honor Code

The Engineering Honor Code is a long-standing Santa Clara tradition; instituted at the request of engineering students, it states: All students taking courses in the School of Engineering agree, individually and collectively, that they will not give or receive unpermitted aid in examinations or other coursework that is to be used by the instructor as the basis of grading. Students and teachers cooperate and share responsibilities under the code. Teachers are responsible for making clear what aid is permissible and for using procedures that minimize temptations to violate the code. Students are responsible for behaving honorably, for actively ensuring that others, as well as themselves, uphold the code, and for being responsive to violations. Information on faculty or student reporting of violations can be found on the university academic integrity web resources at https://www.scu.edu/academic-integrity.

Classes

Classes are taught in the following time slots: 7:10-9:00 a.m., 5:10-7:00 p.m., and 7:10-9:00 p.m., Monday through Friday with some Saturday and/or Sunday offerings; two-unit courses meet one day per week, and four-unit courses meet two days per week. All students are expected to attend the first class meeting of the quarter. Failure to do so can result in an administrative withdrawal from the course by the professor during the first week of the quarter.

Standards of Scholarship

Only courses in which the student has earned assigned grades of C- or higher may be counted for the Master's, Engineer's or Ph.D. degree. The student must earn a minimum 3.0 cumulative grade point average (GPA) overall and a minimum 3.0 grade point average (GPA) in their major of the approved minimum 46 units required for the completion of the M.S. or Engineer's degree or the approved minimum 72 units required for the Ph.D. degree. Only credits, not grade points, are transferred from other institutions.

Students who have not met the minimum cumulative 3.0 GPA overall for two consecutive active quarters are eligible for dismissal. The student's advisor and Department Chair will be notified about their GPA status by email. The decision to be dismissed from the program will be based on a departmental vote, which will be conducted at the request of the advisor and/or Department Chair, and with approval from the Associate Dean for Graduate Programs. Students who have been dismissed from the program can appeal to the Department Chair, and subsequently to the Associate Dean for Graduate Studies.

> EMGT Major Note: In addition to the cumulative GPA requirement, Engineering Management students must also maintain a GPA of 3.0 or higher in both their EMGT courses and their technical STEM courses.

> Note 1: Only classes with assigned grades of C- or higher will count toward the units required for certificates, M.S., Engineer's or Ph.D. degrees. However, the grades of all courses completed during the certificate, M.S., Engineer's, or Ph.D. program are used to compute the final grade point average (GPA).

> Note 2: Directed Research, Independent Study, and Engr courses will not be included in the student's major GPA. Only major subject courses will be calculated in the students' major GPA.

Grading System

The grades A, B, C, and D may be modified by (+) or (-) suffixes, except that the grade of A may not be modified by a (+). Grade point values per unit are assigned as follows: A = 4.0; A- = 3.7; B+ = 3.3; B = 3.0; B- = 2.7; C+ = 2.3; C = 2; C- = 1.7; D+ = 1.3; D = 1.0; D- = 0.7. F= 0. I (incomplete), P (pass), NP (no pass), NS (no show) and W (withdrawn) are all assigned zero points. Unit credit, but not grade point credit, is awarded when the grade of P is assigned.

The University also uses the following marks: AUD (audit), I (incomplete), and N (continuing work), No unit credit or grade point value is granted for any of these marks.

Non-graded Courses

Courses such as seminars (with the exception of COEN 400 and ELEN 200), are limited to a total of four units and must be approved by the student's advisor.

Incomplete Grades

A student's work may be reported incomplete if, due to illness or other serious circumstance, some essential portion of the coursework remains unfinished after the final examination, or if the thesis has not been completed. An incomplete (I) becomes a failure (F) unless the unfinished work is completed to the satisfaction of the instructor and proper notice is filed with the Office of the Registrar within four weeks from the beginning of the next scheduled quarter, not including summer session. Makeup work must be in the hands of the instructor no later than the end of the third week so that the instructor can meet the four-week submission deadline. An N grade for a thesis course indicates continuing work. A final grade must be submitted before graduation.

Change of Grade

Only the faculty member responsible for a course may assign grades. All grades become final when they have been assigned and reported to the Office of the Registrar. A faculty member may report a correction of a final grade to the Office of the Registrar only if a clerical or procedural error was made in assigning, transmitting, or recording the original grade. A grade may not be changed as a result of re-evaluation, re-examination, or the submission of additional work after the term ends. Any grade change must have the approval of the department chair and the associate dean of the student's school or college. No grade may be changed after one year.

Auditing Courses

A student may take courses with a grading basis of "audit" but the following should be kept in mind:

- The current graduate tuition rate of $1,160.00 per unit + the $190.00 Design Center and Student Association engineering fee will be charged.
- No grade points or credit will be earned so the class cannot be counted toward the completion of a certificate, M.S, Engineer's or Ph.D. degree.
- A student will need to register for the class, then send an email to the Director of Records requesting the grading

basis be changed to "Audit":

- The last day to request to audit a course is at the end of the first week of the quarter.

Alumni students can request to audit a course with a reduced tuition fee. Students will need to apply to the Open University program and must meet the application deadline to apply for an audit. Please contact the Director of Records for the alumni audit form. Alumni students must meet the application deadlines listed on our graduate engineering admissions website to apply for an audit.

Repeating Courses

A student may, with the permission of the department, repeat a course in which a grade of D+ or lower was received on the first attempt. All grades, whether received on the first or second attempt, will be used in computing overall student performance. The units from a course may be counted only once in fulfilling graduation requirements.

Withdrawal from Courses

Students may change their course registration as stated in the Academic Calendar. Withdrawal from any course may be accomplished up to the 7th Friday of the term. After the fourth week of the quarter, a withdrawal will be recorded as W on the transcript. After the tenth Friday, an emergency that qualifies may be handled as an incomplete (I). Dropping a course without a formal withdrawal will result in a grade of F. Deadlines are strictly adhered to. There is no tuition refund when a student withdraws from a course if the withdrawal occurs after the tuition refund deadlines listed in the academic calendar. International Students with an F-1 Visa should check with the Global Engagement Office to confirm if they are eligible to drop a course.

Program of Studies

During the first quarter of enrollment, a student in the M.S. degree program is required to meet with a faculty advisor to complete a Program of Studies (POS) form. Here are assigned advisors for the following departments

- Aerospace Engineering-Mohammad Ayoubi and Chris Kitts (Program Advisors)
- Applied Mathematics-Aaron Melman (Department Chair)
- Bioengineering-Please contact the department for available advisors.
- Civil Engineering-Please contact the department for available advisors.
- Computer Science and Engineering-The CSE department will email your advisor information by the end of the first week of the quarter. Also, you can contact the CSE peer advisor at coenpeeradvisors@scu.edu
- Electrical and Computer Engineering-Please contact the department for available advisors.
- Engineering Management and Leadership-Paul Semenza (Department Chair)
- Mechanical Engineering-Please contact the department for available advisors.
- Power Systems and Sustainable Energy-Maryam Khanabaghi (Program Advisor)
- Robotics and Automation-Christopher Kitts (Program Advisor)

The POS must include all planned courses, units and any transfer credit approved by the department. The POS must be signed by the advisor and submitted to the Graduate Engineering Programs Office before the end of the first quarter of enrollment. Failure to submit a new POS will result in a registration hold. Variations from the approved Program of Studies may be made by submitting an updated POS form with the advisor's signature to the Graduate Engineering Programs Office. The final POS form signed by the advisor must include all units and transfer credits, and must be submitted during the student's final quarter for graduation.

Courses Transferred from Santa Clara University

With the approval of their academic advisor, M.S. Students who have an undergraduate degree from Santa Clara University can transfer up to 12 units of eligible graduate level coursework into their program with the following constraints.

- Only those courses completed with a B grade or better will be eligible for transfer.
- The units cannot be transferred if they have been used for another degree.
- Since these courses were taken at SCU, the grades will count toward the overall grade point average.

Courses Transferred from Other Institutions

All M.S. students have the option to transfer a maximum of 6 semester or 9 quarter units of graduate level coursework from an accredited institution into their degree program with their advisor's approval if the conditions below are met. All Ph.D. students have the option to transfer a maximum of 12 semester or 18 quarter units of graduate level coursework from an accredited institution into their degree program with their advisor's approval if the conditions listed below are met.

- The credits were completed by the student with a B grade or better.
- The credits were earned in an incomplete graduate program prior to application to the SCU Master's or Ph.D. program, but no more than 6 years prior to application.
- The credits were not used to earn another degree
- The units were not earned for extension, continuing education or online courses

Please keep the following in mind when transferring the units:

- Only the credit will transfer, but not grades; the overall grade point average will be based only on coursework completed at Santa Clara University.
- An official transcript and course syllabus are required for verification of the units by the student's advisor and Graduate Engineering Programs Office.
- In order to transfer units into a degree program, please follow this procedure:
  - Include the units you wish to transfer in the "Transfer Credit" section of the Program of Studies form and include the Institution Name, Course Number and Title, Grade, Units*, Year and (if applicable) the SCU equivalent course. If no equivalent course is listed, the transfer credit will be processed as general transfer credit (TRCR 300).

*Note that 1 semester unit is equivalent to 1.5 quarter units. Please put the quarter unit value on the Program of Studies so that the final total will be correct.

- The student's academic advisor must sign the Program of Studies form
- The Program of Study form must be submitted to the Graduate Engineering Programs Office by the end of the student's first quarter. A registration hold will be placed on the student's account if the Graduate Programs Office does not receive the POS form.

> NOTE: Courses that were taken more than 6 years ago are generally not accepted for transfer credit. Students who wish to request an exception must petition the Department Chair and receive a written approval with a justification. The final approval is given by the Associate Dean for Graduate Programs.

Petition for Graduation

It is a student's responsibility to file an online petition to graduate by the deadline listed in the Academic Calendar. The petition to graduate is submitted in the student Workday Portal. All graduating students must submit a final Program of Study form and enroll in at least one unit during their final quarter. M.S, students are expected to graduate when they have completed the minimum 46 or maximum 51 units.

> NOTE: Eligibility to participate in the June Commencement ceremony will be based on the completion of all requirements and units by the end of the spring quarter or the participation in the ceremony will be delayed until the following June.

Cooperative Education Option

The objective of cooperative education is to provide students with the opportunity, through the interaction of study and work experience, to enhance their academic knowledge, to further their personal work experience, and to learn about working with people. The Cooperative Education option integrates classroom work with practical industrial experience. It alternates or parallels periods of college education with periods of practical training in industry. The industrial training is related to the field of study in which the student is engaged and often is diversified to afford a wide range of experience. To qualify for this study option, students must complete at least 24 graduate level units at Santa Clara University. **Please note that COEN 900 level courses and transfer credit do not count toward the 24 graduate level unit requirement.**

Students who wish to pursue this option through curricular practical training (CPT) must enroll in ENGR 288. This class is a prerequisite for ENGR 289 (M.S. student) and ENGR 389 (Ph.D. student), and must be taken before you begin an internship. To be eligible to enroll in ENGR 288 students must complete at least 16 units of graduate level courses by the end of their second quarter at SCU or demonstrate that they will complete 24 units of graduate-level coursework by the end of their third quarter with department chair approval. Note: that transfer credits do not count toward the 24 graduate level unit requirement. MS students who plan to start (or continue) their CPT after they have taken ENGR 288 must enroll in ENGR 289 (which is allowed for credit up to three times).** With the approval of their advisor, Ph.D. students who have passed their comprehensive exam and plan to start (or continue) their CPT after they have taken ENGR 288 must enroll in ENGR 389 (which is allowed for credit up to three times) ***Students who were authorized for CPT but did not receive a passing grade in ENGR 288 ,289 or 389 will not be eligible for future CPT authorization since they did not complete the academic requirements associated with their internship.

> *** Note 1: ENGR 288 is not offered in the summer quarter. Students who plan to participate in a summer internship need to enroll in ENGR 288 in the Spring quarter if they meet the requirements listed above.

Concurrent Enrollment

Concurrent Enrollment means that a student is enrolled in two places at the same time. An international student at Santa Clara University may be given permission to engage in Concurrent Enrollment provided the student meets the following USCIS requirements:

- Combined enrollment amounts to a full course of study
- The student has been granted permission from a faculty advisor to enroll at another college (advisor must sign Concurrent Enrollment Form)
- Must receive written approval from DSO at International Student Services
- The student is making normal progress at Santa Clara and is not in danger of probation or disqualification
- Any NON-vocational coursework from the other school will be accepted for fulfilling degree requirements at SCU

For more information, please refer to the International Student Services Office website: www.scu.edu/globalengagement/international-students

Non-enrollment Period

Students in the Master's, Engineer's and Ph.D. program are expected to enroll in at least one unit for the fall, winter and spring quarters. Those students who do not wish to enroll must submit a leave of absence or withdrawal request in their Workday Student Portal. Leave of absence or withdrawal forms must be submitted by the end of the first week of the quarter. Please note the return request is not guaranteed.

Maximum Time Allowed for Degree or Certificate Completion

M.S. and Engineer's degree students are required to complete their degree within six years from their original admit term date. The six-year time frame includes quarters during which a student was not enrolled. Ph.D. students are required to complete their degree within eight years from their original admit term date. The eight-year time frame includes quarters during which a student was not enrolled. Certificate students are required to complete their certificate within two years from their original admit term date.

Withdrawal from the University

Withdrawal from the University is not officially complete until students clear all of their financial obligations with the Bursar's Office. Students on deferments or a Federal Perkins Loan must also clear their financial obligations with the Credit Counseling Office.

Note that students who miss a quarter and fail to contact the Graduate Programs Office will be automatically discontinued as a no-show status. This is the same procedure for students who took a leave of absence or withdrew from the program

Chapter 6: Enrichment Experience and Graduate Core Requirements

The Enrichment Experience is an 8-unit requirement for all M.S. degree-seeking students that is common to most departments in the School of Engineering. Civil Engineering majors may complete the Enrichment Experience with 7 units. The various components that are associated with this requirement were designed to broaden the scope of the student's knowledge, and develop professional skills that are widely perceived as essential for operating in a global environment such as the ability to communicate clearly, to function on interdisciplinary and diverse teams, and to make ethically and socially responsible decisions.

The Enrichment Experience requirement cannot be waived and no substitution will be approved.

In order to fulfill this requirement, students must take

- (minimum 4 units) A course in at least two of the three areas of
  - Emerging Topics in Engineering,
  - Engineering and Business/Entrepreneurship
  - Engineering and Society.

Below is the list of all classes approved for the graduate core in these three areas. Please check our current student resources on our graduate engineering website for the most current list of Graduate Core classes.

- The remaining 4 units can be accumulated by:
  - Taking one or more major technical electives.
    - (Directed Research, Independent Study, Capstone, Thesis and CSE foundation courses cannot be approved as a technical elective)
  - Taking additional classes from the Graduate Core List below
  - Taking Cooperative Education courses (Engr 288 and 289)
  - A combination of courses from the three categories above.

GRADUATE CORE AREAS AND TOPICS

Emerging Topics in Engineering

- AMTH 308 Theory of Wavelets
- AMTH 351 Quantum Computing
- AMTH 367 Mathematical Finance
- AMTH 387 Cryptology
- BIOE 256/ENGR 256 Introduction to Nanobioengineering
- CENG 213 Sustainable Materials
- CENG 215 Sustainable Structural Engineering
- CENG 219 Designing for Sustainable Construction
- CENG 282 Introduction to Building Information Modeling
- ECEN (ELEN) 280/MECH 287 Introduction to Alternative Energy Systems
- ECEN (ELEN) 285 Introduction to the Smart Grid
- ECEN (ELEN) 331 Autonomous Driving Systems
- ENGR 260 Nanoscale Science and Technology
- ENGR 273 Sustainable Energy and Ethics
- ENGR 371/MECH 371 Space Systems Design and Engineering I
- ENGR 372/MECH 372 Space Systems Design and Engineering II

- MECH 268 Computational Fluid Dynamics I

Engineering and Business/Entrepreneurship

- AMTH 367 Mathematical Finance
- BIOE 357/EMGT 357 Root Cause Analysis (RCA) Effective Problem Solving
- CENG 208 Engineering Economics and Project Finance
- CENG 292 Infrastructure Project Management
- CSEN (COEN) 287 Software Development Process Management
- ENGR 245 Innovation, Entrepreneurship and the Evolution of Silicon Valley
- ENGR 302 Managing in the Multicultural Environment
- ENGR 304 Building Global Teams
- ENGR 336 Engineering for the Developing World
- ENGR 338 Mobile Applications for Emerging Markets
- ENGR 350 Success in Global Emerging Markets
- Any course in Engineering Management and Leadership (EMGT)

Engineering and Society

- BIOE 210 Ethical Issues in Bioengineering
- CENG 208 Engineering Economics and Project Finance
- CSEN (COEN) 250 Information Security Management
- CSEN (COEN) 288 Software Ethics
- ECEN Chaos Theory, Metamathematics, and the Limits of Science: An Engineering Perspective on Religion
- ENGR 238 Critical Tools for Social and Environmental Projects
- ENGR 261 Nanotechnology and Society
- ENGR 272 Energy Public Policy
- ENGR 273 Sustainable Energy and Ethics
- ENGR 302 Managing in the Multicultural Environment
- ENGR 303 Gender and Engineering
- ENGR 304 Building Global Teams
- ENGR 306 Engineering and the Law
- ENGR 330 Law, Technology, and Intellectual Property
- ENGR 332 How Engineers, Businesspeople, and Lawyers Communicate With Each Other
- ENGR 334 Energy, Climate Change, and Social Justice
- ENGR 336 Engineering for the Developing World
- ENGR 337 Social Entrepreneurship- Innovating with Impact
- ENGR 340 Distributed & Renewable Energy for the Developing World
- ENGR 341 Innovation, Design and Spirituality
- ENGR 342 3D Print Technology and Society
- ENGR 344 Artificial Intelligence and Ethics
- ENGR 349 Topics in Frugal Engineering

Note 1: Although certain courses (such as ENGR 302 for example) may appear in multiple categories, they cannot be used to satisfy more than one Core requirement. Students are encouraged to periodically check for updates regarding new courses in these areas on the graduate engineering website under current student resources. https://www.scu.edu/engineering/current-student-resources/current-graduate-students/graduate-core/

Please Note: Transfer credit is not approved for core courses, and all core courses must be taken at SCU.

Chapter 7: Department of Applied Mathematics

Senior Lecturer Emeritus: Stephen A. Chiappari

Renewable Term Lecturer: Francisco Villarroya Alvarez, Robert Kleinhenz, Aaron Melman (Department Chair), Magda Metwally

Master of Science Program

The Applied Mathematics Program is open to those students who have earned a B.S. degree in engineering, science, or mathematics, provided that the student has completed a program in undergraduate mathematics that parallels the program of the mathematics major at Santa Clara University. The undergraduate program at Santa Clara includes calculus and differential equations, abstract algebra, linear algebra, advanced calculus and/or real analysis; and a minimum of five upper-division courses chosen from the areas of analysis, complex variables, partial differential equations, numerical analysis, logic, probability, and statistics.

Courses for the master's degree must result in a total of 46 units. These units may include courses from other fields with permission of the Applied Mathematics Department advisor. A minimum of 12 quarter units must be in 300-level AMTH courses.

Concentration in Mathematical Finance within the Master of Science in Applied Mathematics

In addition to its freestanding master's degree program, the Department of Applied Mathematics offers a concentration in mathematical finance within its master's degree program. Specific course requirements change from time to time. For further information, please consult with the chair of the department.

Course Descriptions

Undergraduate Courses

AMTH 106. Differential Equations

Explicit solution techniques for first order differential equations and higher order linear differential equations. Use of numerical and Laplace transform methods. Only one of MATH 22 and AMTH 106 may be taken for credit. Prerequisite: MATH 13. (4 units)

AMTH 108. Probability and Statistics

Definitions of probability, sets, sample spaces, conditional and total probability, random variables, distributions, functions of random variables, sampling, estimation of parameters, testing hypotheses. Prerequisite: MATH 14. (4 units)

AMTH 112. Risk Analysis in Civil Engineering

Set theory and probability, random variables, conditional and total probability, functions of random variables, probabilistic models for engineering analysis, statistical inference, hypothesis testing. Prerequisites: MATH 14 and at least junior standing. (4 units)

AMTH 118. Numerical Methods

Numerical solution of algebraic and transcendental equations, numerical differentiation and integration, and solution of ordinary differential equations. Solution of representative problems on the digital computer. Prerequisites: AMTH 106 or MATH 22 and one of the following: MECH 45; CSEN (COEN) 11; CSCI 10. (4 units)

AMTH 120. Engineering Mathematics

Review of ordinary differential equations (ODEs) and Laplace transform, vector calculus, linear algebra, orthogonal functions and Fourier Series, partial differential equations (PDEs), and introduction to numerical solutions of ODEs. Also listed as MECH 120. Prerequisite: AMTH 106. (4 units)

AMTH 194. Peer Educator in Applied Mathematics

Peer educators in applied mathematics work closely with a faculty member to help students understand course material, think more deeply about course material, benefit from collaborative learning, feel less anxious about testing situations, and enjoy learning. Prerequisite: Enrollment by permission of the instructor. (2 units)

Graduate Courses

All 200-level applied mathematics courses are assumed to be first-year graduate courses. The minimum preparation for these courses is a working knowledge of calculus and a course in differential equations. A course in advanced calculus is desirable. The 300-level applied mathematics courses are graduate courses in mathematics that should be taken only by students who have completed several 200-level courses.

AMTH 200. Advanced Engineering Mathematics I

Method of solution of the first, second, and higher order differential equations (ODEs). Integral transforms including Laplace transforms, Fourier series and Fourier transforms. Also listed as MECH 200. (2 units)

AMTH 201. Advanced Engineering Mathematics II

Method of solution of partial differential equations (PDEs) including separation of variables, Fourier series and Laplace transforms. Introduction to calculus of variations. Selected topics from vector analysis and linear algebra. Also, listed as MECH 201. Prerequisite: AMTH/MECH 200. (2 units)

AMTH 202. Advanced Engineering Mathematics I & II

Method of solution of first, second, and higher order ordinary differential equations, Laplace transforms, Fourier series, and Fourier transforms. Method of solution of partial differential equations, including separation of variables, Fourier series, and Laplace transforms. Selected topics in linear algebra, vector analysis, and calculus of variations. Also listed as MECH 202. (4 units)

AMTH 210. Probability I

Definitions, sets, conditional and total probability, binomial distribution approximations, random variables, important probability distributions, functions of random variables, moments, characteristic functions, joint probability distributions, marginal distributions, sums of random variables, convolutions, correlation, sequences of random variables, limit theorems. The emphasis is on discrete random variables. (2 units)

AMTH 211. Probability II

Continuation of AMTH 210. A study of continuous probability distributions, their probability density functions, their characteristic functions, and their parameters. These distributions include the continuous uniform, the normal, the beta, the gamma with special emphasis on the exponential, Erlang, and chi-squared. The applications of these distributions are stressed. Joint probability distributions are covered. Functions of single and multiple random variables are stressed, along with their applications. Order statistics. Correlation coefficients and their applications in prediction, limiting distributions, the central limit theorem. Properties of estimators, maximum likelihood estimators, and efficiency measures for estimators. Prerequisite: AMTH 210. (2 units)

AMTH 212. Probability I and II

Combination of AMTH 210 and 211. (4 units)

AMTH 214. Engineering Statistics I

Frequency distributions, sampling, sampling distributions, univariate and bivariate normal distributions, analysis of variance, two- and three-factor analysis, regression and correlation, design of experiments. Prerequisite: Solid background in discrete and continuous probability. (2 units)

AMTH 215. Engineering Statistics II

Continuation of AMTH 214. Prerequisite: AMTH 214. (2 units)

AMTH 217. Design of Scientific Experiments

Statistical techniques applied to scientific investigations. Use of reference distributions, randomization, blocking, replication, analysis of variance, Latin squares, factorial experiments, and examination of residuals. Prior exposure to statistics is useful but not essential. Prerequisite: Solid background in discrete and continuous probability. (2 units)

AMTH 220. Numerical Analysis I

Solution of algebraic and transcendental equations, finite differences, interpolation, numerical differentiation and integration, solution of ordinary differential equations, matrix methods with applications to linear equations, curve fittings, programming of representative problems. (2 units)

AMTH 221. Numerical Analysis II

Continuation of AMTH 220. Prerequisite: AMTH 220. (2 units)

AMTH 225. Vector Analysis I

Algebra of vectors. Differentiation of vectors. Partial differentiation and associated concepts. Integration of vectors. Applications. Basic concepts of tensor analysis. (2 units)

AMTH 226. Vector Analysis II

Continuation of AMTH 225. Prerequisite: AMTH 225. (2 units)

AMTH 230. Differential Equations with Variable Coefficients

Solution of ordinary differential equations with variable coefficients using power series and the method of Frobenius. Solution of Legendre differential equation. Orthogonality of Legendre polynomials, Sturm-Liouville differential equation. Eigenvalues and Eigenfunctions. Generalized Fourier series and Legendre Fourier series. (2 units)

AMTH 231. Special Functions and Laplace Transforms

Review of the method of Frobenius in solving differential equations with variable coefficients. Gamma and beta functions. Solution of Bessel's differential equation, properties and orthogonality of Bessel functions. Bessel Fourier series. Laplace transform, basic transforms, and applications. Prerequisite: AMTH 230. (2 units)

AMTH 232. Biostatistics

This course will cover the statistical principles used in Bioengineering encompassing distribution-based analyses and Bayesian methods applied to biomedical device and disease testing including methods for categorical data, comparing groups (analysis of variance) and analyzing associations (linear and logistic regression). Special emphasis will be placed on computational approaches used in model optimization, test-method validation, sensitivity analysis (ROC curve) and survival analysis. Also listed as BIOE 232 Prerequisites: AMTH 108, BIOE 120, or equivalent. (2 units)

AMTH 232L. Biostatistics Laboratory

Laboratory for AMTH 232. Also listed as BIOE 232L. Co-requisite: AMTH 232. (1 unit)

AMTH 235. Complex Variables I

Algebra of complex numbers, calculus of complex variables, analytic functions, harmonic functions, power series, residue theorems, application of residue theory to definite integrals, conformal mappings. (2 units)

AMTH 236. Complex Variables II

Continuation of AMTH 235. Prerequisite: AMTH 235. (2 units)

AMTH 240. Discrete Mathematics for Computer Science

Relations and operation on sets, orderings, combinatorics, recursion, logic, method of proof, and algebraic structures. (2 units)

AMTH 245. Linear Algebra I

Vector spaces, transformations, matrices, characteristic value problems, canonical forms, and quadratic forms. (2 units)

AMTH 246. Linear Algebra II

Continuation of AMTH 245. Prerequisite: AMTH 245. (2 units)

AMTH 247. Linear Algebra I and II

Combination of AMTH 245 and 246. (4 units)

AMTH 256. Applied Graph Theory I

Elementary treatment of graph theory. The basic definitions of graph theory are covered; the fundamental theorems are explored. Subgraphs, complements, graph isomorphisms, and some elementary algorithms make up the content. Prerequisite: Mathematical maturity. (2 units)

AMTH 297. Directed Research

By arrangement. Prerequisite: Permission of the chair of applied mathematics. May be repeated for credit with permission of the chair of applied mathematics. (1–8 units)

AMTH 299. Special Problems

By arrangement. (1–2 units)

AMTH 308. Theory of Wavelets

Construction of Daubechies' wavelets and the application of wavelets to image compression and numerical analysis. Multi resolution analysis and the properties of the scaling function, dilation equation, and wavelet filter coefficients. Pyramid algorithms and their application to image compression. Prerequisites: Familiarity with MATLAB or other high-level language, Fourier analysis, and linear algebra. (2 units)

AMTH 313. Time Series Analysis

Review of forecasting methods. Concepts in time series analysis; stationarity, auto-correlation, Box-Jenkins. Moving average and auto-regressive processes. Mixed processes. Models for seasonal time series. Prerequisite: AMTH 211 or 212. (2 units)

AMTH 315. Matrix Theory I

Properties and operations, vector spaces and linear transforms, characteristic root; vectors, inversion of matrices, applications. Prerequisite: AMTH 246 or 247. (2 units)

AMTH 316. Matrix Theory II

Continuation of AMTH 315. Prerequisite: AMTH 315. (2 units)

AMTH 340. Linear Programming I

Basic assumptions and limitations, problem formulation, algebraic and geometric representation. Simplex algorithm and duality. (2 units)

AMTH 344. Linear Regression

The elementary straight-line "least squares least-squares fit;" and the fitting of data to linear models. Emphasis on the matrix approach to linear regressions. Multiple regression; various strategies for introducing coefficients. Examination of residuals for linearity. Introduction to nonlinear regression. Prerequisite: AMTH 211 or 212. (2 units)

AMTH 351. Quantum Computing

Introduction to quantum computing, with emphasis on computational and algorithmic aspects. Prerequisite: AMTH 246 or 247. (2 units)

AMTH 358. Fourier Transforms

Definition and basic properties. Energy and power spectra. Applications of transforms of one variable to linear systems, random functions, communications. Transforms of two variables and applications to optics. Prerequisites: Calculus sequence, elementary differential equations, fundamentals of linear algebra, and familiarity with MATLAB (preferably) or other high-level programming language. (2 units)

AMTH 360. Advanced Topics in Fourier Analysis

Continuation of AMTH 358. Focus on Fourier analysis in higher dimensions, other extensions of the classical theory, and applications of Fourier analysis in mathematics and signal processing. Prerequisite: AMTH 358 or instructor approval. (2 units)

AMTH 362. Stochastic Processes I

Types of stochastic processes, stationarity, ergodicity, differentiation and integration of stochastic processes. Topics chosen from correlation and power spectral density functions, linear systems, band-limit processes, normal processes, Markov processes, Brownian motion, and option pricing. Prerequisite: AMTH 211 or 212 or instructor approval. (2 units)

AMTH 363. Stochastic Processes II

Continuation of AMTH 362. Prerequisite: AMTH 362 or instructor approval. (2 units)

AMTH 364. Markov Chains

Markov property, Markov processes, discrete-time Markov chains, classes of states, recurrence processes and limiting probabilities, continuous-time Markov chains, time-reversed chains, numerical techniques. Prerequisite: AMTH 211 or 212 or 362 or ECEN (ELEN) 233 or 236. (2 units)

AMTH 367. Mathematical Finance

Introduction to Ito calculus and stochastic differential equations. Discrete lattice models. Models for the movement of stock and bond prices using Brownian motion and Poisson processes. Pricing models for equity and bond options via Black-Scholes and its variants. Optimal portfolio allocation. Solution techniques will include Monte Carlo and finite difference methods. Prerequisite: MATH 53 or permission of instructor and MATH 122 or AMTH 108. Also listed as FNCE 116, MATH 125 AND FNCE 3489. (4 units)

AMTH 370. Optimization Techniques I

Convex sets and functions. Unconstrained optimality conditions. Convergence and rates of convergence. Applications. Numerical methods for unconstrained optimization (and constrained optimization as time permits). Prerequisites: Proficiency in Matlab programming and AMTH 246 or 247. (2 units)

AMTH 371. Optimization Techniques II

Optimization problems in multidimensional spaces involving equality constraints and inequality constraints by gradient and non-gradient methods. Special topics. Prerequisite: AMTH 370. (2 units)

AMTH 372. Semi-Markov and Decision Processes

Semi-Markov processes in discrete and continuous time, continuous-time Markov processes, processes with an infinite number of states, rewards, discounting, decision processes, dynamic programming, and applications. Prerequisite: AMTH 211 or 212 or 362 or 364 or ECEN (ELEN) 233 or 236. (2 units)

AMTH 374. Partial Differential Equations I

Relation between particular solutions, general solutions, and boundary values. Existence and uniqueness theorems. Wave equation and Cauchy's problem. Heat equation. (2 units)

AMTH 375. Partial Differential Equations II

Continuation of AMTH 374. Prerequisite: AMTH 374. (2 units)

AMTH 376. Numerical Solution of Partial Differential Equations

Numerical solution of parabolic, elliptic, and hyperbolic partial differential equations. Basic techniques of finite differences, finite volumes, finite elements, and spectral methods. Direct and iterative solvers. Prerequisites: Familiarity with numerical analysis, linear algebra, and MATLAB. (2 units)

AMTH 377. Design and Analysis of Algorithms

Techniques of design and analysis of algorithms: proof of correctness; running times of recursive algorithms; design strategies: brute-force, divide and conquer, dynamic programming, branch-and-bound, backtracking, and greedy technique; max flow/ matching. Intractability: lower bounds; P, NP, and NP-completeness. Also listed as CSEN (COEN) 279 Prerequisite: CSEN (COEN) 912C or equivalent. (4 units)

AMTH 379. Advanced Design and Analysis of Algorithms

Amortized and probabilistic analysis of algorithms and data structures: disjoint sets, hashing, search trees, suffix arrays and trees. Randomized, parallel, and approximation algorithms. Also listed as CSEN (COEN) 379. Prerequisite: AMTH 377/CSEN (COEN) 279. (4 units)

AMTH 387. Cryptology

Mathematical foundations for information security (number theory, finite fields, discrete logarithms, information theory, elliptic curves). Cryptography. Encryption systems (classical, DES, Rijndael, RSA). Cryptanalytic techniques. Simple protocols. Techniques for data security (digital signatures, hash algorithms, secret sharing, zero-knowledge techniques). Prerequisite: Mathematical maturity at least at the level of upper-division engineering students. (4 units)

AMTH 388. Advanced Topics in Cryptology

Topics may include advanced cryptography and cryptanalysis. May be repeated for credit if topics differ. Prerequisite: AMTH 387. (2 units)

AMTH 397. Master's Thesis

By arrangement. Limited to master's students in applied mathematics. (1–9 units)

AMTH 399. Independent Study

By arrangement. Prerequisite: Instructor approval. (1-4 units)

Chapter 8: Department of Bioengineering

Phil and Bobbie Sanfilippo Professor: Yuling Yan
Associate Professors: Ismail Emre Araci, Prashanth Asuri (Department Chair), Unyoung (Ashley) Kim, Biao (Bill) Lu, Zhiwen (Jonathan) Zhang
Assistant Professor: Hamed Akbari
Lecturers: Maryam Mobed-Miremadi, Eun Ju (Emily) Park
Adjunct Assistant Professor: Julia Scott
Adjunct Faculty: Erhan Yenilmez, Frankie Myers, Murat Baday, Paul Nauleau

Overview

Bioengineering is the fastest-growing area of engineering and holds the promise of improving the lives of all people in straightforward and diverse ways. Bioengineering focuses on the application of electrical, chemical, mechanical, and other engineering principles to understand, modify, or control biological systems. As such, the curriculum teaches principles and practices at the interface of engineering, medicine and the life sciences. The Department of Bioengineering currently offers an M.S. degree program with a focus on biodevice engineering, biomaterials and tissue engineering, and biomolecular engineering.

A number of faculty offer research projects to bioengineering students that are engaging and involve problem-solving at the interface of engineering, medicine and biology.

Dr. Yan's research interests center on bioimaging, image and signal analysis, and AI-assisted medical diagnosis. Notable achievements of her lab include the development of new imaging modalities to study laryngeal dynamics and function, with associated analytical methods for the classification of laryngeal pathologies.

Dr. Zhang is currently engaged in research on several NIH-funded projects spanning protein engineering to drug discovery.

Dr. Araci's research goals are directed toward the development and application of novel microfluidic and optofluidic technologies for biology and medicine. His work is focused on two major areas: i) implantable and miniaturized devices for telemedicine and ii) single molecule protein counting.

Dr. Asuri's research interests involve integrating tools and concepts from biomaterials engineering, biotechnology, and cell biology to explore the role of biomaterial properties such porosity, matrix stiffness, etc., on protein structure and function and in regulating cell fate.

Dr. Kim investigates the application of integrated microfluidic systems for multiple uses in diagnostics as well as experimental science.

Dr. Lu's research focuses on medical translations of protein engineering that includes protein therapeutics and drug delivery as well as molecular sensor and imaging technology.

Dr. Mobed-Miremadi's research interests are in the areas of mesoscience, specifically the interface of cellular engineering/chemical engineering, bio-device development based on membrane-based therapies and bio-fabrication.

Degree Program

The Bioengineering graduate program at Santa Clara University is designed to accommodate the needs of students interested in advanced study in the areas of medical devices/bioinstrumentation and molecular and cellular bioengineering. An individual may pursue the degree of Master of Science (M.S.), either as a full-time or part-time

student, through a customized balance of coursework, directed research and/or thesis research. Students are also required to supplement their technical work with coursework on other topics that are specified in the graduate engineering core curriculum.

Master of Science in Bioengineering

To be considered for admission to the graduate program in bioengineering, an applicant must meet the following requirements:

- A bachelor's degree in bioengineering or related areas from an ABET accredited four-year B.S. degree program or its equivalent
- An overall grade point average (GPA) of at least 3.0 (based on a 4.0 maximum scale)
- Graduate Record Examination (GRE)-general test
- For students whose native language is not English, Test of English as a Foreign Language (TOEFL) or the International English Language Testing systems (ILETS) exam scores are required before application is processed

Applicants who have taken graduate-level courses at other institutions may qualify to transfer a maximum of nine quarter units of approved credit to their graduate program at Santa Clara University.

Upon acceptance or conditional acceptance, to the graduate program in bioengineering, a student will be required to select a graduate advisor (full-time faculty member) from within the Department of Bioengineering. The student's advisor will be responsible for approving the student's course of study. Any changes to a student's initial course of study must have the written approval of the student's advisor.

To qualify for the degree of Master of Science in Bioengineering, students must complete a minimum of 46 quarter units, including required core and elective courses, within the School of Engineering. Required and elective courses for the bioengineering programs are provided below. Students undertaking thesis work are required to engage in research that results, for example, in the development of a new method or approach solving a bioengineering related problem, or a technical tool, design criteria, or a biomedical application. This work should be documented in a journal publication, conference, or research report, and must also be included in a Master's thesis. Alternatively, students may elect to take only courses to fulfill the requirement for the M.S. degree.

Course requirements

• Enrichment Experience (minimum eight units including BIOE 210 Bioethics) (See descriptions in Chapter 6, Enrichment Experience and Graduate Core Requirements)

• Applied Mathematics (4 units) Select from AMTH 200 & 201 (or 202), 210 & 211 (or 212), or AMTH 245 & 246

• Bioengineering Core (15 or 21* units)

Students must take six units from one of the five primary focus areas (additional six units are required for Computational Bioengineering or Translational Bioengineering), four units from other focus areas, three units from biostatistics (BIOE 232 L&L) and two quarter research seminar units (BIOE 200, 2 x 1 unit).

• Five primary focus areas are:

1. Biomolecular Engineering/Biotechnology - BIOE 257, 282, 283, 286, 288, 300, 301

2. Biomaterials and Tissue Engineering - BIOE 208, 240, 245, 269, 273, 378

3. Microfluidics/Biosensors and Imaging - BIOE 203, 260, 267, 268, 276, 277, 308

4. Computational Bioengineering - BIOE 251, 252, 261, 263, 281, 310, 312

Advanced Applied Mathematics* - AMTH 240, 364, 370, 371, 377

5. Translational Bioengineering - BIOE 206, 263, 279, 285, 302, 307, 320, 380

Graduate Capstone Project* - BIOE 294, 295, 296

additional six units required for primary focus in Computational Bioengineering or Translational Bioengineering

• Bioengineering Technical Electives (13* or 19 units)

All graduate-level BIOE courses (except BIOE 210) may count as Technical Elective (TE) units. Select graduate courses from CSEN (COEN), ECEN (ELEN), or MECH, may be credited as Technical Electives upon approval by faculty advisor. A maximum of 4 units total from ENGR and EMGT graduate courses may be credited as Technical Electives. A maximum of 3 units total of Directed Research (BIOE 297) may be credited for Technical Electives if also doing the Master's Thesis option (BIOE 397, maximum 9 units total), otherwise a maximum of 6 units total of BIOE 297 is allowed. Submission of a Master's Thesis is required for BIOE 397.

For students in the five-year BS/MS program, a maximum of 20 units may be transferred. Courses used to meet the 46-unit minimum total for the Master of Science in Bioengineering degree cannot include courses that were used to satisfy a previous undergraduate degree program requirement. This includes cross-listed undergraduate courses at Santa Clara University and/or their equivalent courses at other institutions. If some required courses in the SCU graduate bioengineering program have been completed prior to graduate-level matriculation at SCU, additional elective courses will be required to satisfy the minimum unit total requirement as necessary.

Ph.D. in Bioengineering

The Doctor of Philosophy (Ph.D.) degree is sought by those engineers who wish to become experts in a specific area within bioengineering. The work for the degree consists of bioengineering research, the preparation of a thesis based on the research, and a program of advanced studies in engineering, mathematics, and related physical sciences. The Bioengineering Department also offers an "industrial track" for working professionals as an option to facilitate the collaboration between academia and industry. The student's work is directed by the degree-conferring department, subject to the general supervision of the School of Engineering.

Preliminary Examination

The preliminary examination shall be written and shall include subject matter deemed by the major department to represent sufficient preparation in depth and breadth for advanced study in the major. Only those who pass the written examination may take the oral qualifying examination.

Students currently studying at Santa Clara University for a master's degree who are accepted for the Ph.D. program and who are at an advanced stage of the M.S. program may, with the approval of their academic advisor, take the preliminary examination before completing the M.S. degree requirements. Students who have completed the M.S. degree requirements and have been accepted for the Ph.D. program should take the preliminary examination as soon as possible but not more than two years after beginning the program.

Only those students who pass the preliminary examination shall be allowed to continue in the doctoral program. The preliminary examination may be repeated only once, and then only at the discretion of the thesis advisor.

Thesis Advisor

It is the student's responsibility to obtain consent from a full-time faculty member in the student's major department to serve as his/her prospective thesis advisor.

It is strongly recommended that Ph.D. students find a thesis advisor before taking the preliminary examination. After passing the preliminary examination, Ph.D. students should have a thesis advisor before the beginning of the next quarter following the preliminary examination. Students currently pursuing a master's degree at the time of their preliminary examination should have a thesis advisor as soon as possible after being accepted as a Ph.D. student.

The student and the thesis advisor jointly develop a complete program of studies for research in a particular area. The complete program of studies (and any subsequent changes) must be filed with the Graduate Services Office and approved by the student's doctoral committee. Until this approval is obtained, there is no guarantee that courses taken will be acceptable toward the Ph.D. course requirements.

Doctoral Committee

After passing the Ph.D. preliminary exam, a student requests their thesis advisor to form a doctoral committee. The committee consists of at least five members, each of which must have earned a doctoral degree in a field of engineering or a related discipline. This includes the student's thesis advisor, at least two other current faculty members of the student's major department at Santa Clara University, and at least one current faculty member from another appropriate academic department at Santa Clara University. The committee reviews the student's program of study, conducts an oral comprehensive exam, conducts the dissertation defense, and reviews the thesis. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, thesis defense, and thesis itself meet with the approval of all committee members.

Residence

The doctoral degree is granted on the basis of achievement, rather than on the accumulation of units of credit. However, the candidate is expected to complete a minimum of 72 quarter units of graduate credit beyond the master's degree. Of these, 36 quarter units may be earned through coursework and independent study, and 36 through the thesis. All Ph.D. thesis units are graded on a Pass/No Pass basis. A maximum of 18 quarter units (12 semester units) may be transferred from other accredited institutions at the discretion of the student's advisor.

Ph.D. students must undertake a minimum of four consecutive quarters of full-time study at the University; spring and fall quarters are considered consecutive. The residency time shall normally be any period between passing the preliminary examination and completion of the thesis. For this requirement, full-time study is interpreted as a minimum registration of eight units per quarter during the academic year and four units during summer session. Any variation from this requirement must be approved by the doctoral committee.

Comprehensive Examinations and Admission to Candidacy

After completion of the formal coursework approved by the doctoral committee, the student shall present their research proposal for comprehensive oral examinations on the coursework and the subject of their research work. The student should make arrangements for the comprehensive examinations through the doctoral committee. A student who passes the comprehensive examinations is considered a degree candidate. The comprehensive examinations normally must be completed within four years from the time the student is admitted to the doctoral program. Comprehensive examinations may be repeated once, in whole or in part, at the discretion of the doctoral committee.

Thesis Research and Defense

The period following the comprehensive examinations is devoted to research for the thesis, although such research may begin before the examinations are complete. After successfully completing the comprehensive examinations, the student must pass an oral examination on their research and thesis, conducted by the doctoral committee and whomever they appoint as examiners. The thesis must be made available to all examiners one month prior to the examination. The oral examination shall consist of a presentation of the results of the thesis and the defense. This examination is open to all faculty members of Santa Clara University, but only members of the doctoral committee have a vote.

Thesis and Publication

At least one month before the degree is to be conferred, the candidate must submit to the Office of the Dean of Engineering two copies of the final version of the thesis describing the research in its entirety. The thesis will not be considered as accepted until approved by the doctoral committee and one or more refereed articles based on it are

accepted for publication in a first-tier professional or scientific journal approved by the doctoral committee. All doctoral theses must also be reproduced on microfilm by University Microfilms International, which keeps on deposit the master microfilm copy and responds to requests for copies by individuals and libraries.

Time Limit for Completing Degrees

All requirements for the doctoral degree must be completed within eight years following initial enrollment in the Ph.D. program. Extensions will be allowed only in unusual circumstances and must be recommended in writing by the student's doctoral committee, and approved by the dean of engineering in consultation with the Graduate Program Leadership Council.

Additional Graduation Requirements

The requirements for the doctoral degree in the School of Engineering have been made to establish the structure in which the degree may be earned. Upon written approval of the provost, the dean of the School of Engineering, the doctoral committee, and the chair of the major department, other degree requirements may be established. The University reserves the right to evaluate the undertakings and the accomplishments of the degree candidate in total, and award or withhold the degree as a result of its deliberations.

Bioengineering Laboratory Facilities

The ***Anatomy & Physiology Laboratory*** provides a full range of activities to study human anatomy and organ function. Through computational modeling, organ dissection, and design projects, students will develop essential skills in conceiving and implementing engineering solutions to medical problems.

The ***Bioimaging/Image and Signal Analysis Laboratory*** carries out fundamental and translational research on voice. Current research in the laboratory includes the development of imaging modalities to study laryngeal dynamics and function, and novel approaches for image/biosignal-based analysis and assessment of voice pathologies. The lab also supports the development of new detection and analytical methods using optical probes for applications in high-contrast fluorescence imaging in cells and tissues.

The ***Biological Micro/Nanosystems Laboratory*** supports research and teaching activities in the broad areas of microfluidics/biosensing. Utilizing microfluidic technologies, spectroscopy, and microfabrication techniques, we develop innovative microfluidic platforms for applications in basic biology, diagnostics, and cellular engineering.

The ***Biomaterials Engineering Laboratory*** focuses on the use of hydrogels to develop in vitro platforms that explore the role of in vivo-like microenvironmental cues on controlling protein structure and function and regulating cell fate. The lab also supports the design and characterization of biomaterial nanocomposites for applications in tissue engineering.

The ***Biomolecular Engineering Laboratory*** conducts "bioengineering towards therapy." The idea is to engineer novel materials (particularly proteins and peptides) and devices and apply them to study basic biological and medical questions that ultimately lead to drug discovery and disease diagnosis.

The ***Biophotonics & Bioimaging Laboratory*** supports research and teaching on portable imaging systems for wearable/implantable biosensors as well as on optical coherence tomography (OCT) probes for stereotactic neurosurgery. The time-lapse fluorescence microscopy setup is used for measuring enzyme activity and single cell protein expression at the single molecular level.

The ***Biosignals Laboratory*** provides a full range of measurement and analysis capabilities including electrocardiography (ECG), electroencephalography (EEG), and electromyography (EMG) measurement system, vocal signal recording, and analysis software.

The ***Micro-devices & Microfluidics Laboratory*** focuses on the fabrication and testing of microfluidic devices for biomedical research and teaching. The soft-lithography room is equipped with necessary instruments (e.g., mixer, spinner, plasma cleaner) to build micro-devices using a wide variety of materials and processes. Multiple microfluidic test setups (i.e., computer-controlled solenoid valves and microscopes) allow several tests to be run simultaneously.

The ***Tissue Engineering Laboratory*** supports research and teaching activities related to mammalian cell and tissue culture. Activities include but are not limited to 2D and 3D mammalian cell culture, investigation of the role of biophysical cues on cancer cell migration and response to drugs, and genetic manipulation of mammalian cells.

Course Descriptions

Undergraduate Courses

BIOE 100. Bioengineering Research Seminar
A series of one-hour seminars will be presented by guest professors and researchers on their particular research topics in bioengineering or related fields. Students are required to attend four to five seminars and submit a one-page report summarizing the presentation for each seminar. May be repeated for credit up to three times. P/NP grading. Also listed as BIOE 200. (1 unit)

BIOE 106. Design Control for Medical Devices
This course will cover the principles behind design control. All of the essential elements required in the regulated medical device environment will be covered from design planning, inputs and outputs to verification, validation, risk management and design transfer. A problem-based learning approach will be utilized so that students will develop proficiency to apply the principles. Knowledge will be acquired through lectures, class activities, industry guest lectures and field trips. Also listed as BIOE 206. (2 units)

BIOE 107. Medical Device Product Development
The purpose of this course is to provide background information and knowledge to start or enhance a career in medical device product development. Discusses medical device examples, product development processes, regulation, industry information, and intellectual property. Also listed as BIOE 307 and EMGT 307. (2 units)

BIOE 108. Biomedical Devices: Role of Polymers
This course is designed to highlight the role that polymers play in the design and fabrication of various medical devices ranging from simple intravenous drip systems to complex cardiac defibrillator implants and transcatheter heart valves. Topics include polymer basics, biocompatibility, biodegradation, and other tangentially-related topics such as regulatory body approvals and intellectual property. Also listed as BIOE 208.

BIOE 109. Translational Development for Emerging Biomedical Devices
This course exposes the student to ongoing case-based interventional cardiology diagnostic and therapeutic biomedical device and clinical translational problems, where real-world bioengineering innovative solutions are being envisioned, and at times successfully being applied by startup teams of bioengineers and medical professionals. Bioengineering device design concepts and clinical translational development considerations are analyzed and case-based team project reports are assigned for final grading. Prerequisites: BIOE 21, BIOE 108 or BIOE 153 preferred. (4 units)

BIOE 111. Introduction to Healthcare Innovation
A project-based course that introduces students to healthcare innovation processes for advanced and emerging markets. The course will provide foundational training to address healthcare challenges around the world through innovation. Students in the course will work as teams on problem identification and assessment, iterative development and prototyping of solutions, and concept and business model development, as well as formulation of strategies to ensure regulatory compliance and commercialization success. Prerequisite: Sophomore to senior standing. (4 units)

BIOE 120. Experimental Methods in Bioengineering

This course will cover the principles of data representation, analysis, and experimental designs in bioreactors, biomaterials, and medical devices. Topics include error analyses, modeling, normality testing, hypothesis testing. Special emphasis will be placed on the interpretation of data from high-throughput assays used in "omics"/tissue engineering. Prerequisite: MATH 14. (4 units)

BIOE 130. Immune System for Engineers

This course will discuss two significant aspects of human immune systems in bioengineering: 1) Complex hurdles associated with the body's immune systems for biomaterials, biodevice, and implants; and 2) profound opportunities with engineered therapeutics. Also listed as BIOE 230. (4 units)

BIOE 131. Cancer Immunotherapy

This course aims to provide the scientific and clinical background necessary to understand cancer immunotherapy's fundamental topics and analyze its strengths and limitations. Emphasis will be on checkpoint blockades, CAR-T and other cell therapy, and cancer vaccines. These topics and the latest developments will be discussed through lectures and journal club presentations. Also listed as BIOE 320. (2 units)

BIOE 138. Medicinal Chemistry and Drug Design I

Small molecule medicines are coming back! In two seminal courses, principles of medicinal chemistry will be discussed in detail, as well as the related drug designs. Medicines and their designs in the following categories will be studied in the part I: Acid-Base disorders; antihistamines; anticholinergics; anti-inflammation (NSAIDs and Glucocorticoids). The contents of the course are offered at the same level as in pharmacy schools. Students are encouraged to have strong background in biology, organic chemistry and physiology. Also listed as BIOE 238. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31. (2 units)

BIOE 139. Medicinal Chemistry and Drug Design II

This is the part II of the seminal courses – Medicinal Chemistry and Drug Design. Students will study the principles of medical chemistry in detail, as well as the pharmacology for drug design. Medicines and their design will be studied in the following categories: Non-steroidal anti-inflammatory drugs (NSAIDs), Glucocorticoids, Thyroid and Thyroid Drugs, Estrogens and Progestins. On top of the understanding of the principles of drugs, the sequel will be concluded with the "rules" of drug discovery and clinical therapy. Also listed as BIOE 239. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31. (2 units)

BIOE 153. Biomaterials Science

Basic principles of material properties, biomaterials categories, biomaterials engineering concepts and selected applications and practical aspects are taught in this class. This course is a foundation for an entry level medical device engineer or bioengineering advanced degree. Prerequisite: CHEM 12. (4 units)

BIOE 154. Introduction to Biomechanics

Engineering mechanics and applications in the analysis of human body movement, function, and injury. Review of issues related to designing devices for use in, or around, the human body including safety and biocompatibility. Prerequisites: PHYS 33. (4 units)

BIOE 155. Biological Transport Phenomena

The transport of mass, momentum, and energy are critical to the function of living systems and the design of medical devices. This course develops and applies scaling laws and the methods of continuum mechanics to biological transport phenomena over a range of length and time scales. Prerequisites: PHYS 33, AMTH 106. (4 units)

BIOE 156. Introduction to NanoBioengineering

This course is designed to present a broad overview of diverse topics in nanobioengineering, with emphasis on areas that directly impact applications in biotechnology and medicine. Specific examples that highlight interactions between nanomaterials and various biomolecules will be discussed, as well as the current status and future possibilities in the development of functional nanohybrids that can sense, assemble, clean, and heal. Also listed as BIOE 256 and ENGR 256. (2 units)

BIOE 157. Introduction to Biofuel Engineering

This course will cover the basic principles used to classify and evaluate biofuels in terms of thermodynamic and economic efficiencies as well as environmental impact for resource recovery. Special emphases will be placed on emerging applications, namely, microbial fuel cell technology and photo-bioreactors. Also listed as BIOE 257/ENGR 257. Prerequisites: BIOE 21 (or BIOL 1B), CHEM 13, PHYS 33. (2 units)

BIOE 158. Soft Biomaterials Characterization

This course will cover the fundamental principles of characterization and biodegradation of soft implantable/injectable biomaterials including polymers, hydrogels, liquid crystalline colloids starting with the linkage of microscopic to macroscopic properties and, emphasis on elasticity, adhesion, diffusion and light scattering. Also listed as BIOE 258. Prerequisite: BIOE 153. Co-requisite: BIOE 158L. (4 units)

BIOE 158L. Soft Biomaterials Characterization Laboratory

Laboratory for BIOE 158. Also listed as BIOE 258L. Co-requisite: BIOE 158. (1 unit)

BIOE 159. Hard Biomaterials Characterization

This course will cover the fundamental principles of characterization and biodegradation of hard biomaterials including bioceramics and metals starting with the linkage of microscopic to macroscopic properties and, emphasis on corrosion, coatings, (nano/micro)-indentation and accelerated implant analysis. Instruction will be complimented by software-enabled simulation of prototyping and driving forces' analyses. Also listed as BIOE 259. Prerequisite: BIOE 153. Co-requisite: BIOE 159L. (4 units)

BIOE 159L. Hard Biomaterials Characterization Laboratory

Laboratory for BIOE 159. Also listed as BIOE 259L. Co-requisite: BIOE 159. (1 unit)

BIOE 161. Bioinstrumentation

Transducers and biosensors from traditional to nanotechnology; bioelectronics and measurement system design; interface between biological system and instrumentation; data analysis; clinical safety. Laboratory component will include traditional clinical measurements and design and test of a measurement system with appropriate transducers. Prerequisites: BIOE 21 (or BIOL 1B), ELEN 50. Co-requisite: BIOE 161L. (4 units)

BIOE 161L. Bioinstrumentation Laboratory

Laboratory for BIOE 161. Co-requisite: BIOE 161. (1 unit)

BIOE 162. Signals and Systems for Bioengineers

Origin and characteristics of bioelectric, bio-optical, and bioacoustic signals generated from biological systems. Behavior and response of biological systems to stimulation. Acquisition and interpretation of signals. Signal processing methods include FFT spectral analysis and time-frequency analysis. Laboratory component will include modeling of signal generation and analysis of signals such as electrocardiogram (ECG), electromyogram (EMG), and vocal sound pressure waveforms. Prerequisites: BIOE 45, ECEN (ELEN) 50, AMTH 106. Co-requisite: BIOE 162L. (4 units)

BIOE 162L. Signals and Systems for Bioengineers Laboratory

Laboratory for BIOE 162. Co-requisite: BIOE 162. (1 unit)

BIOE 163. Bio-Device Engineering

This course will instruct students with the fundamental principles of bio-device design, fabrication and biocompatibility, and let students experiment with the state-of-the-art bio-devices. Students will gain the hands-on experience with these bio-instruments which are also used in the field. Emphasis is given to the cutting-edge applications in biomedical diagnostics and pharmaceutical drug discovery and development, particularly detection and monitoring interaction, and activity of biomolecules, such as enzymes, receptors, antibody, nucleic acids, and bioanalytes. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31. Co-requisite: BIOE 163L. (4 units)

BIOE 163L. Bio-Device Engineering Laboratory

Laboratory for BIOE 163. Co-requisite: BIOE 163. (1 unit)

BIOE 166. Biosignal and Medical Image Processing I

This course covers the principles and methods of signal and image processing and their applications in biomedical engineering. A complete set of signal and image processing tools, including diagnostic decision-making tools will be introduced at a useful, working depth. Also listed as BIOE 216. Prerequisite: BIOE 162. (2 units)

BIOE 167. Introduction to Medical Imaging

This course will cover basics of technical aspects and clinical applications of medical imaging. Practicing radiologists will introduce the students to the history of radiology and medical imaging, as well as specific modalities such as X-ray, CT, MR, ultrasound, nuclear medicine, and interventional radiology. A brief discussion of applications of information technology to radiology is also included. Also listed as BIOE 267. (2 units)

BIOE 168. Biophotonics and Bioimaging

This course focuses on the interactions of light with biological matter and includes topics on the absorption of light by biomolecules, cells, and tissues, and the emission of light from these molecules via fluorescence and phosphorescence. The course will cover the application of biophotonics in cell biology, biotechnology, and biomedical imaging. Also listed as BIOE 268. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31, PHYS 33. Co-requisite: BIOE 168L. (2 units)

BIOE 168L. Biophotonics and Bioimaging Laboratory

The lab will provide hands-on experience for essential imaging and microscopy techniques as well as advanced techniques such as fiber-optics and optical coherence tomography. Some of the experiments that will be conducted are: measuring the focal length of lenses and imaging using a single lens and a lens system, determining the magnification of optical systems (e.g., of a microscope), interference in Young's double slit and Michelson configuration, diffraction, polarization, and polarization rotation. Also listed as BIOE 268L. Co-requisite: BIOE 168. (1 unit)

BIOE 170. Mechanobiology

This course will focus on the mechanical regulation of biological systems. Students will gain an understanding of how mechanical forces are converted into biochemical activity. The mechanisms by which cells respond to mechanical stimuli and current techniques to determine these processes will be discussed. Class discussions will primarily center around assigned readings of published literature guided by lecture topics. Also listed as BIOE 270. Prerequisite: BIOE 154. (2 units)

BIOE 171. Physiology and Anatomy for Engineers

Examines the structure and function of the human body and the mechanisms for maintaining homeostasis. The course will provide a molecular-level understanding of human anatomy and physiology in select organ systems. The course will include lectures, class discussions, case studies, computer simulations, field trips, lab exercises, and team projects. Prerequisite: BIOE 21 (or BIOL 1B). Co-requisite: BIOE 171L. (4 units)

BIOE 171L. Physiology and Anatomy for Engineers Laboratory

Laboratory for BIOE 171. Co-requisite: BIOE 171. (1 unit)

BIOE 172. Introduction to Tissue Engineering

Introduces the basic principles underlying the design and engineering of functional biological substitutes to restore tissue function. Cell sourcing, manipulation of cell fate, biomaterial properties and cell-material interactions, and specific biochemical and biophysical cues presented by the extracellular matrix will be discussed, as well as the current status and future possibilities in the development of biological substitutes for various tissue types. Prerequisite: BIOE 22 (or BIOL 1C). (4 units)

BIOE 173. Advanced Topics in Tissue Engineering

Overview of the progress achieved in developing tools, technologies, and strategies for tissue engineering-based therapies for a variety of human diseases and disorders. Lectures will be complemented by a series of student-led discussion sessions and student team projects. Also listed as BIOE 273. Prerequisite: BIOE 172 or instructor approval. (2 units)

BIOE 174. Microfabrication and Microfluidics for Bioengineering Applications
Microfluidics uses principles from a broad range of disciplines including fluid mechanics, material science and optics for miniaturization, and automation of biochemical applications. This course will introduce the basic physical and engineering concepts which have practical importance in microfluidics and will allow better understanding of molecule and cell manipulation in the micro-domain. The course aims to introduce students to the state-of-art applications of various microfluidic techniques (e.g. mLSI, droplet and paper-based), in biological and biomedical research through lectures and discussion of current literature. Prerequisites: BIOE 21 (or BIOL 1B). Co-requisite: BIOE 174L. (4 units)

BIOE 174L. Microfabrication and Microfluidics for Bioengineering Applications Laboratory
Multilayer soft-lithography will be taught and integrated microfluidic chips will be built. Basic pressure driven microfluidic chip tests will be performed. A team design project that stresses interdisciplinary communication and problem-solving is required in this course. Co-requisite: BIOE 174. (1 unit)

BIOE 175. Biomolecular and Cellular Engineering I
This course will focus on solving problems encountered in the design and manufacturing of biopharmaceutical products, including antibiotics, antibodies, protein drugs, and molecular biosensors, with particular emphasis on the principle and application of protein engineering and reprogramming cellular metabolic networks. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31, or equivalent knowledge and by instructor's permission. BIOE 153 is recommended. Co-requisite: BIOE 175L. (4 units)

BIOE 175L. Biomolecular and Cellular Engineering I Laboratory
Laboratory for BIOE 175. Co-requisite: BIOE 175. (1 unit)

BIOE 176. Biomolecular and Cellular Engineering II
This course will focus on the principle of designing, manufacturing synthetic materials and their biomedical and pharmaceutical applications. Emphasis of this class will be given to chemically synthetic materials, such as polymers, and inorganic and organic compounds. Also listed as BIOE 226. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31, or equivalent knowledge and by instructor's permission. BIOE 171 and 175 are recommended. (4 units)

BIOE 176L. Biomolecular and Cellular Engineering II Laboratory
Laboratory for BIOE 176. Co-requisite: BIOE 176. (1 unit)

BIOE 177A. Machine Learning and Applications in Biomedical Engineering
This course covers fundamental methods that form the core of modern machine learning (ML)/deep learning (DL). Supervised and unsupervised learning techniques, and neural networks will be introduced. Selected biomedical applications will be presented. A second course of this series (BIOE 177B) will introduce programming in Python and include building ML projects with TensorFlow. Prerequisite: MATH 14. (2 units)

BIOE 177B. Machine Learning and Algorithm Implementation
This course will introduce programming in Python and focus on building machine learning projects with TensorFlow, Keras, and NumPy. Prerequisite: BIOE 177A. (2 units)

BIOE 178 Microfluidics and Lab-on-a-Chip
The interface between engineering and miniaturization is among the most intriguing and active areas of inquiry in modern technology. This course aims to illuminate and explore microfluidics and LOC (lab-on-a-chip) as an interdisciplinary research area, with an emphasis on emerging microfluidics disciplines, LOC device design, and micro/nanofabrication. Credit not allowed for both BIOE 178 and 276. Cross-listed with BIOE 276.

BIOE 179. Introduction to Neural Engineering
This course provides a foundation in the neural principles underlying existing and upcoming neurotechnologies. The goal is to understand the design criteria necessary for engineering interventions in neural structure and function with application to neurological diseases, disorders, and injuries. Topics include brain imaging and stimulation, neural implants, nanotechnologies, stem cell and tissue engineering. This course includes lectures, literature critiques, and design projects. Also listed as BIOE 275. Prerequisites: BIOE 21 (or BIOL 1B). BIOE 171 recommended. (2 units)

BIOE 180. Clinical Trials: Design, Analysis and Ethical Issues

This course will cover the principles behind the logistics of design and analysis of clinical trials from statistical and ethical perspectives. Topics include methods used for quantification of treatment effect(s) and associated bias interpretation, crossover designs used in randomized clinical trials, and clinical equipoise. Also listed as BIOE 380. Prerequisites: BIOE 120 (or AMTH 108), or with consent of the instructor. (4 units)

BIOE 181. Sampling Plans in Biomedical Engineering

Statistical sampling plans are used from bench top to scale up in diagnostics, biodevice manufacturing for defect sampling by the FDA. Starting from a review of the Central Limit Theorem, continuity correction and moment generating functions, the course transitions into discrete variable distributions used in single, multiple, and rectifying sampling plans. Instruction will be completed by JMP/SAS software. Also listed as BIOE 381. Prerequisites: BIOE 180. (2 units)

BIOE 185. Physiology and Disease Biology

This course will provide a molecular-level understanding of physiology and disease biology, an overview of gastrointestinal diseases, and an introduction to medical devices used in diagnosis and treatment, as well as challenges in this field. This course will include lectures, class discussions, case studies, and team projects. Also listed as BIOE 285. Prerequisite: BIOE 21 (or BIOL 1B). BIOE 171 recommended. (2 units)

BIOE 186. Introduction to Biotechnology

This course is designed to introduce basic and practical biotechniques to students with minimum training and background in biomolecular engineering. The basic principles and concepts of modern biotechniques will be illustrated and highlighted by studying real cases in lectures. Also listed as BIOE 286. Prerequisite: BIOE 22 or BIOL 1C. (2 units)

BIOE 187. Biotechnology II

The course is designed to discuss practical applications of recombinant DNA technologies, data science, and other modern technologies in the biotechnology industry beyond pharmaceutical development. Specific topics include microbial, industrial, agricultural, environmental biotechnologies, and forensic science. The technical principles and concepts will be highlighted by reviewing real-world cases in lectures. The course will also discuss critical issues such as ethics, regulations, market, and business. Also listed as BIOE 288. (2 units)

BIOE 188. Co-op Education

This course is designed to prepare students for the working environment, and enable them to relate their experience in the industry to their academic program. They will then engage in practical work experience related to their academic field of study and career objectives. All students must enroll in BIOE 188 before enrolling in BIOE 189. Students can take BIOE 188 during the first quarter of work experience, or before an internship begins. International students who wish to start (or continue) their CPT after they have taken BIOE 188 must be enrolled in BIOE 189. Prerequisites: Junior status and cum GPA ≥ 2.75. (2 units)

BIOE 189. Work Experience and Co-op Technical Report

Credit is given for a technical report on a specific activity, such as a design or research activity, after completing a co-op work assignment. Letter grades will be based on the content and quality of the report. May be taken more than once. Prerequisites: Junior status, cum GPA ≥ 2.75, and approval of departmental co-op advisor. (2 units)

BIOE 190. Drug Development Process

This course is designed to discuss an overview of the modern pharmaceutical development process, from drug discovery and development, manufacturing, and the regulatory approval process. Specific topics will include current concepts of drug discovery, advanced drug screening methods, preclinical studies and requirements, and the four major phases of clinical development. There will be an emphasis on product development and manufacturing processes for biologics, such as monoclonal antibody-based drugs. Also listed as BIOE 290. (2 units)

BIOE 194. Design Project I

Specification of an engineering project, selected with the mutual agreement of the student and the project advisor. Complete initial design with sufficient detail to estimate the effectiveness of the project. Initial draft of the project

report. Prerequisite: Senior standing. (2 units)

BIOE 195. Design Project II

Continued design and construction of the project, system, or device. Second draft of project report. Prerequisite: BIOE 194. (2 units)

BIOE 196. Design Project III

Continued design and construction of the project, system, or device. Final report. Prerequisite: BIOE 195. (2 units)

BIOE 198. Internship

Directed internship in local bioengineering and biotech companies or research in off-campus programs under the guidance of research scientists or faculty advisors. Required to submit a professional research report. Open to upper-division students. (Variable units)

BIOE 199. Supervised Independent Research

By arrangement. Prerequisite: Advisor approval. (1–4 units)

Graduate Courses

BIOE 200. Graduate Research Seminar

Seminar lectures on the progress and current challenges in fields related to bioengineering. P/NP grading. Also listed as BIOE 100. (1 unit)

BIOE 203. Bio-Electromagnetics

Fundamentals of electromagnetics applied to bioengineering. Dielectric characteristics of biological materials. Tissue characterization. Wave propagation in layered medium. RF/Microwave interaction mechanisms in biological materials. Electromagnetic field absorption and SAR. Safety and standards. Microwave hyperthermia. Design of on-body and implant antennas. Also listed as ECEN (ELEN) 203. Prerequisite: ECEN (ELEN) 201 or BIOE 168/268. (2 units)

BIOE 206. Design Control for Medical Devices

This course will cover the principles behind design control. All of the essential elements required in the regulated medical device environment will be covered from design planning, inputs and outputs to verification, validation, risk management and design transfer. A problem-based learning approach will be utilized so that students will develop proficiency to apply the principles. Knowledge will be acquired through lectures, class activities, industry guest lectures and field trips. Also listed as BIOE 106. (4 units)

BIOE 207. Medical Device Product Development

The purpose of the course is to provide skills, knowledge, and confidence, to start or enhance a career in medical device product development. The course includes medical device examples, market data, product development processes, regulation, industry information, and intellectual property. Also listed as BIOE 107 and BIOE 307. (2 units)

BIOE 208. Biomedical Devices: Role of Polymers

This course is designed to highlight the role polymers play in the design and fabrication of various medical devices ranging from simple intravenous drip systems to complex cardiac defibrillator implants and transcatheter heart valves. Topics include polymer basics, biocompatibility, biodegradation and other tangentially related topics such as regulatory body approvals and intellectual property. Also listed as BIOE 108. (2 units)

BIOE 209. Development of Medical Devices in Interventional Cardiology

This course will be an in-depth, case-based review of medical devices that are currently used in clinical practice, meeting the heart patient's medical needs. Directed reading will be assigned, and the in-class discussions will focus on bioengineering design considerations including measurements of physiology vs. anatomy, intracoronary blood flow vs. pressure, invasive vs. non-invasive imaging; as well as the significant economic challenges facing innovative start-ups developing medical devices within our changing health care delivery system. (2 units)

BIOE 210. Ethical Issues in Bioengineering

This course serves to introduce bioengineering students to ethical issues related to their work which includes introductions to ethical theories, ethical decision-making, accessibility, and social justice concerns, questions in personalized medicine, environmental concerns, and so on. This course will also cover ethical and technical issues related to biomedical devices. (2 units)

BIOE 216. Biosignal and Medical Image Processing I

This course covers the principles and methods of signal and image processing and their applications in biomedical engineering. A complete set of signal and image processing tools, including diagnostic decision-making tools will be introduced at a useful, working depth. Also listed as BIOE 166. Prerequisite: BIOE 162. (2 units)

BIOE 226. Biomolecular and Cellular Engineering II

This course will focus on the principle of designing, manufacturing synthetic materials and their biomedical and pharmaceutical applications. Emphasis of this class will be given to chemically synthetic materials, such as polymers, inorganic and organic compounds. Also listed as BIOE 176. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31, or equivalent knowledge and instructor approval. BIOE 175 and 171 is recommended. (4 units)

BIOE 227A. Machine Learning and Applications in Biomedical Engineering

This course covers theoretical foundations and methods that form the core of modern machine learning. Topics include supervised methods for regression and classification (linear regression, logistic regression, support vector machine, instance-based and ensemble methods, neural networks) and unsupervised methods for clustering and dimensionality reduction. Selected biomedical applications will be presented. Also listed as BIOE 177A. (2 units)

BIOE 227B. Machine Learning and Algorithm Implementation

This course introduces programming in Python and focus on building machine learning projects with Numpy, TensorFlow and Keras. Also listed as BIOE 177B. Prerequisite: BIOE 227A. (2 units)

BIOE 230. Immune System for Engineers

This course will discuss two significant aspects of human immune systems in bioengineering: 1) Complex hurdles associated with the body's immune systems for biomaterials, biodevice, and implants; and 2) profound opportunities with engineered therapeutics. Also listed as BIOE 130. (4 units)

BIOE 232. Biostatistics

This course will cover the statistical principles used in Bioengineering encompassing distribution-based analyses and Bayesian methods applied to biomedical device and disease testing including methods for categorical data, comparing groups (analysis of variance) and analyzing associations (linear and logistic regression). Special emphases will be placed on computational approaches used in model optimization, test-method validation, sensitivity analysis (ROC curve) and survival analysis. Also listed as AMTH 232. Prerequisite: AMTH 108 or BIOE 120 or equivalent. (2 units)

BIOE 232L. Biostatistics Laboratory

Laboratory for BIOE 232. Also listed as AMTH 232L. Co-requisite: BIOE 232. (1 unit)

BIOE 238. Medicinal Chemistry and Drug Design I

Small molecule medicines are coming back! In two seminal courses, principles of medicinal chemistry will be discussed in detail, as well as the related drug designs. Medicines and their designs in the following categories will be studied in the part I: Acid-Base disorders; antihistamines; anticholinergics; anti-inflammation (NSAIDs and Glucocorticoids). The contents of the course are offered at the same level as in pharmacy schools. Students are encouraged to have strong background in biology, organic chemistry and physiology. Also listed as BIOE 138. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31. (2 units)

BIOE 239. Medicinal Chemistry and Drug Design II

This is the part II of the seminal courses – Medicinal Chemistry and Drug Design. Students will study the principles of medical chemistry in detail, as well as the pharmacology for drug design. Medicines and their design will be studied in the following categories: Non-steroidal anti-inflammatory drugs (NSAIDs), Glucocorticoids, Thyroid and Thyroid Drugs,

Estrogens and Progestins. On top of the understanding of the principles of drugs, the sequel will be concluded with the "rules" of drug discovery and clinical therapy. Also listed as BIOE 139. Prerequisites: BIOE 22 (or BIOL 1C) and CHEM 31. (2 units)

BIOE 245. Introductory Biotribology for Orthopedic Implants
This course will provide an introduction to surface mechanics and tribology as applied to biological systems and medical devices, with a specific focus on orthopedic tissues and implants. Students will learn about the mechanisms of friction, lubrication, and wear in tissues and considerations for the design of implants to minimize adverse interactions in vivo while maximizing lifespan. Topics will include dry, lubricated, and mixed mode contact and the physiological conditions resulting in each case. Class discussions will primarily center around assigned readings of published literature guided by lecture topics. Prerequisites: BIOE 240 or BIOE 153, 154, BIOE 21 (or BIOL 1B). (2 units)

BIOE 249. Topics in Bioengineering
An introduction to the central topics of bioengineering including physiological modeling and cellular biomechanics (e.g., modeling of the human voice production and speech biomechanics), biomedical imaging, visualization technology and applications, biosignals and analysis methods, bioinstrumentation and bio-nanotechnology. Also listed as ENGR 249. (2 units)

BIOE 251. Introduction to Bioinformatics
This course provides an introduction to tools and databases essential for bioengineering including DNA, RNA, and protein. Topics include but are not limited to pairwise sequence alignment, multiple sequence alignment, hidden Markov models and protein sequence motifs, phylogenetic analysis, and fragment assembly. Protein structure and domain analysis, as well as genome rearrangement and DNA computing, are also covered. Students will become proficient in searching multiple databases (Genome, GenBank, Protein, and Conserved Domain), retrieving and analyzing sequences, and working with metadata. Students will design a new gene/protein or write an original program to complete an independent search project. Prerequisite: BIOE 22 or BIOL 1C. Programming experience and BIOL 175 recommended. (2 units)

BIOE 252. Computational Neuroscience I
This course provides a foundation in cellular and molecular neuroscience and applied computational techniques for the purpose of modeling neuronal and whole brain structural and functional network organization. The central ideas, methods, and practice of modern computational neuroscience will be discussed in the context of relevant applications in biomedical interventions. (2 units)

BIOE 252L. Computational Neuroscience Lab
Laboratory for BIOE 252. Co-requisite: BIOE 252. (1 unit)

BIOE 256. Introduction to Nano Bioengineering
This course is designed to present a broad overview of diverse topics in nano bioengineering, with emphasis on areas that directly impact applications in biotechnology and medicine. Specific examples that highlight interactions between nanomaterials and various biomolecules will be discussed, as well as the current status and future possibilities in the development of functional nanohybrids that can sense, assemble, clean, and heal. Also listed as ENGR 256. (2 units)

BIOE 257. Introduction to Biofuel Engineering
This course will cover the basic principles used to classify and evaluate biofuels in terms of thermodynamic and economic efficiencies as well environmental impact for resource recovery. Special emphases will be placed on emerging applications namely Microbial Fuel Cell Technology and Photo-bioreactors. Also listed as ENGR 257 and BIOE 157. Prerequisites: BIOE 21 (or BIOL 1B), CHEM 13, PHYS 33. (2 units)

BIOE 258. Soft Biomaterials Characterization
This course will cover the fundamental principles of characterization and biodegradation of soft implantable/injectable biomaterials including polymers, hydrogels, liquid crystalline colloids starting with the linkage of microscopic to macroscopic properties and, emphasis on elasticity, adhesion, diffusion and light scattering. Also listed as BIOE 158. Prerequisite: BIOE 153. Co-requisite: BIOE 258L. (4 units)

BIOE 258L. Soft Biomaterials Characterization Laboratory

Laboratory for BIOE 258. Also listed as BIOE 158L. Co-requisite: BIOE 258. (1 unit)

BIOE 259. Hard Biomaterials Characterization

This course will cover the fundamental principles of characterization and biodegradation of hard biomaterials including bioceramics and metals starting with the linkage of microscopic to macroscopic properties and, emphasis on corrosion, coatings, (nano/micro)-indentation and accelerated implant analysis. Instruction will be complimented by software-enabled simulation of prototyping and driving forces' analyses. Also listed as BIOE 159. Prerequisite: BIOE 153. Co-requisite: BIOE 259L. (4 units)

BIOE 259L. Hard Biomaterials Characterization Laboratory

Laboratory for BIOE 259. Also listed as BIOE 159L. Co-requisite: BIOE 259. (1 unit)

BIOE 260. Selected Topics in Bio-Transport Phenomena

This course will cover the principles of mass and oxygen transport and across extra-corporeal devices and bio-membrane design principles, dialyzers, blood-oxygenators, hollow-fiber based bio-artificial organs and PK/PD. Prerequisite: BIOE 155 or equivalent. BIOE 232 recommended. (2 units)

BIOE 261. Omics: Global High-throughput Technologies in Life Sciences Discovery Research

This course provides a practical application-focused survey of global high-throughput technologies in life sciences discovery research. The impact of all facets of study design and execution on obtaining valuable molecular insights from genomics, metagenomics, transcriptomics, metabolomics, and proteomics methods will be explored. Strategies for integration and interpretation of data-rich read-outs will be applied to case studies focused on research and development of companion diagnostics. Prerequisite: BIOE 21. (2 units)

BIOE 263. Applications of Genome Engineering and Informatics in Mammalian System

Advances in genome engineering technologies offer versatile solutions to systematic interrogation and alteration of mammalian genome function. Among them, zinc finger transcription factor nuclease (ZNF), transcription activator-like effector nuclease (TALEN) and CRSPR-associated RNA-guided Cas9 endonuclease (CRISPR/Cas9) have become major drivers for innovative applications from basic biology to biotechnology. This course covers principles and real cases of genome engineering using either ZFN/TALEN or CRSPR/Cas9-based systems. Key applications will be discussed comparatively to understand the advantages/disadvantages of each system better. In addition, informatics tools that facilitate the application design, implementation, data analysis will be covered. Prerequisites BIOE 22 or BIOL 1C or equivalent. (2 units)

BIOE 266. Advanced Nano-Bioengineering

In Introduction to Nano-bioengineering (BIOE 256), students were introduced to how nanomaterials offer the unique possibility of interacting with biological entities (cells, proteins, DNA, etc.) at their most fundamental level. This course will provide a detailed overview of nano bioengineering approaches that support research in life sciences and medicine. Topics will include nano topographical control of in vivo and in vitro cell fate, miniaturization and parallelization of biological assays, and early diagnosis of human disease. Prerequisite: BIOE 256. (2 units)

BIOE 267. Introduction to Medical Imaging

This course will cover basics of technical aspects and clinical applications of medical imaging. Practicing radiologists will introduce the students to the history of radiology and medical imaging, as well as specific modalities such as X-ray, CT, MR, ultrasound, nuclear medicine, and interventional radiology. A brief discussion of applications of information technology to radiology is also included. Also listed as BIOE 167. (2 units)

BIOE 268. Biophotonics and Bioimaging

This course starts with an introduction of optics and basic optical components (e.g. lenses, mirrors, diffraction grating, etc.), then focuses on light propagation and propagation modeling to examine interactions of light with biological matter (e.g. absorption, scattering). Other topics that will be covered in this course are: laser concepts, optical coherence tomography, microscopy, confocal microscopy, polarization in tissue, absorption, diffuse reflection, light

scattering, Raman spectroscopy, and fluorescence lifetime imaging. Graduate students will prepare a presentation/report on one of the state-of-the-art biophotonics technologies. Also listed as BIOE 168. Prerequisite: PHYS 33. (4 units)

BIOE 268L. Biophotonics and Bioimaging Laboratory

The lab will provide hands-on experience for basic imaging and microscopy techniques as well as advanced techniques such as fiber-optics and optical coherence tomography. Some of the experiments that will be conducted are: measuring the focal length of lenses and imaging using a single lens and a lens system, determining the magnification of optical systems (e.g. of a microscope), interference in Young's double slit and in Michelson configuration, diffraction, polarization and polarization rotation. Also listed as BIOE 168L. (1 unit)

BIOE 269. Stem Cell Bioengineering

A majority of recent research in bioengineering has focused on engineering stem cells for applications in tissue engineering and regenerative medicine. The graduate level course aims to illuminate the breadth of this interdisciplinary research area, with an emphasis on engineering approaches currently being used to understand and manipulate stem cells. The course topics will include basic principles of stem cell biology, methods to engineer the stem cell microenvironment, and the potential of stem cells in modern medicine. (2 units)

BIOE 270. Mechanobiology

This course will focus on the mechanical regulation of biological systems. Students will gain an understanding of how mechanical forces are converted into biochemical activity. The mechanisms by which cells respond to mechanical stimuli and current techniques to determine these processes will be discussed. Class discussions will primarily center around assigned readings of published literature guided by lecture topics. Also listed as Bioe 170. Prerequisite: BIOE 154. (2 units)

BIOE 273. Advanced Topics in Tissue Engineering

Overview of the progress achieved in developing tools, technologies, and strategies for tissue engineering-based therapies for a variety of human diseases and disorders. Lectures will be complemented by a series of student-led discussion sessions and student team projects. Also listed as BIOE 173. Prerequisite: BIOE 172 or instructor approval. (2 units)

BIOE 275. Introduction to Neural Engineering

This course provides a foundation in the neural principles underlying existing and upcoming neurotechnologies. The goal is to understand the design criteria necessary for engineering interventions in neural structure and function with application to neurological diseases, disorders, and injuries. Topics include brain imaging and stimulation, neural implants, nanotechnologies, stem cell and tissue engineering. This course includes lectures, literature critiques, and design projects. Also listed as BIOE 179. Prerequisites: BIOE 21 (or BIOL 21). BIOE 171 recommended. (2 units)

BIOE 276. Microfluidics and Lab-on-a-Chip

The interface between engineering and miniaturization is among the most intriguing and active areas of inquiry in modern technology. This course aims to illuminate and explore microfluidics and LOC (lab-on-a-chip) as an interdisciplinary research area, with an emphasis on emerging microfluidics disciplines, LOC device design, and micro/nanofabrication. Prerequisite: BIOE 155 or instructor approval. (2 units)

BIOE 277. Biosensors

This course focuses on underlying engineering principles used to detect DNA, small molecules, proteins, and cells in the context of applications in diagnostics, fundamental research, and environmental monitoring. Sensor approaches include electrochemistry, fluorescence, optics, and impedance with case studies and analysis of commercial biosensors. (2 units)

BIOE 279. Stem Cell & Regenerative Medicine

Few events in science have captured the same level of sustained interest and imagination of the non-scientific community as Stem Cells and Regenerative Medicine. The fundamental concept of Regenerative Medicine is appealing to scientists, physicians, and laypeople alike: to heal tissue or organ defects that the current medical practice deems difficult or impossible to cure. Regenerative medicine is a new branch of medicine that attempts to

change the course of chronic disease; in many instances regenerating failing organ systems lost due to age, disease, damage, or congenital defects. The area is rapidly becoming one of the most promising treatment options for patients suffering from tissue failure. This course covers principles and real cases of stem cell and regenerative medicine. Its major applications will be discussed comparatively to understand the advantages/disadvantages of each system better. Overall, this course provides a more in-depth exploration of the next generation biotechnology - a wide variety of cells, biomaterials, interfaces and applications for tissue engineering. Prerequisite: BIOE 269. (2 units)

BIOE 280. Special Topics in Bio-therapeutic Engineering
This class will cover current topics on the engineering of biomimetic drugs, particularly protein drugs, and the development of vaccine, therapeutic antibody and biomarkers. Prerequisite: BIOE 270 or equivalent. (2 units)

BIOE 281. Deep Learning for Bioengineering I
This course covers a spectrum of topics ranging from the fundamentals of neural networks, to state-of-the-art deep learning methods, and applications in biomedical engineering with focus on medical image analysis and disease identification. (2 units)

BIOE 282. Bioprocess Engineering
This course will cover the principles of designing, production, and purification of biologicals using living cells in a large scale and industrial scale, including bio-reactor design. Prerequisite: BIOE 21 (or BIOL 1B), AMTH 106 or equivalent. (2 units)

BIOE 283. Bioprocess Engineering II
This course will cover principles of bio-separation processes. Driving forces behind upstream and downstream separation processes from post-culture cell collection to end-stage purification will be analyzed. Special emphasis will be placed on scale-up and economics of implementation of additional purification processes vs. cost illustrated by the use of Simulink software. Prerequisite: BIOE 282 or equivalent. (2 units)

BIOE 285. Physiology and Disease Biology
The course will provide a molecular-level understanding of physiology and disease biology, an overview of gastrointestinal diseases, and an introduction to medical devices used in the diagnosis and treatment as well as challenges in this field. The course will include lectures, class discussions, case studies, and team projects. Also listed as BIOE 185. Prerequisite: BIOE 21 (or BIOL 1B). BIOE 171 recommended. (2 units)

BIOE 286. Biotechnology
The course is designed to introduce fundamental and practical biotechniques to the students with minimum training and background in biomolecular engineering. The basic principles and concepts of modern biotechniques will be illustrated and highlighted by studying real cases in lectures. Also listed as BIOE 186. Prerequisite: BIOE 22 or BIOL 1C. (2 units)

BIOE 287. Pharmaceutical Drug Development and Chemical Analysis
This course will introduce the fundamental principles of drug discovery and development, also discussing essential drug targets in drug discovery. While addressing analytical-chemical characteristics of selected drug substances, basic concepts for the common analytical methods that are used in the quantitative and qualitative chemical analysis of pharmaceutical drugs will be addressed. International Pharmacopoeias, Regulations and Guidelines will also be reviewed. (2 units)

BIOE 288. Biotechnology II
The course is designed to discuss practical applications of recombinant DNA technologies, data science, and other modern technologies in the biotechnology industry beyond pharmaceutical development. Specific topics include microbial, industrial, agricultural, environmental biotechnologies, and forensic science. The technical principles and concepts will be highlighted by reviewing real-world cases in lectures. The course will also discuss critical issues such as ethics, regulations, market, and business. Also listed as BIOE 187. (2 units)

BIOE 290. Biotechnology III - Drug Development Process

This course is designed to discuss an overview of the modern pharmaceutical development process, from drug discovery and development, manufacturing, and the regulatory approval process. Specific topics will include current concepts of drug discovery, advanced drug screening methods, preclinical studies and requirements, and the four major phases of clinical development. There will be an emphasis on product development and manufacturing processes for biologics, such as monoclonal antibody-based drugs. Also listed as BIOE 190. (2 units)

BIOE 294. Graduate Capstone Project I

Specification of a translational bioengineering project, selected with the mutual agreement of the student and the project advisor, completion of initial design and feasibility analysis, and submission of a preliminary study report. (2 units)

BIOE 295. Graduate Capstone Project II

Continued design and development of the project (system or prototype), and submission of a draft project report. Prerequisite: BIOE 294. (2 units)

BIOE 296. Graduate Capstone Project III

Continued design and development of the project (system or prototype), and submission of the final project report. Prerequisite: BIOE 295. (2 units)

BIOE 297. Directed Research

By arrangement. (1–6 units)

BIOE 300. Antibody Bioengineering

This course will cover significant areas of antibody engineering, including recent progress in the development of antibody-based products and future direction of antibody engineering and therapeutics. The product concept and targets for antibody-based products are outlined and basic antibody structure, and the underlying genetic organization which allows easy antibody gene manipulation, and the isolation of novel antibody binding sites will be described. Antibody library design and affinity maturation techniques and deep-sequencing of antibody responses, together with biomarkers, imaging and companion diagnostics for antibody drug and diagnostic applications of antibodies, as well as clinical design strategies for antibody drugs, including phase one and phase zero trial design will be covered. Prerequisite: BIOE 176 or equivalent. (2 units)

BIOE 301. Protein Engineering and Therapeutics

Protein-based therapeutics has played an increasingly important role in medicine. Future protein drugs are likely to be more extensively engineered to improve their efficacy in patients. Such technologies might ultimately be used to treat cancer, neurodegenerative diseases, diabetes, and cardiovascular or immune disorders. This course will provide an overview of protein therapeutics and its enabling technology, protein engineering. Topics will cover the following areas of interest: therapeutic bioengineering, genome, and druggable genes, classification of pharmacological proteins, advantages and challenges of protein-based therapeutics, principles of recombinant protein design, approaches of protein production, and potential modifications. Specific applications will include drug delivery, gene therapy, vaccination, tissue engineering, and surface engineering. Students will work on teams where they will take examples of concepts, designs, or models of protein therapeutics from literature and determine their potential in specific engineering applications. Prerequisite: BIOE 176 or equivalent. (2 units)

BIOE 302. Gene and Cell Therapy

This course covers principles and applications of gene and cell therapy. Key concepts and technologies such as gene and gene expression, gene variation and genetic defect, therapeutic vector design and construction, as well as ex vivo and in vivo gene delivery will be discussed. The course will culminate in a design project focused on implementing gene or cell-based solutions for a specific disease. After taking this course, participants will: 1) Know the concepts and principles of gene therapy; 2) Understand multiple aspects of gene therapy, including disease gene identification, therapeutic gene design and expression vector construction, as well as gene delivery strategy and efficacy evaluation;

3) Gain skills to use analytical software to aid design; 4) Gain skills to use sequence manipulation software in expression vector design; 5) Gain skills to use genome database and other related databases; and 6) Present and critically analyze original research concerning gene and cell therapy. (2 units)

BIOE 307. Medical Device Product Development

The course purpose is to discuss and practice product development using medical devices as the model. The course includes identification of product need, invention, development and implementation or commercialization. Also listed as BIOE 107 and EMGT 307.

BIOE 308. Wearable Sensors and Actuators for Biomedical Applications

Wearable sensor and robotics technologies have the potential to extend the range of the healthcare system from hospitals to the community, improving diagnostics and monitoring, and maximizing the independence and participation of individuals. In this course, we will cover operation principles, challenges, and promises of wearables for physiological and biochemical sensing, as well as for motion sensing, in depth. (2 units)

BIOE 312. Deep Learning for Bioengineering II

This course focuses on convolutional and recurrent network structures, non-convex optimization problems, and the mathematical, statistical, and computational challenges of building stable representations and analysis for high-dimensional data, such as images and text. Programming and building projects in TensorFlow, Keras, and NumPy will be discussed. Prerequisite: BIOE 281 or equivalent. (2 units)

BIOE 320. Immunotherapy

The goal of this course is to provide conceptual, preclinical and clinical background necessary to understand the strengths and limits of the main types of cancer immunotherapy and to assess efficacy of the treatment using immunoassays. Emphasis will be given to antibody-drug conjugates, checkpoint blockade, CAR-T cell therapy, cancer vaccines, cytokines, and interferon, through lectures and journal club presentations. (2 units)

BIOE 357. Root Cause Analysis (RCA) Effective Problem Solving

Solving problems is one of the main functions of engineering and one of the main concerns of engineering managers. This course will focus on a step by step problem solving approach, used by the best engineering practitioners in the world, designed to improve the efficiency and effectiveness of the problem-solving process. Topics will include proper methods of problem description, identification, correction, and containment. Also listed as EMGT 357. (2 units)

BIOE 378. Advanced Biomaterials

The objective of this course is to examine the range of new biomaterials potentially applicable to medical and biotechnology devices. The content will focus on chemistry and fabrication of polymeric biomaterials, surface properties, nano-scale analytical tools, effects of the biological environment and interaction with cells and tissues. In teams of 2 to 4, students will prepare and orally present a design study for a solution to a medical problem requiring one or more biomaterials, using tissue engineering and regenerative approaches. Students should be familiar with or prepared to learn medical, anatomical and physiological terminology. Written assignments are an annotated bibliography drawn from research literature on the topic of the design study and an individually-written section of the team's report. Material from lectures and student presentations will be covered in short quizzes and a final examination. (2 units)

BIOE 380. Clinical Trials: Design, Analysis, and Ethical Issues

This course will cover the principles behind the logistics of design and analysis of clinical trials from the statistical and ethical perspectives. Topics include methods used for quantification of treatment effect(s) and associated bias interpretation, cross-over designs used in randomized clinical trials and clinical equipoise. Also listed as BIOE 180. Prerequisites: BIOE 120 or AMTH 108, or instructor approval. (4 units)

BIOE 381. Sampling Plans in Biomedical Engineering

Statistical sampling plans are used from bench top to scale up in diagnostics, biodevice manufacturing for defect sampling by the FDA. Starting from a review of the Central Limit Theorem, continuity correction and moment

generating functions, the course transitions into discrete variable distributions used in single, multiple, and rectifying sampling plans. Instruction will be completed by JMP/SAS software. Also listed as BIOE 181. Prerequisites: BIOE 180/380 or BIOE 232. (2 units)

BIOE 397. Master's Thesis Research

By arrangement. (1–9 units)

BIOE 497. Ph.D. Thesis Research

By arrangement. Limited to Bioengineering Ph.D. students only. May be repeated up to 36 units. (1–9 units per quarter)

Chapter 9: Department of Civil, Environmental and Sustainable Engineering

Professor Emeritus: E. John Finnemore, P.E.
Associate Professor Emeritus: Steven C. Chiesa, P.E.
Professors: Aria Amirbahman, P.E. (Sukhmander Singh Professor and Department Chair), Edwin Maurer, P.E. (Robert W. Peters Professor), Reynaud L. Serrette, Sukhmander Singh, P.E., G.E.
Associate Professors: Rachel He, Hisham Said
Senior Lecturer: Tonya Nilsson, P.E. (Department Vice-Chair)
Lecturers: Tracy Abbott, S.E., Laura Doyle

Overview

The Department of Civil, Environmental and Sustainable Engineering offers graduate programs in the areas of structural engineering, general civil engineering, construction engineering and management, and water and environmental engineering. The focus of the educational effort is on modeling, analysis, and practical methods used to analyze, design and construct structures and other civil engineering-related infrastructure systems. As such, many of the courses offered are beneficial to civil and construction engineers, and construction managers interested in advancing their knowledge and enhancing their technical skills.

Degree Program

The Civil, Environmental and Sustainable engineering graduate program at Santa Clara University is designed to accommodate the needs of students interested in advanced study. An individual may pursue the degree of Master of Science (M.S.) as either a full-time or part-time student through a customized balance of coursework, design projects, and directed research. Program participants are also required to supplement their technical work with coursework on project management topics addressed in the graduate engineering core curriculum.

The structural engineering (SE) track provides students with an opportunity to effectively link theory and practice by completing a combination of analysis- and design-oriented courses. Options within the structural engineering track allow students to either complete a capstone design project or a faculty-directed research investigation. This program track is aimed at individuals looking to prepare for a career in consulting structural engineering or in structural plan review.

The general civil engineering (GCE) track has been configured to provide students with additional analytical and design coursework in several infrastructure-related areas of civil engineering. This track could potentially include work in water resources engineering, environmental engineering, transportation engineering, and geotechnical engineering. A capstone design or research project with a required sustainability component is available to integrate these different elements. This track is geared toward individuals preparing for a career in land development, municipal engineering, or public works.

The construction engineering and management (CEM) track is designed to prepare students with skills and knowledge required to effectively manage time, cost, safety, quality, and sustainability requirements of construction projects. The track has some flexibility to accommodate students with interests in practical applications or research investigations. This track is designed for students with career objectives of managing building or substantial construction projects for contractors, owners, and developers.

The water and environmental engineering (WEE) track prepare students to engage in advanced engineering analysis, design, and research to solve complex issues by quantifying risks related to water supply, flooding, and contamination and designing systems to treat contamination to protect public health and the environment. This track is ideal for people interested in working on these topics with public agencies, consulting firms, nonprofits, or pursuing further graduate work.

Master of Science in Civil Engineering

To be considered for admission to the graduate program in Civil, Environmental and Sustainable Engineering, an applicant must meet the requirements outlined in the Admissions section of the bulletin, with the following additional criteria:

Applicant's undergraduate degree must be:

- A civil engineering B.S. from an Accreditation Board for Engineering and Technology (ABET)-accredited four-year program or its equivalent, or
- A B.S. in a relevant technical area for the proposed graduate track. In such cases, applicants must take sufficient additional courses beyond the 46-unit minimum to ensure coverage of prerequisite material for the required classes. For example, applicants pursuing the water/environmental track would need CENG 41, CENG 141, CENG 143, plus any missing differential equations, physics, and chemistry prerequisites to those. These additional classes are subject to the same grade requirements as described elsewhere in the bulletin.

Applicant's undergraduate record must show:

- An overall grade point average (GPA) of at least 2.75 (based on a 4.0 maximum scale).

In very rare cases, applicants not meeting this may be admitted with a requirement to successfully complete a defined course of studies within a limited time period.

See the **Academic Information section** of this bulletin for details on transferring credit for courses taken at other institutions.

Upon acceptance to the graduate program in Civil, Environmental and Sustainable Engineering, a student will be required to select a graduate advisor (full-time faculty member) from within the Department of Civil, Environmental and Sustainable Engineering. The student's advisor will be responsible for approving the student's course of study. Any changes to a student's initial course of study must have the written approval of the student's advisor.

To qualify for the degree of Master of Science in Civil, Environmental and Sustainable Engineering, the students must complete a minimum of 46 quarter units, including elective and required core courses, within the School of Engineering. Required and elective courses for structural engineering, general civil engineering, and construction management tracks are provided below. Students may elect to do a design project or research project. Students undertaking a design project would investigate applying a new technique or method in the analysis or design of a structure, system, or element, and this must be documented in a design report. Students undertaking a research project would develop a new technique, method, component, or design criteria, and this must be documented in a conference or journal publication, or report.

Course requirements for the SE, GCE, CEM and WEE tracks are summarized in the following table:

---	Structural Engineering Track	General Civil Engineering Track	Construction Engineering and Management Track	Water and Environmental Engineering Track

Required Technical Coursework	CENG 205† (2) CENG 206† (2) CENG 222 (4) CENG 233* (4) CENG 234 (4) CENG 236 (4) CENG 237 (4) **(24 units)**	CENG 219^ (3) CENG 237 (4) CENG 238 (4/1) CENG 249 (4) CENG 250 (4) CENG 282^ (3) **(24 units)**	CENG 218 (3) CENG 219^ (3) CENG 281 (3) CENG 282^ (3) CENG 284 (3) CENG 285 (3) CENG 286 (3) CENG 287 (3) **(24 units)**	**At least 15 units from:** CENG 242 (4) CENG 249 (4) CENG 253 (3/1) CENG 254 (3/1) CENG 258 (4) CENG 259 (3)
Elective Technical Coursework	**6 units from:** CENG 207 (2) CENG 218 (3) CENG 220 (4) CENG 231 (4) CENG 232 (2) CENG 238 (4) CENG 239 (2) CENG 240 (2) CENG 241 (2) CENG 244 (2) CENG 246 (4) CENG 293 CENG 295 CENG 297	**6 units from:** CENG 218 (3) CENG 242 (4) CENG 251 (4) CENG 253 (3) CENG 254 (3/1) CENG 256 (3) CENG 258 (4) CENG 259 (3) CENG 261 (3) CENG 262 (3) CENG 263 (4) CENG 293 CENG 295 CENG 297	**6 units from:** CENG 249 (4) CENG 256 (3) CENG 288 (4) CENG 293 CENG 295 CENG 297 EMGT 253 (2) EMGT 255 (2) EMGT 292 (2) EMGT 357 (2) EMGT 380 (2) EMGT 395 (2) ENGR 357^ (2)	**At least 16 units from: **** CENG 219 (3) CENG 252 (3) CENG 260 (3) CENG 261 (4) CENG 262 (3) CENG 297 (3) MECH 266 (2) MECH 268 (2) ENVS 117 (5) ENVS 122 (5) ENVS 145 (5) ENVS 166 (5) ENVS 185 (5)
Applied	**4 units from:** AMTH 210 (2) & 211 (2)	**4 units from:** AMTH 210 (2) & 211 (2)	**4 units from:** AMTH 210 (2) & 211 (2)	**4 units from:** AMTH 210 (2) & 211 (2)

Applied Mathematics	AMTH 214 (2) & 215 (2) AMTH 220 (2) & 221 (2) AMTH 245 (2) & 246 (2)	AMTH 214 (2) & 215 (2) AMTH 220 (2) & 221 (2) AMTH 245 (2) & 246 (2)	AMTH 367 (4) AMTH 370 (2) & 371 (2)	AMTH 220 (2) & 221 (2) AMTH 245 (2) & 246 (2)
Project Management, Leadership and Communications	**5 units from:** CENG 282^ (3) EMGT 255^ (2) EMGT 272^ (2) EMGT 330^ (2) EMGT 335^ (2)	**5 units from:** CENG 260 (3) EMGT 255^ (2) EMGT 272^ (2) EMGT 330^ (2) EMGT 335^ (2)	**6 units from:** EMGT 269 (2) EMGT 270 (2) EMGT 272^ (2) EMGT 285 (2) EMGT 322 (2) EMGT 324 (2) EMGT 349 (2)	**4 units from:** CENG 208^ (2) CENG 292^ (2) EMGT 272^ (2 EMGT 330^ (2 EMGT 335^ (2) ENGR 304^ (2) ENGR 336^ (2)
Enrichment Experience	[minimum 7 units] composed of: A minimum of 4 units from at least two of the three areas in the Graduate Core Areas (Emerging Topics in Engineering, Engineering and Business/Entrepreneurship and Engineering and Society). The remaining three units may be fulfilled by a) Taking additional classes from the Graduate Core, b) Taking one or more major technical electives, c) Taking Cooperative Education courses (ENGR 288, 299) and d) combining courses from categories a, b and c. **See Chapter 6, Enrichment Experience and Graduate Core requirements for additional information.**			

Units are shown in parentheses: x/y indicates x-unit course with y-unit lab. No more than 6 units from CENG 293, 295, and 297 may be used to satisfy degree requirements. Taking Required Technical Course(s) that repeat previously taken course(s) is discouraged; in such cases, Elective Technical course(s) may be substituted. In rare occasions, program plans may deviate from these requirements with Department approval.

† CENG 205 & 206 may be replaced by MECH 251.

- Replace with CENG 246 if a timber design course was taken previously.

Courses listed in the required section not taken to satisfy that requirement may be used as technical electives. An advisor may approve selected upper-level undergraduate classes including those listed (no more than 12 units total) that do not duplicate course content of graduate courses in the program of studies.

^ May simultaneously satisfy a Graduate Core requirement, but course credit may only count once toward the degree. Balance of credits shall be made of technical electives.

Upon the approval of the student's advisor, alternative elective courses may be taken. Courses used to satisfy the 46-unit minimum total for the Master of Science in Civil, Environmental and Sustainable Engineering degree cannot be used to satisfy any previous undergraduate degree program requirement. This includes cross-listed undergraduate courses at Santa Clara University and/or their equivalent courses at other institutions. Where required courses in the SCU graduate Civil, Environmental, and Sustainable Engineering program have been completed prior to graduate-level matriculation at SCU, additional elective courses may be required to satisfy the minimum unit total requirement as necessary.

Laboratories

The *Civil, Environmental and Sustainable Engineering Laboratories* contain equipment and facilities to support research and teaching in materials engineering, structural engineering, stress analysis, soil mechanics, geology, transportation engineering and surveying, environmental engineering, and hydraulics.

The *Simulation and Design Laboratory* maintains Windows-based personal computers that are used extensively in course assignments, design projects, and research. Commercial software packages in all the major areas of civil engineering are available on the systems, with full documentation available to students.

The *Concrete Testing Laboratory* contains facilities for mixing, casting, curing, and testing concrete cylinders and constructing reinforced concrete test specimens.

The *Environmental Laboratory* is equipped with the instrumentation needed for basic chemical and biological characterization of water, wastewater, and air samples. Several pilot-scale treatment systems are also available.

The *Geology Laboratory* is equipped with extensive rock and mineral samples, as well as topographic, geologic, and soil maps.

The *Hydraulics Laboratory* is shared with the Mechanical Engineering Department. The laboratory contains a tilting flume that can be fitted with various open-channel fixtures.

The *Soil Mechanics Laboratory* contains equipment for testing soils in shear, consolidation, and compaction, and for conducting other physical and chemical tests. Field-testing and sampling equipment are also available. A complete cyclic triaxial testing system with computer control is used for both research and instructional purposes.

The *Structures and Materials Testing Laboratory* is equipped with three universal testing machines and an interim high-bay structural test system. These machines/systems are used for testing a variety of construction materials and assemblies under quasi-static and pseudo-dynamic loading. Complementing this equipment are a series of digital and analog instruments, and high-speed data acquisition and control systems.

The **Structural Laboratory Annex** (offsite) is a high-bay test facility equipped with a closed-loop hydraulic system, high-speed data acquisition and control systems, and a variety of digital instrumentation. The Annex has the capability to test unique building components that incorporate wall/frames and floor systems.

The *Surveying Laboratory* has a wide variety of equipment, including automatic levels, digital theodolites, total stations, and GPS-based surveying instruments available for instructional purposes.

The *Traffic Laboratory* has electronic volume counters that are used in studies to classify vehicles and measure their speeds in user-specified ranges and periods of time

Course Descriptions

Lower-Division Undergraduate Courses

CENG 7. Graphic Communication

Introduction to technical drawing including isometric and multi-view drawings, use of sectional views and dimensioning, understanding blueprints and scales. Co-requisite: CENG 7L. (3 units)

CENG 7L. Laboratory for CENG 7

Freehand drawing, manual and computer-aided drafting of physical models, construction of models from drawings. Co-requisite: CENG 7. (1 unit)

CENG 10. Surveying

The use and care of survey instruments. Principles of topographic mapping, linear measurements, leveling, traverses, curves, boundary, and public surveys. Co-requisite: CENG 10L. (3 units)

CENG 10L. Laboratory for CENG 10

Fieldwork using traditional surveying instrumentation and equipment. Co-requisite: CENG 10. (1 unit)

CENG 15. Computer Applications in Civil Engineering

Solution techniques for civil engineering problems using common software and programming languages. Introduction to matrix analysis, graphical and numerical solution methods, regression analysis, and linear optimization using spreadsheets, basic programming, and math analysis programs. Students must complete a paper and presentation on a topic developed with analytical tools used in the course. (3 units)

CENG 20. Geology

Development and formation of geologic materials. Significance of structure, landform, erosion, deposition. Stream and shoreline processes. Surface water. Co-requisite: CENG 20L. (3 units)

CENG 20L. Laboratory for CENG 20

Identification, examination, and characterization of rock specimens. Co-requisite: CENG 20. (1 unit)

CENG 41. Mechanics I: Statics

Resolution and composition of force systems and equilibrium of force systems acting on structures and mechanisms. Distributed forces. Friction. Moments of inertia. Prerequisite: PHYS 31. (4 units)

CENG 43. Mechanics II: Strength of Materials

Analysis of stresses and strains in machines and structural members. Fundamental study of the behavior and response of statically determinate and indeterminate structural members subjected to axial, torsional, flexural, shear, and combined stresses. Introduction to the stability of columns. Prerequisite: CENG 41. Co-requisite: CENG 43L. (4 units)

CENG 43L. Laboratory for CENG 43

Testing of structural elements subjected to axial tension and compression loads, bending, torsion, and combined loading. Analysis of test data and laboratory report writing. Co-requisite: CENG 43. (1 unit)

CENG 44A. Strength of Materials I

CENG 44AL. Strength of Materials Laboratory

Testing of structural elements subjected to axial tension and compression loads, bending, torsion, and combined loading. Analysis of test data and laboratory report writing. Co-requisite: CENG 44A. (1 unit)

CENG 44B. Strength of Materials II

Continuation of topics covered in CENG 44A. Shear flow and shear center. Indeterminate systems. Introduction to plastic behavior and column stability. Prerequisite: CENG 44A. (2 units)

CENG 45. Construction Materials

Exploration of the various materials used and applied in the building construction process. The characteristics, specifications, and applications of basic construction materials such as soil, concrete, wood, steel, and bituminous products. Includes presentation, discussion, and analysis of conventional and non-conventional construction materials along with their sustainability implications. Civil Engineering students cannot enroll in this course and should enroll in CENG 115. Corequisite: CENG 45L. (2 units)

CENG 45L. Construction Materials Laboratory

Laboratory testing and processing of steel, concrete, wood, and other non-conventional civil engineering construction materials. Corequisite: CENG 45. (1 unit)

Upper-Division Undergraduate Courses

CENG 115. Civil Engineering Materials

Review of the structure and properties, production processes, and experimental methods used for determining key properties of common civil engineering materials with a focus on steel, concrete, and wood. Non-conventional building materials and their implications of any material choice. Prerequisites: CHEM 11 and CENG 44A. Co-requisite: CENG 115L. (4 units)

CENG 115L. Laboratory for CENG 115

Laboratory testing of steel, concrete, wood, and other non-conventional civil engineering construction materials. Co-requisite: CENG 115. (1 unit)

CENG 118. Construction Engineering

Introduction to construction roles and responsibilities, construction project phases, building systems, bidding and cost estimating, building trades and subcontractors, construction methods, and safety and quality management. Also listed as CENG 218. Prerequisite: Junior standing. (3 units)

CENG 119. Design for Sustainable Construction

Design strategies for sustainable commercial and residential construction. Use of LEED criteria for assessing sustainable construction. Team-based project planning, design, and construction. Economic evaluation of sustainable technologies. Prefabrication. Overall project management. Also listed as CENG 219. Prerequisite: Junior standing. (3 units)

CENG 121A. Geotechnical Engineering

Origin, development, and properties of soils. Classification of soils and applications of engineering mechanics to soils as an engineering material. Water in soils. Soil-testing methods. Compaction, stabilization, consolidation, shear strength, and slope stability. Prerequisites: CENG 20 and 44A. Co-requisite: CENG 121AL. (3 units)

CENG 121AL. Laboratory for CENG 121

Application of soil testing methods. Co-requisite: CENG 121A. (1 unit)

CENG 121AL. Laboratory for CENG 121

Application of soil testing methods. Co-requisite: CENG 121A. (1 unit)

CENG 121B. Geotechnical Engineering

Theory and basic factors related to earth pressure, slope stability, and foundations. Prerequisite: CENG 121A. (3 units)

CENG 122. Air Pollution

The study of generation of common air pollutants, their transport, effects, and state-of-the-art air pollution control strategies. Also listed as CENG 252. Prerequisite: CENG 143 or instructor's consent. (3 units)

CENG 123. Pollutant Fate and Transport

Study of reaction energetics, kinetics, interphase mass transfer, and partitioning as they relate to pollutant transformation in the environment. Application to surface waters and groundwater. Also listed as CENG 253. Prerequisites: CHEM 11, CENG 143, AMTH 106, and junior standing, or instructor's consent. Corequisite: CENG 123L (3 units)

CENG 123L. Laboratory for CENG 123

Use of experimentation and computer modeling to analyze problems in chemical kinetics, pollutant transport, and phase partitioning. Also listed as CENG 253L. Co-requisite: CENG 123. (1 unit)

CENG 124. Water Law and Policy

Introduction to the legal and regulatory concepts related to water. Examines rights, policies, and laws, including issues related to water supply and access (water transfers/water markets, riparian and appropriative doctrines), flood control, water pollution and quality (the Clean Water Act, EPA standards, instream flows for fish), and on-site stormwater management/flood control. A focus on California water law and policy is complemented with some national and international case studies. Cross-listed with CENG 258 and ENVS 124. (4 units)

CENG 125. Municipal Engineering Design

Various aspects of civil engineering as applied in municipal (public works) design practice. Maps and plats; site layout and earthworks; drainage; streets and utilities. Prerequisites: CENG 7 and CENG 10. Co-requisite: CENG 125L. (3 units)

CENG 125L. Laboratory for CENG 125

Development of CAD drawings for a design project. Co-requisite: CENG 125. (1 unit)

CENG 128. Engineering Project Management

Time value of money, economic analysis of engineering projects, rate-of-return analysis, cash-flow analysis, depreciation, project management, planning and capital budgeting, scheduling, preliminary cost estimates, risk analysis, financial analysis. Prerequisite: Junior standing. (3 units)

CENG 132. Structural Analysis

Distribution of loads in structural systems. Analysis of statically determinate and indeterminate beams, trusses, and frames. Influence lines for beams and trusses. Introduction to structural modeling, and elastic analysis using commercial software programs. Prerequisite: CENG 44A. Co-requisite: CENG 44B. (4 units)

CENG 133. Wood Design

Design of wood structural systems. Design of sawn and structural composite lumber members for tension, compression, bending, and shear. Introduction to shear wall and diaphragm design. Design of connections. Also listed as CENG 233. Prerequisite: CENG 132. (4 units)

CENG 134. Structural Steel Design I

Design of structural steel buildings. Design of steel members for tension, flexure, shear, compression, and combined loading. Design of composite floor beams. Introduction to connection design. Prerequisite: CENG 148. (4 units)

CENG 135. Reinforced Concrete Design

Design of one-way slabs, tee beams, and doubly-reinforced beams for flexure and shear; moment coefficient method; deflection estimates; longitudinal bar cutoffs and detailing; biaxial bending and slender columns. Prerequisite: CENG 148. Co-requisite: CENG 135L. (4 units)

CENG 135L. Laboratory for CENG 135

Experimental tests of reinforced concrete building components; problem solving and review sessions; field trip(s). Co-requisite: CENG 135. (1 unit)

CENG 136. Advanced Concrete Structures

Confinement, moment-curvature and shear-displacement response; modeling; design and detailing of special moment frames, shear walls, and diaphragms; pre-stressed concrete beams. Also listed as CENG 236. Prerequisite: CENG 135 and CENG 137. (4 units)

CENG 137. Earthquake Engineering Design

Introduction to seismic sources, wave propagation, and effects on structures. Spectral representations of demands. Design according to current code provisions, and using simplified pushover methods. Also listed as CENG 237. Prerequisite: CENG 148. (4 units)

CENG 138. Geotechnical Engineering Design II

Foundation exploration; bearing capacity and settlement analysis; spread foundations; piles and caissons; earth-retaining structures; loads on underground conduits; subsurface construction. Also listed as CENG 238. Prerequisite: CENG 121A/B. (4 units)

CENG 138L. Geotechnical Engineering Design Laboratory

Structural design of footings, piles, and retaining walls. Also listed as CENG 238L. Prerequisite: CENG 148. Co-requisite: CENG 138. (1 unit)

CENG 139. Groundwater Hydrology

Groundwater occurrence, flow principles, flow to wells, and regional flow. Groundwater contamination, management, and models. Field methods. Field trips. Also listed as CENG 259. Prerequisite: CENG 141 or instructor's consent. (3 units)

CENG 140. Water Resources Engineering

Concepts, analysis, and engineering design related to various aspects of water resources: hydrologic cycle, evaporation, infiltration, precipitation, snow, flood frequency, water supply, and runoff management. Impacts of development, land use, and climate changes on water supply, and importance of these changes to society. Field trips. Prerequisite: CENG 141 or instructor's consent. Co-requisite: CENG 140L. (4 units)

CENG 140L. Laboratory for CENG 140

Computational exercises for water resources analysis, field trips demonstrating hydrologic monitoring systems and complex regional water management systems. Co-requisite: CENG 140. (1 unit)

CENG 141. Fluid Mechanics and Hydraulic Engineering

CENG 141L. Fluid Mechanics and Hydraulic Engineering Laboratory

Experiments demonstrating the principles of fluid flow and hydraulics for flow in pipes and in open channels. Use of modern data acquisition and writing of formal lab reports. Co-requisite: CENG 141. (1 unit)

CENG 142. Water Resources Design

Design of system components for water supply and flood control projects, including storage facilities, closed conduits, open channels, well fields, and pumping systems. Also listed as CENG 242. Prerequisites: CENG 141 and CENG 140 (CENG 140 may be taken concurrently) or instructor's consent. (4 units)

CENG 143. Environmental Engineering

Water and air quality. Water supply and pollution control; air pollution control. Management of solid wastes. Prerequisites: CHEM 11 and MATH 12. Co-requisite: CENG 143L. (3 units)

CENG 143L. Laboratory for CENG 143

Laboratory analysis of aqueous samples and ideal reactor systems. Analysis of non-point pollution prevention strategies. Solid waste characterization. Co-requisite: CENG 143. (1 unit)

CENG 144. Water and Wastewater Treatment

Design of water and municipal wastewater treatment systems. Topics include unit operations such as flocculation, sedimentation, filtration, biological treatment, nutrient removal, disinfection, and sludge management. Also listed as CENG 254. Prerequisites: CENG 143 or instructor's consent. Corequisite: CENG 144L. (3 units)

CENG 144L. Laboratory for CENG 144

Laboratory experiments to characterize water samples, including BOD and COD measurements. Field trips to local water and wastewater treatment plants. Also listed as CENG 254L. Corequisite: CENG 144. (1 unit)

CENG 145. Transportation Engineering Design

Transportation systems analysis. Dynamics and traffic flow. Highway geometric design, traffic control, transportation planning. Transportation policies and economics. Prerequisites: CENG 10 and junior standing. (4 units)

CENG 146. Design of Cold-Formed Steel Frame Structures

Introduction to cold-formed steel design and construction. Practical design of members for tension, compression, shear, and torsion. Connection detailing. Lateral force-resisting systems. Also listed as CENG 246. Prerequisite: CENG 132. (4 units)

CENG 148. Structural Systems

Structural requirements for building systems. Design loads, load combinations, and load path. Fire, sound, thermal, and mechanical requirements. An introduction to design of steel and reinforced concrete beams and columns. Prerequisite: CENG 132. Co-requisite: CENG 148L. (4 units)

CENG 148L. Structural Systems Laboratory

Modeling, analysis, and evaluation of structural systems. Structural drawings/schematics. Co-requisite: CENG 148. (1 unit)

CENG 149. Civil Systems Engineering

Introduction to engineering systems analysis and management technologies and their applications to civil engineering problems, such as transportation, assignment, critical path, and maximum flow problems. Topics include linear programming, nonlinear programming, probability, and queuing theory, as well as relevant applications to civil engineering problems. Also listed as CENG 249. Prerequisites: MATH 13 and junior standing. (4 units)

Introduction to engineering systems analysis and management technologies and their applications to civil engineering problems, such as transportation, assignment, critical path, and maximum flow problems. Topics include linear programming, nonlinear programming, probability, and queuing theory, as well as relevant applications to civil engineering problems. Also listed as CENG 249. Prerequisites: MATH 13 and junior standing. (4 units)

CENG 150. Traffic Engineering: Design and Operations

Basic characteristics of motor-vehicle traffic, highway and intersection capacity, applications of traffic control devices, traffic data studies, signal design, traffic safety. Also listed as CENG 250. Prerequisite: CENG 145. (4 units)

CENG 151. Special Topics in Transportation Engineering

Coverage of special topics in transportation engineering including dynamic traffic flow forecasting, analysis and application of traffic flow patterns, and static and dynamic traffic analysis and modeling for short-term and long-term planning and optimization. Also listed as CENG 251. Prerequisite: CENG 145. (4 units)

CENG 160. GIS in Water Resources

Introduction to Geographical Information Systems (GIS) technology with applications in watershed analysis, interpolation, site suitability assessment, and spatial analysis of environmental data. Obtaining and processing digital information at different scales for state-wide, watershed, and urban areas and combination of location information with tabular information such as census data. Commercial and open-source software are used. Also listed as CENG 260. Prerequisites: Junior standing and experience with Windows directory and file management, or permission of instructor. (3 units)

CENG 161. Sustainable Water Resources

Analysis and design of water resource systems, from flood control projects to drinking water supply, as environmental constraints and societal values shift. Quantitative analysis of environmental data is used to detect changes and project future conditions. Includes sustainable and low-impact design techniques, climate change impacts on water, assessing sustainability, life-cycle economics, and current topics. Also listed as CENG 261. Prerequisite: CENG 140 or instructor's consent. (3 units)

CENG 162. Computational Water Resources

Use of professional application software to analyze systems for water resources engineering projects. Computational tools include the development of a computer model to translate rainfall into runoff for a river basin, and assess the impacts of climate variability and change on water supply. Also listed as CENG 262. Prerequisite: CENG 140, which may be taken concurrently, or equivalent. (3 units)

CENG 182. Introduction to Building Information Modeling

Parametric design and modeling, BIM-based scheduling and estimating, model checking and validation, 4D visualization, green building design, applications in integrated project delivery and facilities management, interoperability, standardization, and web-based collaboration. Also listed as CENG 282. Prerequisites: CENG 125 and junior standing. (3 units)

CENG 184. Construction Project Delivery

Project organization and delivery systems, Project stakeholders authorities and responsibilities, contractual payment schemes, bidding process, preconstruction administration, contracts, payment measurement, change orders, quality management, safety, claims and disputes, risk and liability sharing, project documentation and closeout, lean construction, pull planning, work structuring, lean supply chain, lean project delivery system. Also listed as CENG 284. Prerequisite: Junior standing. (3 units)

CENG 185. Cost Estimation

Types of construction cost estimates and their uses. Direct and indirect costs. Cost budgeting and control. Quantity Takeoff. Cost databases and software. Detailed cost estimates of main building systems. Also listed as CENG 285. Prerequisite: CENG 118. (3 units)

CENG 186. Construction Planning and Control

Work breakdown structure; work sequencing and logic; activity duration estimates; schedule network representations; critical path method; resources loading, allocation, and leveling; planning of repetitive tasks; cost estimates; time-cost tradeoffs; project cash flow analysis; and, time-cost control. Use of commercial scheduling software. Group project on construction planning. Also listed as CENG 286. Prerequisite: Junior standing. (3 units)

CENG 187. Heavy Construction

Earthmoving with dozers, scrapers, and excavators; hauling, compacting, concrete operations, asphalt paving, work and production plans. Machine power and resistance, piling, cranes, and rigging operations. Also listed as CENG 287. Prerequisite: Junior standing. (3 units)

CENG 188. Co-op Education

Practical experience in a planned program designed to give students practical work experience related to their academic field of study and career objectives. Satisfactory completion of the work assignment includes preparation of a summary report on co-op activities. P/NP grading. May not be taken for graduate credit. (1–2 units)

CENG 189. Co-op Technical Report

Technical report on a specific activity such as a design or research project, etc., completed during a co-op assignment. Approval of department advisor required. Letter grade based on content and quality of report. May not be taken for graduate credit. Prerequisite: CENG 188. (2 units)

CENG 192A. Civil Engineering Project Development

Introduction to problem-solving methodology for the design of civil engineering systems and components. Selection of Capstone Design Project, definition of problem, and conceptual design. Prerequisite: Junior standing. (1 unit)

CENG 192B. Elements of Civil Engineering Practice

Further development of problem-solving methodology; introduction to project management. Applications of engineering techniques and procedures to civil engineering design. Schematic designs, alternatives analysis and cost estimates. Preliminary design of critical components or subsystems of Capstone Design Project. Environmental impact assessment. Prerequisite: CENG 192A. Co-requisite: CENG 192C. (2 units)

CENG 192C. Professional Development Seminar

Importance of licensing and lifelong learning in the practice of civil engineering. Advanced workshops on topics relevant to Capstone Design Projects. Review of topics covered on the Fundamentals of Engineering (FE) exam. Corequisite: 192B. (1 unit)

CENG 193. Detailed Project Design

Investigation of an approved Capstone Design Project. The design process, including problem formulation, analysis, preliminary design, final design, and plans, is completed. Formal presentation of preliminary and final designs. Prerequisite: CENG 192B. (4 units)

CENG 194. Design Project Communication

Completion of design project documentation and public presentation of results. Prerequisite: CENG 193. (1 unit)

CENG 197. Special Topics in Civil Engineering

Subjects of current interest. May be taken more than once if topics differ. (1–4 units)

Investigation of an approved engineering problem and preparation of a suitable project report. Conferences with faculty advisor are required. Prerequisite: Junior standing. (1–5 units)

Graduate Courses

CENG 205. Finite Element Methods I

Introduction to structural and stress analysis problems using the finite element method. Use of matrix methods, interpolation (shape) functions and variational methods. Formulation of global matrices from element matrices using direct stiffness approach. Development of element matrices for trusses, beams, 2D, axisymmetric and 3D problems. Theory for linear static problems and practical use of commercial FE codes. (2 units)

CENG 206. Finite Element Methods II

Isoparametric elements and higher order shape functions for stiffness and mass matrices using numerical integration. Plate and shell elements. Mesh refinement and error analysis. Linear transient thermal and structural problem using finite element approach. Eigenvalue/eigenvector analysis, frequency response and direct integration approaches for transient problems. Application of commercial FE codes. Prerequisite: CENG 205. (2 units)

CENG 207. Finite Element Methods III

Solution of nonlinear problems using finite element analysis. Methods for solving nonlinear matrix equations. Material, geometrical, boundary condition (contact) and other types of nonlinearities and applications to solid mechanics. Transient nonlinear problems in thermal and fluid mechanics. Application of commercial FE codes to nonlinear analysis. Also listed as MECH 252. Prerequisite: CENG 206. (2 units)

CENG 208. Engineering Economics and Project Finance

Time value of money, cash-flow, rate of return, and depreciation; financing approaches and sources; applications to large scale energy projects such as wind and solar energy, cogeneration, biomass, and geothermal. (3 units)

CENG 211. Advanced Strength of Materials

Bending of beams with nonsymmetrical cross section. Curved beams. Shear center. Shear flow in open and closed sections. Torsion of open and closed section members. Energy theorems and their applications. Beams on elastic foundations. Beam analysis using Fourier series. Stress analysis of composite materials. (4 units)

CENG 218. Construction Engineering

Introduction to construction roles and responsibilities, construction project phases, building systems, bidding and cost estimating, building trades and subcontractors, construction methods, and safety and quality management. Also listed as CENG 118. (3 units)

CENG 219. Designing for Sustainable Construction

Design strategies for sustainable commercial and residential construction. Use of LEED criteria for assessing sustainable construction. Team-based project planning, design, and construction. Economic evaluation of sustainable technologies. Prefabrication. Overall project management. Also listed as CENG 119. (3 units)

CENG 220. Structural Dynamics

Analysis and behavior of simple linear oscillators. Natural mode shapes and frequencies for distributed and lumped mass systems. Introduction to nonlinear vibrations. (4 units)

CENG 221. Advanced Dynamics

Continuation of CENG 220. Distributed parameter systems. Nonlinear transient dynamics. Dynamic response in the frequency domain. Component mode methods. Prerequisite: CENG 220. (2 units)

Analysis and behavior of simple linear oscillators. Natural mode shapes and frequencies for distributed and lumped mass systems. Introduction to nonlinear vibrations. (4 units)

CENG 221. Advanced Dynamics

Continuation of CENG 220. Distributed parameter systems. Nonlinear transient dynamics. Dynamic response in the frequency domain. Component mode methods. Prerequisite: CENG 220. (2 units)

CENG 222. Advanced Structural Analysis

Advanced methods for the analysis of statically indeterminate and non-conventional structural systems. Explicit modeling of cross-sections and joints in structural systems. Hands-on experience with modern commercial analysis software. Prerequisite: CENG 132. (4 units)

CENG 223. Stability of Structures

Energy methods. Elastic stability of columns under axial loads and bending moments. Introduction to inelastic stability analysis of columns. Stability analysis of frames. Stability of flat plates and cylindrical shells. Lateral buckling of beams. (4 units)

CENG 226. Plastic Theory of Structures

Concepts of plastic behavior of structures. Collapse mechanisms for beams and frames. Applications of energy methods in solution procedures. (2 units)

CENG 228. Fracture Mechanics of Solids

Elastic and elastic-plastic fracture criteria. Stress intensity solutions. Metallurgical aspects of toughness. Design and alloy selection. Failure analysis techniques applied to actual engineering problems. (2 units)

CENG 231. Bridge Engineering

An introduction to modern bridge structural systems, bridge loading, bridge deck slab design, girders, and substructure. Prerequisites: CENG 134 and CENG 135. (4 units)

CENG 232. Masonry Engineering

Design of unreinforced and reinforced masonry structures, including shear-wall and bearing-wall systems. Prerequisite: CENG 135. (2 units)

CENG 233. Wood Design

Design of wood structural systems. Design of sawn and structural composite lumber members for tension, compression, bending, and shear. Introduction to shear wall and diaphragm design. Design of connections. Also listed as CENG 133. Prerequisite: CENG 132. (4 units)

CENG 234. Structural Steel Design II

Design of lateral systems, including new and innovative systems, and connections. Introduction to hybrid and composite design. Application of performance-based design requirements for steel structures. Prerequisite: CENG 134. (4 units)

CENG 236. Advanced Concrete Structures

Confinement, moment-curvature and shear-displacement response; modeling; design and detailing of special moment frames, shear walls, and diaphragms; pre-stressed concrete beams. Also listed as CENG 136. Prerequisite: CENG 135. (4 units)

CENG 237. Earthquake Engineering Design

Introduction to seismic sources, wave propagation, and effects on structures. Spectral representations of demands. Design according to current code provisions and using simplified pushover methods. Also listed as CENG 137. (4 units)

CENG 238. Geotechnical Engineering Design

Foundation exploration; bearing capacity and settlement analysis; spread foundations; piles and caissons; earth-retaining structures; loads on underground conduits; subsurface construction. Also listed as CENG 138. Prerequisite: CENG 121A/B. (3 units)

CENG 238L. Geotechnical Engineering Design Laboratory

Structural design of footings, piles, and retaining walls. Also listed as CENG 138L. Prerequisite: CENG 148 or instructor approval. Co-requisite: CENG 238. (1 unit)

CENG 239. Earthquake Engineering II

Continuation of CENG 237. Performance-based earthquake engineering. Use of advanced techniques for design of new buildings and rehabilitation of existing buildings to meet clearly delineated seismic performance expectations. Modeling of structural components and use of nonlinear analysis software for static and dynamic analyses. Prerequisite: CENG 237. Co-requisite: CENG 239L. (3 units)

CENG 239L. Earthquake Engineering Laboratory

Co-requisite: CENG 239. (1 unit)

CENG 240. Soil-Structure Interaction

Introduction of soil-structure analysis for evaluating seismic response. Dynamic interaction between the structure and its surrounding soil. Soil-structure interaction models. Prerequisites: CENG 237 and CENG 238. (2 units)

CENG 241. Introduction to Blast Analysis

This introductory course will cover well-established procedures and principles used to design structures to resist the effects of accidental explosions. Concepts covered include design considerations; risk analysis and reduction; acceptable performance criteria; levels of protection; air-blast loading phenomenon, blast loading functions, current state of practice of structural blast analysis, design and detailing requirements. Prerequisite: CENG 148 or instructor approval. (2 units)

CENG 242. Water Resources Design

Design of system components for water supply and flood control projects, including storage facilities, closed conduits, open channels, well fields, and pumping systems. Also listed as CENG 142. Prerequisites: CENG 141 and CENG 140 (CENG 140 may be taken concurrently) or permission of instructor. (4 units)

CENG 243. Blast-Resistant Design of Concrete Structures

Introduction to the design of walls, slabs, beams and columns for far and close-in explosion effects; dynamic design considerations; detailing requirements, connections; acceptable performance criteria; damage assessment and levels of protection. (2 units)

CENG 244. Progressive Collapse and Structural Integrity

Introduction to procedures and principles used to analyze and design structures to mitigate the possibility of the progressive collapse. Concepts covered include examples and causes, mechanisms of occurrence of progressive collapse, analysis and modeling principles, current state of practice, design and detailing considerations for steel and concrete moment frame structures, levels of protection and risk reduction concepts; course project. (2 units)

CENG 246. Design of Cold-Formed Steel Frame Structures

Introduction to cold-formed steel design and construction. Practical design of members for tension, compression, shear, and torsion. Connection detailing. Lateral force-resisting systems. Also listed as CENG 146. (4 units)

CENG 249. Civil Systems Engineering

Introduction to engineering systems analysis and management technologies and their applications to civil engineering problems, such as transportation, assignment, critical path, and maximum flow problems. Topics include linear programming, nonlinear programming, probability and queuing theory, as well as relevant applications to civil engineering problems. Also listed as CENG 149. (4 units)

CENG 250. Traffic Engineering: Design and Operations

Basic characteristics of motor-vehicle traffic, highway and intersection capacity, applications of traffic control devices, traffic data studies, signal design, traffic safety. Also listed as CENG 150. Prerequisite: CENG 145. (4 units)

CENG 251. Special Topics in Transportation Engineering

Coverage of special topics in transportation engineering, including dynamic traffic flow forecasting, analysis and application of traffic flow patterns, and static and dynamic traffic analysis and modeling for short-term and long-term planning and optimization. Also listed as CENG 151. Prerequisite: CENG 145. (4 units)

CENG 252. Air Pollution

The study of generation of common air pollutants, their transport, effects, and state-of-the-art air pollution control strategies. Also listed as CENG 122. Prerequisite: CENG 143 or instructor's consent. (3 units)

CENG 253. Pollutant Fate and Transport

Study of reaction energetics, kinetics, interphase mass transfer, and partitioning as they relate to pollutant transformation in the environment. Application to surface waters and groundwater. Also listed as CENG 123. Prerequisites: CHEM 11, AMTH 106 or instructor's consent. Corequisite: CENG 253L (3 units)

CENG 253L. Laboratory for CENG 253

Use of experimentation and computer modeling to analyze problems in chemical kinetics, pollutant transport, and phase partitioning. Also listed as CENG 123L. Co-requisite: CENG 253. (1 unit)

CENG 254. Water and Wastewater Treatment

Design of water and municipal wastewater treatment systems. Topics include unit operations such as flocculation, sedimentation, filtration, biological treatment, nutrient removal, disinfection, and sludge management. Also listed as CENG 144. Prerequisites: CENG 143 or instructor's consent. Corequisite: CENG 254L. (3 units)

CENG 254L. Laboratory for CENG 254

Laboratory experiments to characterize water samples, including BOD and COD measurements. Field trips to local water and wastewater treatment plants. Also listed as CENG 144L. Corequisite: CENG 254. (1 unit)

CENG 256. Public Transportation

Evolution of mass transit in the United States. Characteristics of major components of mass transit: bus, light- and rapid-rail transit. Prominent systems of mass transit in selected major U.S. cities. Paratransit systems. Financing and administering transit and paratransit systems. New technology applications in mass transit. Course requires students to get hands-on experience on one of the major transit systems in the Bay Area as a case study. (3 units)

CENG 258. Water Law and Policy

Introduction to the legal and regulatory concepts related to water. Examines rights, policies, and laws, including issues related to water supply and access (water transfers/water markets, riparian and appropriative doctrines), flood control, water pollution and quality (the Clean Water Act, EPA standards, instream flows for fish), and on-site stormwater

management/flood control. A focus on California water law and policy is complemented with some national and international case studies. Cross-listed with CENG 124 and ENVS 124. (4 units)

CENG 259. Groundwater Hydrology

Groundwater occurrence, flow principles, flow to wells, and regional flow. Groundwater contamination, management, and modeling. Field methods. Field trips. Also listed as CENG 139. Prerequisite: CENG 141 or instructor's consent. (3 units)

CENG 260. GIS in Water Resources

Introduction to Geographical Information Systems (GIS) technology with applications in watershed analysis, interpolation, site suitability assessment, and spatial analysis of environmental data. Obtaining and processing digital information at different scales for state-wide, watershed, and urban areas and combination of location information with tabular information such as census data. Commercial and open-source software are used. Prerequisite: experience with Windows directory and file management. Also listed as CENG 160. (3 units)

CENG 261. Sustainable Water Resources

Analysis and design of water resource systems, from flood control projects to drinking water supply, as environmental constraints and societal values shift. Quantitative analysis of environmental data is used to detect changes and project future conditions. Includes sustainable and low-impact design techniques, climate change impacts on water, assessing sustainability, life-cycle economics, and current topics. Also listed as CENG 161. Prerequisite: CENG 140 or instructor's consent. (3 units)

CENG 262. Computational Water Resources

Use of professional application software to analyze systems for water resources engineering projects. Computational tools include the development of a computer model to translate rainfall into runoff for a river basin and assess the impacts of climate variability and change on water supply. Also listed as CENG 162. Prerequisite: CENG 140, which may be taken concurrently, or equivalent. (3 units)

CENG 281. Construction Law for Civil Engineers

Legal aspects of construction procedures. Quantitative methods, case studies and procedures for measuring, analyzing and mitigating the value of change orders and claims. Discussion of key construction topics for the construction professional. General review of contract types, tort law, contract interpretation, liens, claims and disputes. A project term paper is required. (3 units)

CENG 282. Introduction to Building Information Modeling

Parametric design and modeling, BIM-based scheduling and estimating, model checking and validation, 4D visualization, green building design, applications in integrated project delivery and facilities management, interoperability, standardization, and web-based collaboration. Also listed as CENG 182. (3 units)

CENG 284. Construction Project Delivery

Project organization and delivery systems, Project stakeholders authorities and responsibilities, contractual payment schemes, bidding process, preconstruction administration, contracts, payment measurement, change orders, quality management, safety, claims and disputes, risk and liability sharing, project documentation and closeout, lean construction, pull planning, work structuring, lean supply chain, lean project delivery system. Also listed as CENG 184. (3 units)

CENG 285. Cost Estimation

Types of construction cost estimates and their uses. Direct and indirect costs. Cost budgeting and control. Quantity Takeoff. Cost databases and software. Detailed cost estimates of main building systems. Also listed as CENG 185. Prerequisite: CENG 118. (3 units)

CENG 286. Construction Planning and Control

Work breakdown structure; work sequencing and logic; activity duration estimates; schedule network representations; critical path method; resources loading, allocation, and leveling; planning of repetitive tasks; cost estimates; time-cost tradeoffs; project cash flow analysis; and time-cost control. Use of commercial scheduling software. Group project on construction planning. Also listed as CENG 186. (3 units)

CENG 287. Heavy Construction

Earthmoving with dozers, scrapers, and excavators; hauling, compacting, concrete operations, asphalt paving, work and production plans. Machine power and resistance, piling, cranes, and rigging operations. Also listed as CENG 187. (3 units)

CENG 288. Engineering Decision and Risk Analysis

Epistemic and aleatory uncertainty, reliability and probabilistic risk assessment, risk management, decision trees, sensitivity analysis, optimization, reliability analysis (MCFOSM/FORM/SORM), Monte Carlo, Latin Hypercube and importance sampling, utility theory. Prerequisite: AMTH 108 or instructor's consent. (4 units)

CENG 293. Graduate Design Project

Design of an approved civil engineering system using new methods and/or materials. A formal design report is required. (1–4 units)

CENG 295. Master's Thesis Research

By arrangement. Limited to MSCE candidates. (1–6 units)

CENG 297. Directed Research

By arrangement and department chair approval. (1–6 units)

CENG 299. Independent Study

Special/advanced topics. By arrangement. (1–6 units)

Chapter 10: Department of Computer Science and Engineering

Professor Emeritus: Ronald L. Danielson, Daniel W. Lewis
Wilmot J. Nicholson Family Professor: Nam Ling (IEEE Fellow)
Dianne McKenna Professor: Silvia Figueira (Chair)
Professor: Ruth E. Davis
Associate Professors: Margareta Ackerman, Ahmed Amer, Darren Atkinson, Behnam Dezfouli, Yi Fang, Yuhong Liu, Weijia Shang
Assistant Professors: David C. Anastasiu, Younghyun Cho, Sean Choi, I-Han Hsiao, Shiva Jahangiri, Max Kreminski, Xiang Li, Ying Liu, Kai Lukoff
RTL Lecturers: Salem Al-Agtash, Farokh H. Eskafi, Angela Musurlian
AYAL Lecturers: Keyvan Moataghed, Yuan Wang

Overview

The most successful graduates in the field of computing are those who understand computers as systems—not just the design of hardware or software, but also the relationships and interdependencies between them and the underlying theory of computation.

The Computer Science and Engineering degree includes courses that cover the breadth of the discipline, from the engineering aspects of hardware and software design to the underlying theory of computation.

Degree Programs

Students are required to meet with their advisors to define and file a program of study during their first quarter. In general, no credit is allowed for courses that duplicate prior coursework, including courses listed as degree requirements. Students should arrange adjustment of these requirements with their academic advisor when they file their program of study.

With the prior written consent of the advisor, master's students may take a maximum of 12 units of coursework for graduate credit from selected senior-level undergraduate courses.

Master of Science in Computer Science and Engineering (MSCSE)

All students admitted to the MSCSE program are expected to already have competence in the fundamental subjects listed below, as required within an accredited program for a B.S. in Computer Science Engineering. An applicant without such background (but who has completed college level calculus and advanced programming) may still be admitted, provided the deficiencies are corrected by coursework that is in addition to the normal degree requirements, and that is completed within the first year of graduate study. Alternatively, a student may take a similar course at another approved accredited institution. Online, continuing education, extension courses, and courses without a closed book exam are not accepted. The subjects and corresponding SCU courses that may be used to correct the deficiencies include:

1. Logic design CSEN(COEN) 21 or 921C

2. Data structures CSEN(COEN) 12 or 912C

3. Computer organization & assembly language CSEN(COEN) 20 or 920C or ECEN(ELEN) 33

4. Discrete math AMTH 240

5. Probability AMTH 210

6. One of the following: Differential Equations (AMTH 106), Numerical Analysis (AMTH 220, 221), or Linear Algebra (AMTH 245, 246)

7. One additional advanced programming course or one year of programming experience in industry.

The SCU CSEN/COEN and ECEN/ELEN courses listed above and AMTH 106 are considered undergraduate-level and may not be used to satisfy the requirements for the M.S. in Computer Science and Engineering. However, students who have not satisfied item 4 above may use AMTH 240 as an elective; students who have not satisfied item 5 above may use AMTH 210 as an elective; students who have satisfied item 6 above, but who have never studied numerical analysis, may use AMTH 220/221 as electives; students who have satisfied item 6 above, but who have never studied linear algebra, may use AMTH 245/246 as electives. Laboratory components are not required for the above courses.

The above courses are considered as foundation courses for the MSCSE program. A grade of B or better is required for each to be considered a pass.

Degree Requirements

Engineering Graduate Core- Enrichment Experience Students must take a minimum of 8 units of the Graduate Core Enrichment Experience.

- A minimum of 4 units must be from the Graduate Core which requires at least two courses from the three areas
  - Emerging Topics in Engineering
  - Engineering and Business/Entrepreneurship
  - Engineering and Society
- The remaining 4 units can be accumulated by the following
  - a) Taking one or more major technical electives
  - b) Taking additional classes from the Graduate Core
  - c) Taking Cooperative Education courses (Engr 288, Engr 289)
  - d) Combining courses from a, b and c.

Please refer to **Chapter 6, Enrichment Experience and Graduate Core Requirements** for additional information and the core course list.

MSCSE Core

- **CSEN(COEN)** 210, 279, and 283
  - Students who have taken one or more of these core courses or their equivalent must replace said course(s) with the advanced course equivalent CSEN(COEN) 313, 379, and/or 383) or, with their advisor's approval, replace said course(s) with elective(s).

MSCSE Electives

- A student must take a minimum of 8 units of CSEN(COEN) 300-899 courses. CSE electives must be approved by the advisor.
- Electives: Sufficient units to bring the total to at least 46. (The minimum number of CSEN(COEN) graduate units should be at least 36 units, and courses must be approved by the advisor.)

Please Note: Students wishing to do a thesis (CSEN(COEN) 497) should consult with their academic advisor regarding a modification of these requirements.

Master of Science in Software Engineering (MSSE)

We are currently not accepting applications for the Master of Science in Software Engineering program.

Doctor of Philosophy in Computer Science and Engineering

The Doctor of Philosophy (Ph.D.) degree is conferred by the School of Engineering primarily in recognition of competence in the subject field and the ability to investigate engineering problems independently, resulting in a new contribution to knowledge in the field. The work for the degree consists of engineering research, the preparation of a thesis based on that research, and a program of advanced study in engineering, mathematics, and related physical sciences. The student's work is directed by the department, subject to the general supervision of the School of Engineering. **See Chapters 2 and 3, Academic Programs and Requirements and Admissions**, for details on admission and general degree requirements. The following departmental information augments the general requirements.

Preliminary Exam

A preliminary written exam is offered at least once per year by the School of Engineering as needed. The purpose is to ascertain the depth and breadth of the student's preparation and suitability for Ph.D. work. Only those students who pass the preliminary examination shall be allowed to continue in the doctoral program. The preliminary examination may be repeated only once, and then only at the discretion of the thesis advisor.

The exam consists of three core subjects in the computer science and engineering area: computer architecture, algorithms, and operating systems. Students who do not pass all subjects during the first attempt are required to take the exam(s) of the failed subject(s) in the second attempt.

Thesis Advisor

The student and his or her advisor jointly develop a complete program of study for research in a particular area. The complete program of study (and any subsequent changes) must be filed with the Engineering Graduate Programs Office and approved by the student's doctoral committee. Until this approval is obtained, there is no guarantee that courses taken will be acceptable toward the Ph.D. course requirements.

Doctoral Committee and Other Requirements

After passing the Ph.D. preliminary exam, a student requests his or her thesis advisor to form a doctoral committee. The committee consists of at least five members, each of which must have earned a doctoral degree in a field of engineering or a related discipline. This includes the student's thesis advisor, at least two other current faculty members of the student's major department at Santa Clara University, and at least one current faculty member from another appropriate academic department at Santa Clara University.

The committee reviews the student's program of study, conducts an oral comprehensive exam (presentation of research proposal for examinations on the subject of research work), conducts the dissertation defense, and reviews the thesis. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, dissertation defense, and thesis itself meet with the approval of all committee members. In addition, acceptance of publications (at least one article accepted by a refereed journal with an impact factor of at least 1.0) with the student as the primary (first) author is required. More details are described in **Chapter 2, Academic Programs and Requirements.**

The student is expected to complete a minimum of 72 units of graduate credit beyond the master's degree with an overall GPA of 3.0 or better. Of these, 36 quarter units may be earned through coursework, independent study and directed research, and 36 through the thesis.

Time Limit for Completing Degree

All requirements for the doctoral degree must be completed within eight years following initial enrollment in the Ph.D. program. Extensions will be allowed only in unusual circumstances and must be recommended in writing by the student's doctoral committee and approved by the Dean of Engineering in consultation with the Graduate Program Leadership Council (GPLC).

Engineer's Degree in Computer Science and Engineering

The program leading to the engineer's degree is particularly designed for the education of the practicing engineer. The degree is granted on completion of an approved academic program and a record of acceptable technical achievement in the candidate's field of engineering. The academic program consists of a minimum of 46 units beyond the master's degree. Courses are selected to advance competence in specific areas relating to the engineering professional's work. Evidence of technical achievement must include a paper principally written by the candidate and accepted for publication by a recognized engineering journal prior to the granting of the degree. A letter from the journal accepting the paper must be submitted to the department chairperson. In certain cases, the department may accept publication in the proceedings of an appropriate conference.

Admission to the program will generally be granted to those students who demonstrate superior ability in meeting the requirements for their master's degree. Normally, the master's degree is earned in the same field as that in which the engineer's degree is sought. Students who have earned a master's degree from Santa Clara University must file a new application (by the deadline) to continue work toward the engineer's degree. A program of study for the engineer's degree should be developed with the assistance of an advisor and submitted during the first term of enrollment.

LABORATORIES

The **Artificial Intelligence (AI) Laboratory** conducts research across diverse facets of AI, including foundational and applied machine learning, and computational creativity, exploring the capabilities of AI systems to be autonomously creative as well as act as co-creative partners.

The **Cloud Laboratory** focuses on research in designing, developing, and testing the next-generation cloud-based systems and applications: (1) develop and utilize domain-specific hardware for cloud applications, and (2) optimizing existing systems to better serve new and coming applications that rely on the cloud, such as self-driving car, 5G, and serverless computer.

The **Computing Systems & Informatics Laboratory (CSI Lab)** researches developing and evaluating innovative user- and group-adaptive web-based computing systems and technologies. The Lab explores a range of HCI + AI methods to design technologies (i.e. visual analytics, educational technologies, Learn to Code in AR, etc.).

The **Data Science Laboratory** is devoted to the extraction of knowledge from data and to the theory, design, and implementation of information systems to manage, retrieve, mine, and utilize data.

The **Human-Computer Interaction Laboratory (HCI Lab)** uses human-centered methods to research, design, and develop technologies with social impact, with a focus on digital wellbeing and AR/VR technologies.

The **Humanitarian Computing Laboratory** focuses on developing applications to empower the underserved and their communities.

The **Internet of Things (IoT) Research Laboratory (SIOTLAB)** focuses on the design and development of (1) sensing and actuation systems, (2) energy-efficient, reliable, real-time, and secure networking protocols, and (3) edge and fog computing platforms for various applications such as healthcare, advanced manufacturing, and smart cities.

The **Machine Learning and Computational Genomics Laboratory** focuses on algorithmic design for machine learning problems with real-world applications and impact, especially those with unconventional inputs, such as sparse data, sets of multivariate time series, video streams, and genomics and proteomics data.

The **Multimedia Visual Processing Laboratory (MVP Lab)** supports research in image and video coding (compression and decompression) and processing with visual processing and deep learning methods.

The **Network Security and Optimization Laboratory** focuses on using advanced algorithms and data-driven optimization to solve security-related problems in various real-world complex networks.

The **Sustainable Systems Laboratory** is dedicated to research in systems software and data storage technologies. The projects it supports focus on durable, scalable, and efficient solutions to computing problems, and the application of systems software technologies to broader sustainability problems.

The **Trustworthy Computing Laboratory** conducts research on ensuring the security and trustworthiness of distributed systems and networks.

The **Video and Image Processing Laboratory (VIP Lab)** investigates state-of-the-art machine learning and signal processing techniques for image and video processing and analysis.

For details of faculty research areas, please see https://www.scu.edu/engineering/academic-programs/department-of-computer-engineering/research/.

Course Descriptions

Please Note: Depending on enrollment, some courses may not be offered every year.

Lower-Division Undergraduate Courses

CSEN (COEN) 10. Introduction to Programming
Overview of computing. Introduction to program design and implementation: problem definition, functional decomposition, and design of algorithm programming in PHP and C: variables, data types, control constructs, arrays, strings, and functions. Program development in the Linux environment: editing, compiling, testing, and debugging. Credit is not allowed for more than one introductory class such as CSEN(COEN) 10, CSCI 10, or OMIS 30. Co-requisite: CSEN(COEN) 10L. (4 units)

CSEN (COEN) 10L. Introduction to Programming Laboratory
Laboratory for CSEN (COEN) 10. Co-requisite: CSEN (COEN) 10. (1 unit)

CSEN (COEN) 11. Advanced Programming The C Language: structure and style. Types, operators, and expressions. Control flow. Functions. Pointers, arrays, and strings. Structures and dynamic memory allocation. I/O and file processing. Special operators. Recursion and threads. The Unix environment. Prerequisites: Previous programming experience and/or a grade of C- or better in an introductory computer programming course such as CSEN (COEN) 10, CSCI 10, or OMIS 30. Co-requisite: CSEN (COEN) 11L. (4 units)

CSEN (COEN) 11L. Advanced Programming Laboratory
Laboratory for CSEN (COEN) 11. Co-requisite: CSEN (COEN) 11. (1 unit)

CSEN (COEN) 12. Abstract Data Types and Data Structures
Data abstraction: abstract data types, information hiding, interface specification. Basic data structures: stacks, queues, lists, binary trees, hashing, tables, graphs; implementation of abstract data types in the C language. Internal sorting: review of selection, insertion, and exchange sorts; quicksort, heapsort; recursion. Analysis of run-time behavior of algorithms; Big-O notation. Introduction to classes in C++. Credit not allowed for more than one

introductory data structures class, such as CSEN (COEN) 12 or CSCI 61. Prerequisite: A grade of C- or better in CSEN (COEN) 11. Co-requisite: CSEN (COEN) 12L. Recommended co-requisite: CSEN (COEN 19) or MATH 51. (4 units)

CSEN (COEN) 12L. Abstract Data Types and Data Structures Laboratory
Laboratory for CSEN (COEN) 12. Co-requisite: CSEN (COEN)12. (1 unit)

CSEN (COEN) 19. Discrete Mathematics
Predicate logic, methods of proof, sets, functions, sequences and summations, modular arithmetic, cardinality, induction, elementary combinatorial analysis, recursion, and relations. Also listed as MATH 51. (4 units)

CSEN (COEN) 20. Introduction to Embedded Systems
Introduction to computer organization: CPU, registers buses, memory, and I/O. Number systems: information representation, signed and unsigned representation of integers, radix conversions and binary arithmetic. Assembly language programming: addressing techniques, arithmetic, shifting, bitwise and logic operations, overflow, branching and looping, and parameter passing. Calling assembly language functions from a C main program. Fixed and floating-point representation of real numbers. Performance issues: address alignment, instruction pipelining, pipeline stalls. Prerequisite: A grade of C- or better in CSEN(COEN) 11 or CSCI 60. Co-requisite: CSEN (COEN) 20L. Recommended co-requisite or prerequisite: CSEN (COEN) 12 or CSCI 61. (4 units)

CSEN (COEN) 20L. Embedded Systems Laboratory
Laboratory for CSEN (COEN) 20. Co-requisite: CSEN (COEN 20). (1 unit)

CSEN (COEN) 21. Introduction to Logic Design
Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flip-flops; timing; registers; counters. Programmable logic, PLD, and FPGA. Use of industry quality CAD tools for schematic capture and HDL in conjunction with FPGAs. Also listed as ECEN (ELEN) 21. Co-requisite: CSEN (COEN) 21L. (4 units)

CSEN (COEN) 21L. Logic Design Laboratory
Laboratory for CSEN (COEN) 21. Also listed as ECEN (ELEN) 21L. Co-requisite: CSEN (COEN) 21. (1 unit)

CSEN (COEN) 29. Current Topics in Computer Science and Engineering
Subjects of current interest. May be taken more than once if topics differ. (4 units)

CSEN (COEN) 60. Introduction to Web Technologies
Overview of the Internet and World Wide Web technologies and practices. Introduction to basic markup language, style sheet language, server-side scripting language, and website design. Emerging web applications. Co-requisite: CSEN (COEN) 60L. (4 units)

CSEN (COEN) 60L. Introduction to Web Technologies Laboratory
Laboratory for CSEN (COEN) 60. Co-requisite: CSEN (COEN) 60. (1 unit)

CSEN (COEN) 79. Object-Oriented Programming and Advanced Data Structures
Object-oriented programming concepts; specification, design, and implementation of data structures with emphasis on software reliability and reusability. Design and implementation of static and dynamic data structures, such as sequence, vector, list, stack, queue, deque, priority queue, set, multiset, map, multimap, and graphs. Software development using inheritance, templates and iterators. Memory allocation and performance. Using data structures in real-world applications. Time analysis of data structures. Informal use of specifications to guide implementation and validation of programs. Prerequisites: A grade of C– or better in either CSEN(COEN) 12 or CSCI 61 and in either CSEN(COEN) 19 or MATH 51. Co-requisite: CSEN(COEN) 79L. (4 units)

CSEN (COEN) 79L. Object-Oriented Programming and Advanced Data Structures Laboratory
Laboratory for CSEN (COEN) 79. Co-requisite: CSEN(COEN) 79. (1 unit)

Upper-Division Undergraduate Courses

CSEN (COEN) 100. Research Seminar
Introduction to research in computing, covering several research areas. (1 unit)

CSEN (COEN) 120. Real Time Systems
Overview of real-time systems: classification, design issues and description. Finite state machines and state charts. Robot programming: odometry and the use of sensors. Real-time programming languages, real-time kernels and multi-threaded programming. Unified Modeling Language for the design of real-time applications. Performance analysis. Prerequisite: A grade of C- or better in either CSEN (COEN) 12 or CSCI 61. Co-requisite: CSEN(COEN) 120L. (4 units)

CSEN (COEN) 120L. Real Time Systems Laboratory
Laboratory for CSEN(COEN) 120. Co-requisite: CSEN(COEN) 120. (1 unit)

CSEN (COEN) 122. Computer Architecture
Overview of computer systems. Performance measurement. Instruction set architecture. Computer arithmetic. CPU datapath design. CPU control design. Pipelining. Data/control hazards. Memory hierarchies and management. Introduction of multiprocessor systems. Hardware description languages. Laboratory project consists of a design of a CPU. Prerequisites: A grade of C- or better in either CSEN(COEN) 20 or ECEN()ELEN 33 and in either CSEN(COEN) 21 or ECEN(ELEN) 21. Co-requisite: CSEN(COEN) 122L. (4 units)

CSEN (COEN) 122L. Computer Architecture Laboratory
Laboratory for CSEN(COEN) 122. Co-requisite: CSEN(COEN) 122. (1 unit)

CSEN (COEN) 123. Mechatronics
Introduction to behavior, design, and integration of electromechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and integration of transducers, microcontrollers, and actuators. Also listed as ECEN(ELEN) 123 and MECH 143. Prerequisites: ECEN(ELEN) 50 with a grade of C– or better and CSEN(COEN) 11. Co-requisite: CSEN(COEN) 123L. (4 units)

CSEN (COEN) 123L. Mechatronics Laboratory
Laboratory for CSEN(COEN) 123. Also listed as ECEN(ELEN) 123L and MECH 143L. Co-requisite: CSEN (COEN) 123. (1 unit)

CSEN (COEN) 127. Advanced Logic Design
Contemporary design of finite-state machines as system controllers using MSI, PLDS, or FPGA devices. Minimization techniques, performance analysis, and modular system design. HDL simulation and synthesis. Also listed as ECEN(ELEN) 127. Prerequisite: CSEN(COEN) 21. Co-requisites: CSEN(COEN) 127L and ECEN(ELEN) 115. (4 units)

CSEN (COEN) 127L. Advanced Logic Design Laboratory
Laboratory for CSEN(COEN) 127. Design, construction, and testing of controllers from verbal specs. Use of CAD design tools. Also listed as ECEN(ELEN) 127L. Co-requisite: CSEN(COEN) 127. (1 unit)

CSEN (COEN) 129. Current Topics in Computer Science and Engineering
Subjects of current interest. May be taken more than once if topics differ. (4 units)

CSEN (COEN) 140. Machine Learning and Data Mining
Machine learning as a field has become increasingly pervasive, with applications from the web (search, advertisements, and recommendation) to national security, from analyzing biochemical interactions to traffic and emissions to astrophysics. This course presents an introduction to machine learning and data mining, the study of

computing systems that improve their performance through learning from data. This course is designed to cover the main principles, algorithms, and applications of machine learning and data mining. Prerequisites: A grade of C- or better in AMTH 108, MATH 53, and CSEN(COEN) 12. (4 units)

CSEN (COEN) 140L. Machine Learning and Data Mining Laboratory
Laboratory for CSEN(COEN) 140. Co-requisite: CSEN(COEN) 140. (1 unit)

CSEN (COEN) 143. Internet of Things
Applications and architectures of IoT systems. Embedded and low-power processors. Interfacing digital sensors and actuators. Interrupts and exceptions in a concurrent world. Operating systems for resource-constrained devices. Multitasking and memory allocation. Wireless channel access, low-power wireless, real-time and reliable communication. IP networking, protocol translation and compression. Multi-hop communication. Application layer protocols. Security protocols and architectures. Cloud and edge computing. Prerequisites: a grade of C- or better in CSEN(COEN) 146 and CSEN(COEN) 177. (4 units)

CSEN (COEN) 143L. Internet of Things Laboratory
Laboratory for CSEN(COEN) 143. Co-requisite: CSEN(COEN) 143. (1 unit)

CSEN (COEN) 145. Introduction to Parallel Computing
How to effectively program parallel computers, from smartphones to large clusters. Types of parallel architectures, routing, data parallel, shared-memory, and message-passing parallel programming, load balancing, evaluation of parallel algorithms, advanced topics. Case studies in real-world data analytics, including parallel algorithms for sparse matrix and graph operations. Hands-on lab on multi-core CPUs and many-core GPUs. Prerequisites: a grade of C- or better in either CSEN(COEN) 12 or CSCI 61. Corequisite: CSEN(COEN) 145L. (4 units)

CSEN (COEN) 145L. Introduction to Parallel Computing Laboratory
Laboratory for CSEN(COEN) 145. Co-requisite: CSEN(COEN) 145. (1 unit)

CSEN (COEN) 146. Computer Networks
Data Communication: circuit and packet switching, latency and bandwidth, throughput/delay analysis. Application Layer: client/ server model, socket programming, web, email, FTP. Transport Layer: TCP and UDP, flow control, congestion control, sliding window techniques. Network Layer: IP and routing. Data Link Layer: shared channels, media access control protocols, error detection and correction. Mobile computing and wireless networks. Network security. Laboratory consists of projects on software development of network protocols and applications. Prerequisite: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61. Co-requisite: CSEN(COEN) 146L. Recommended co-requisite or prerequisite: AMTH 108 or MATH 122. (4 units)

CSEN (COEN) 146L. Computer Networks Laboratory
Laboratory for CSEN(COEN) 146. Co-requisite: CSEN(COEN) 146. (1 unit)

CSEN (COEN) 148. Computer Graphics Systems
Interactive graphic systems. Graphics primitives, line and shape generation. Simple transforming and modeling. Efficiency analysis and modular design. Interactive input techniques. Three-dimensional transformations and viewing, hidden surface removal. Color graphics, animation, real-time display considerations. Parametric surface definition and introduction to shaded-surface algorithms. Offered in alternate years. Prerequisite: MATH 53; a grade of C- or better in either CSEN(COEN) 12 or CSCI 61. (4 units)

CSEN (COEN) 150. Introduction to Information Security
Security principles; operating system security: process security, file system security, application program security; access control models: DAC, MAC, RBAC, ABAC; malware: virus, Trojan, worms, rootkits, botnets, adware, spyware; network security attacks and defenses at different layers; web security: attacks on clients and servers; cryptographic basis: symmetric cryptography, public-key cryptography, cryptographic hash functions, digital signature; application security: database security, email security, social networking security. Prerequisites: A grade of C- or better in CSEN(COEN) 146. Co-requisite: CSEN(COEN) 150L (4 units)

CSEN (COEN) 150L. Introduction to Information Security Laboratory
Laboratory for CSEN(COEN) 150. Co-requisite: CSEN(COEN) 150. (1 unit)

CSEN (COEN) 152. Introduction to Computer Forensics
Procedures for identification, preservation, and extraction of electronic evidence. Auditing and investigation of network and host system intrusions, analysis and documentation of information gathered, and preparation of expert testimonial evidence. Forensic tools and resources for system administrators and information system security officers. Ethics, law, policy, and standards concerning digital evidence. Prerequisite: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61 and in CSEN(COEN) 20. Co-requisite: CSEN(COEN) 152L. (4 units)

CSEN (COEN) 152L. Introduction to Computer Forensics Laboratory
Laboratory for CSEN(COEN) 152. Co-requisite: CSEN(COEN) 152. (1 unit)

CSEN (COEN) 160. Object-Oriented Analysis, Design and Programming
Four important aspects of object-oriented application development are covered: fundamental concepts of the OO paradigm, building analysis and design models using UML, implementation using Java, and testing object-oriented systems. Prerequisite: A grade of C- or better in CSEN(COEN) 79 or CSCI 61. Co-requisite: CSEN(COEN) 160 (4 units)

CSEN (COEN) 160L. Object-Oriented Analysis, Design and Programming Laboratory
Laboratory for CSEN(COEN) 160. Co-requisite: CSEN(COEN) 160. (1 unit)

CSEN (COEN) 161. Web Development
Fundamentals of World Wide Web (www) and the technologies that are required to develop web-based applications. Topics cover HTML5, CSS, JavaScript, PHP, MYSQL and XML. Prerequisite: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61. Co-requisite: CSEN(COEN) 161L. (4 units)

CSEN (COEN) 161L. Web Development Laboratory
Laboratory for CSEN(COEN) 161. Co-requisite: CSEN(COEN) 161. (1 unit)

CSEN (COEN) 162. Web Infrastructure
History and overview of World Wide Web technology. Web protocols. Web navigation. Web caching and load balancing. P2P and content delivery networks. Streaming technologies. Prerequisite: A grade of C- or better in CSEN(COEN) 146. (4 units)

CSEN (COEN) 163. Web Usability
Principles of user-centered design. Principles of human-computer interaction. Fundamental theories in cognition and human factors: information processing, perception and representation, constructivist and ecological theories, Gestalt laws of perceptual organization. Usability engineering: user research, user profiling, method for evaluating user interface, usability testing. Prototyping in user interface: process, methods of evaluating and testing. Inclusive design in user interface design: accessibility issues, compliance with section 508 of Rehabilitation Act. Prerequisite: A grade of C- or better in CSEN(COEN) 12 or CSCI 61. Co-requisite: CSEN(COEN) 163L. (4 units)

CSEN (COEN) 163L. Web Usability Laboratory
Laboratory for CSEN(COEN) 163. Co-requisite: CSEN(COEN) 163. (1 unit)

CSEN (COEN) 164. Advanced Web Development
Advanced topics in Web Application Development; Development with Web Frameworks (Ruby with Rails), implementing web services and management of web security. Prerequisite: A grade of C- or better in CSEN(COEN) 161 or demonstrated knowledge of web development technology covered in CSEN(COEN) 161. Co-requisite: CSEN(COEN) 164L. (4 units)

CSEN (COEN) 164L. Advanced Web Development Laboratory
Laboratory for CSEN(COEN) 164. Co-requisite: CSEN(COEN) 164. (1 unit)

CSEN (COEN) 165. Introduction to 3D Animation & Modeling/Modeling & Control of Rigid Body Dynamics
Mathematical and physical principles of motion of rigid bodies, including movement, acceleration, inertia and collision. Modeling of rigid body dynamics for three-dimensional graphic simulation; controlling the motion of rigid bodies in robotic applications. May be repeated twice for credit. Also listed as ARTS 173. (5 units)

CSEN (COEN) 166. Artificial Intelligence
Philosophical foundations of Artificial Intelligence, problem solving, knowledge and reasoning, neural networks and other learning methods. Prerequisites: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61 and in either CSEN(COEN)19 or MATH 51. (4 units)

CSEN (COEN) 166L. Artificial Intelligence Laboratory
Laboratory for CSEN(COEN) 166. Co-requisite: CSEN(COEN) 166. (1 unit)

CSEN (COEN) 168. Mobile Application Development
Design and implementation of applications running on a mobile platform such as smart phones and tablets. Programming languages and development tools for mobile SDKs. Writing code for peripherals—GPS, accelerometer, touchscreen. Optimizing user interface for a small screen. Effective memory management on a constrained device. Embedded graphics. Persistent data storage. Prerequisite: a grade of C- or better in CSEN(COEN) 20 or CSEN(COEN) 79 or equivalent. Co-requisite: CSEN(COEN) 168L. Co-located with CSEN(COEN) 268. (4 units)

CSEN (COEN) 168L. Mobile Application Development Laboratory
Laboratory for CSEN(COEN) 168. Co-requisite: CSEN(COEN) 168. (1 unit)

CSEN (COEN) 169. Web Information Management
Theory, design, and implementation of information systems that process, organize, analyze large-scale information on the Web. Search engine technology, recommender systems, cloud computing, social network analysis. Prerequisite: AMTH 108 or MATH 122, CSEN(COEN) 12 or CSCI 61, or permission of the instructor. (4 units)

CSEN (COEN) 171. Principles of Design and Implementation of Programming Languages
High-level programming language concepts and constructs. Costs of use and implementation of the constructs. Issues and trade-offs in the design and implementation of programming languages. Critical look at several modern high-level programming languages. Prerequisite: A grade C- or better in CSEN(COEN) 79 or CSCI 61. (4 units)

CSEN (COEN) 174. Software Engineering
Software development life cycle. Project teams, documentation, and group dynamics. Software cost estimation. Requirements of engineering and design. Data modeling, object modeling, and object-oriented analysis. Object-oriented programming and design. Software testing and quality assurance. Software maintenance. Prerequisite: A grade of C- or better in CSEN(COEN) 12 or CSCI 61. Co-requisite: CSEN(COEN) 174L and CSEN(COEN) 194 (or consent of instructor). (4 units)

CSEN (COEN) 174L. Software Engineering Laboratory
Laboratory for CSEN(COEN) 174. Co-requisite: CSEN(COEN) 174. (1 unit)

CSEN (COEN) 175. Introduction to Formal Language Theory and Compiler Construction
Introduction to formal language concepts: regular expressions and context-free grammars. Compiler organization and construction. Lexical analysis and implementation of scanners. Top-down and bottom-up parsing and implementation of top-down parsers. An overview of symbol table arrangement, run-time memory allocation, intermediate forms, optimization, and code generation. Prerequisites: A grade of C- or better in CSEN(COEN) 20 and CSEN(COEN) 79. Co-requisite: CSEN(COEN) 175L. (4 units)

CSEN (COEN) 175L. Introduction to Formal Language Theory and Compiler Construction Laboratory
Laboratory for CSEN(COEN) 175. Co-requisite: CSEN(COEN) 175. (1 unit)

CSEN (COEN) Operating Systems
Introduction to operating systems. Operating system concepts, computer organization models, storage hierarchy, operating system organization, processes management, inter process communication and synchronization, memory

management and virtual memory, I/O subsystems, and file systems. Design, implementation, and performance issues. Prerequisites: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61 and in CSEN(COEN) 20. Co-requisite: CSEN(COEN) 177L. (4 units)

CSEN (COEN) 177L. Operating Systems Laboratory
Laboratory for CSEN(COEN) 177. Co-requisite: CSEN(COEN) 177. (1 unit)

CSEN (COEN) 178. Introduction to Database Systems
ER diagrams and the relational data model. Database design techniques based on integrity constraints and normalization. Database security and index structures. SQL and DDL. Transaction processing basics. Prerequisite: A grade of C- or better in CSEN(COEN) 12 or CSCI 61. Co-requisite: CSEN(COEN) 178L. (4 units)

CSEN (COEN) 178L. Introduction to Database Systems Laboratory
Laboratory for CSEN(COEN) 178. Co-requisite: CSEN(COEN) 178. (1 unit)

CSEN (COEN) 179. Theory of Algorithms
Introduction to techniques of design and analysis of algorithms: asymptotic notations and running times of recursive algorithms. Design strategies: brute-force, divide and conquer, decrease and conquer, transform and conquer, dynamic programming, greedy technique. Intractability: P and NP, approximation algorithms. Also listed as CSCI 163A. Prerequisites: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61 and in either CSEN(COEN) 19 or MATH 51, or equivalents. (5 units)

CSEN (COEN) 180. Introduction to Information Storage
Storage hierarchy. Caching. Design of memory and storage devices, with particular emphasis on magnetic disks and storage-class memories. Error detection, correction, and avoidance fundamentals. Disk arrays. Storage interfaces and buses. Network attached and distributed storage, interaction of economy and technological innovation. Also listed as ECEN(ELEN) 180. Prerequisites: A grade of C- or better in either CSEN(COEN) 12 or CSCI 61. Recommended prerequisite: CSEN(COEN) 20. (4 units)

CSEN (COEN) 188. Co-op Education
Integration of classroom study and practical experience in a planned program designed to give students practical work experience related to their academic field of study and career objectives. Satisfactory completion of the work assignment includes preparation of a summary report on co-op activities and reflection on learning. P/NP grading. May be taken twice. May not be taken for graduate credit. (2 units)

CSEN (COEN) 189. Co-op Technical Report
Credit given for a technical report on a specific activity such as a design or research project, etc., after completing the co-op assignment. Approval of department advisor required. Letter grades based on content and quality of report. May be taken twice. May not be taken for graduate credit. Prerequisite: CSEN (COEN 188). (2 units)

CSEN (COEN) 193. Undergraduate Research
Involves working on a year-long research project with one of the faculty members. Students should register three times in a row for a total of 6 units. Does not substitute for the senior project, which may be a continuation of the research done. Registration requires the faculty member's approval. Students must have junior or senior standing and a minimum GPA of 3.0. (2 units)

CSEN (COEN) 194. Design Project I
Specification of an engineering project, selected with the mutual agreement of the student and the project advisor. Complete initial design with sufficient detail to estimate the effectiveness of the project. Initial draft of the project report. (2 units)

CSEN (COEN) 195. Design Project II
Continued design and construction of the project, system, or device. Initial draft of project report. Prerequisite: CSEN(COEN) 194. (2 units)

CSEN (COEN) 196. Design Project III
Continued design and construction of the project, system, or device. Formal public presentation of results. Final report. Prerequisite: CSEN(COEN) 195. (2 units)

CSEN (COEN) 199. Directed Research/Readin
Special problems. By arrangement. (1–5 units)

Graduate Courses

Some graduate courses may not apply toward certain degree programs. During the first quarter of study, students should investigate with their faculty advisors the program of study they wish to pursue.

CSEN (COEN) 200. Logic Analysis and Synthesis
Analysis and synthesis of combinational and sequential digital circuits with attention to static, dynamic, and essential hazards. Algorithmic techniques for logic minimization, state reductions, and state assignments. Decomposition of state machine, algorithmic state machine. Design for test concepts. Also listed as ECEN(ELEN) 500. Prerequisite: CSEN(COEN) 127C or equivalent. (2 units)

CSEN (COEN) 201. Digital Signal Processing I
Description of discrete signals and systems. Z-transform. Convolution and transfer functions. System response and stability. Fourier transform and discrete Fourier transform. Sampling theorem. Digital filtering. Also listed as ECEN(ELEN) 233. Prerequisite: ECEN(ELEN) 210 or its undergraduate equivalent of ECEN(ELEN) 110. (2 units)

CSEN (COEN) 201E. Digital Signal Processing I & II
Same description as CSEN(COEN) 201 and CSEN(COEN) 202. Credit not allowed for both CSEN(COEN) 201/202 and 201E. Also listed as ECEN(ELEN) 233E. (4 units)

CSEN (COEN) 202. Digital Signal Processing II
Continuation of CSEN/COEN 201. Digital FIR and IIR filter design and realization techniques. Multi-rate signal processing. Fast Fourier transform. Quantization effects. Also listed as ECEN(ELEN) 234. Prerequisite: CSEN(COEN) 201. (2 units)

CSEN (COEN) 203. VLSI Design I
Introduction to VLSI design and methodology. Analysis of CMOS integrated circuits. Circuit modeling and performance evaluation supported by simulation (SPICE). Ratioed, switch, and dynamic logic families. Design of sequential elements. Fully-custom layout using CAD tools. Also listed as ECEN(ELEN) 387. Prerequisite: CSEN(COEN) ECEN(ELEN) 127 or equivalent. (2 units)

CSEN (COEN) 204. VLSI Design II
Continuation of VLSI design and methodology. Design of arithmetic circuits and memory. Comparison of semi-custom versus fully custom design. General concept of floor planning, placement and routing. Introduction of signal integrity through the interconnect wires. Also listed as ECEN(ELEN) 388. Prerequisite: CSEN(COEN)/ECEN(ELEN) 387 or equivalent, or ECEN(ELEN) 153. (2 units)

CSEN (COEN) 207. SoC (System-on-Chip) Verification
This course presents various state-of-the art verification techniques used to ensure the corrections of the SoC (System-on-Chip) design before committing it to manufacturing. Both Logical and Physical verification techniques will be covered including Functional Verification, Static Timing, Power and Lay Out Verification. Also, the use of Emulation Assertion-based Verification and Hardware/Software CO-Verification techniques will be presented. Also listed as CSEN(COEN) 207. Prerequisites: ECEN(ELEN) 500 or CSEN(COEN) 200 and ECEN(ELEN) 303 or equivalent. (2 units)

CSEN (COEN) 210. Computer Architecture
Historical perspective. Performance analysis. Instruction set architecture. Computer arithmetic. Datapath. Control unit. Pipelining. Data and control hazards. Memory hierarchy. Cache. Virtual memory. Parallelism and multiprocessor. Prerequisites: CSEN(COEN) 920C and CSEN(COEN) 921C or equivalent. (4 units)

CSEN (COEN) 218. Input-Output Structures
I/O architecture overview. I/O programming: dedicated versus memory-mapped I/O addresses. CPU role in managing I/O: Programmed I/O versus Interrupt-Based I/O versus DMA–based I/O. I/O support hardware: interrupt controllers (priority settings, and arbitration techniques), DMA controllers and chip-sets. I/O interfaces: point to point interconnects, busses, and switches. Serial versus parallel interfaces. Synchronous versus asynchronous data transfers. System architecture considerations: cache coherency issues, I/O traffic bandwidth versus latency (requirements and tradeoffs). Error detection and correction techniques. Examples: a high bandwidth I/O device, a parallel I/O protocol, and a serial I/O protocol. Prerequisite: CSEN(COEN) 210. (2 units)

CSEN (COEN) 225. Secure Coding in C and C++
Writing secure code in C, C++. Vulnerabilities based on strings, pointers, dynamic memory management, integer arithmetic, formatted output, file I/O. Attack modes such as (stack and heap based) buffer overflow and format string exploits. Recommended practices. Prerequisites: CSEN(COEN) 210 and experience with coding in C or C++. (2 units)

CSEN (COEN) 233. Computer Networks
Fundamentals of computer networks: protocols, algorithms, and performance. Data Communication: circuit and packet switching, latency and bandwidth, throughput/ delay analysis. Application Layer: client/server model, socket programming, web, e-mail, FTP. Transport Layer: TCP and UDP, flow control, congestion control, sliding window techniques. Network Layer: IP and routing. Data Link Layer: shared channels, media access control protocols, error detection and correction. Mobile and wireless networks. Multimedia Networking. Network security. Prerequisites: CSEN(COEN) 20 or equivalent and AMTH 108 or equivalent. (4 units)

CSEN (COEN) 234. Network Management
Covers the fundamentals of network management. Management functions and reference models, management building blocks (information, communication patterns, protocols, and management organization), and management in practice (integration issues, service-level management). Prerequisite: CSEN(COEN) 233 or equivalent. (2 units)

CSEN (COEN) 235. Client/Server Programming
Client/server paradigm in the context of the Web and the Internet. Objects, components, frameworks, and architectures. Current platforms, such as J2EE, CORBA, and .NET. Prerequisites: Knowledge of Java programming and HTML. (4 units)

CSEN (COEN) 238. Multimedia Information Systems
Overview and applications of multimedia systems. Brief overview of digital media compression and processing. Operating system support for continuous media applications. System services, devices, and user interface. Multimedia file systems and information models. Presentation and authoring. Multimedia over network. Multimedia communications systems and digital rights management. Knowledge-based multimedia systems. MPEG-7. MPEG-21. Prerequisites: AMTH 377 and CSEN(COEN) 177 or 283. (2 units)

CSEN (COEN) 239. Network Design Analysis
Focus on current modeling and analysis of computer networks. Graph theory for networks, queuing theory, simulation methodology, principles and tools for network design, protocol definition, implementation, validation and evaluation. Prerequisite: CSEN(COEN) 233 or equivalent. (4 units)

CSEN (COEN) 240. Machine Learning
Covers theoretical foundations of machine learning. Learning theory or concept learning, overfitting/regularization, decision tree learning, cluster algorithms, artificial neural networks, gradient descent. Students will implement select machine learning algorithms. Prerequisite: AMTH 108 or AMTH 210, MATH 53 or AMTH 246, CSEN(COEN) 179 or 279. (4 units)

CSEN (COEN) 241. Cloud Computing

Introduction to cloud computing, cloud architecture and service models, the economics of cloud computing, cluster/grid computing, virtualization, big data, distributed file system, MapReduce paradigm, NoSQL, Hadoop, horizontal/vertical scaling, thin client, disaster recovery, free cloud services and open source software, example commercial cloud services, and federation/presence/identity/privacy in cloud computing. Prerequisites: CSEN(COEN) 12 and CSEN(COEN) 146 or 233. (4 units)

CSEN (COEN) 242. Big Data

Introduction to Big data. NoSQL data modeling. Large-scale data processing platforms. HDFS, MapReduce and Hadoop. Scalable algorithms used to extract knowledge from Big data. Advanced scalable data analytics platforms. Prerequisites: AMTH 108 or AMTH 210 and CSEN(COEN) 178 or 280. (4 units)

CSEN (COEN) 243. Internet of Things

Application domains. Architectures. Edge and fog computing. Embedded processors. Interfacing digital sensors and actuators. Interrupts and exceptions in a concurrent world. Operating systems. Multitasking. Memory allocation. Low-power wireless communication. Real-time and reliable communication. IP networking. Protocol compression and translation. Multi-hop networking. Application layer protocols. Securing resource-constrained devices. Prerequisites: CSEN(COEN) 12 or 912C and CSEN(COEN) 146 or 233. (4 units)

CSEN (COEN) Information Security Management

Techniques and technologies of information and data security. Managerial aspects of computer security and risk management. Security services. Legal and ethical issues. Security processes, best practices, accreditation, and procurement. Security policy and plan development and enforcement. Contingency, continuity, and disaster recovery planning. Preparation for design and administration of a complete, consistent, correct, and adequate security program. (2 units)

CSEN (COEN) 251. Network Security

Protocols and standards for network security. Network-based attacks. Authentication, integrity, privacy, non-repudiation. Protocols: Kerberos, Public Key Infrastructure, IPSec, SSH, PGP, secure email standards, etc. Wireless security. Programming required. Prerequisite: CSEN(COEN) 250, CSEN(COEN) 233 or instructor approval. (4 units)

CSEN (COEN) 252. Computer Forensics

Procedures for identification, preservation, and extraction of electronic evidence. Auditing and investigation of network and host system intrusions, analysis and documentation of information gathered, and preparation of expert testimonial evidence. Forensic tools and resources for system administrators and information system security officers. Ethics, law, policy, and standards concerning digital evidence. Prerequisite: CSEN(COEN) 20 or 920C or equivalent. Co-requisite: CSEN(COEN) 252L. (4 units)

CSEN (COEN) 252L. Laboratory for CSEN/COEN 252

Co-requisite: CSEN(COEN)252. (1 unit)

CSEN (COEN) 253. Secure Systems Development and Evaluation

Software engineering for secure systems. Security models and implementations. Formal methods for specifying and analyzing security policies and system requirements. Development of secure systems, including design, implementation, and other life-cycle activities. Verification of security properties. Resource access control, information flow control, and techniques for analyzing simple protocols. Evaluation criteria, including the Orange and Red books and the Common Criteria, technical security evaluation steps, management, and the certification process. Hands-on materials in methods for high-assurance using systems such as PVS from SRI, and the NRL Protocol Analyzer. Prerequisite: CSEN(COEN) 250. (4 units)

CSEN (COEN) 259. Advanced Compilers Design

Principles and practice of the design and implementation of a compiler, focusing on the application of theory and trade-offs in design. Lexical and syntactic analysis. Semantic analysis, symbol tables, and type checking. Run-time organization. Code generation. Optimization and data-flow analysis. Prerequisite: CSEN(COEN) 256, 283 or 210. (4 units)

CSEN (COEN) 266. Artificial Intelligence
Fundamental concepts of intelligent agents and agent design, search algorithms, adversarial search, constraint satisfaction problems, decision trees, Bayesian networks, Markov decision processes, and reinforcement learning. Students will implement algorithms to solve real-world problems. Prerequisites: CSEN(COEN) 12 or 912C or equivalent, AMTH 210 and 245 or equivalent. (4 units)

CSEN (COEN) 268. Mobile Application Development
Design and implementation of applications running on a mobile platform such as smartphones and tablets. Programming languages and development tools for mobile SDKs. Writing code for peripherals—GPS, accelerometer, and touchscreen. Optimizing user interface for a small screen. Effective memory management on a constrained device. Embedded graphics. Persistent data storage. Prerequisite: CSEN(COEN) 12 or 912C or equivalent. (4 units)

CSEN (COEN) 272. Web Search and Information Retrieval
Basic and advanced techniques for organizing large-scale information on the Web. Search engine technologies. Big data analytics. Recommendation systems. Text/Web clustering and classification. Text mining. Prerequisites: AMTH 108 or AMTH 210, MATH 53 or AMTH 246, and CSEN(COEN) 179 or 279. (4 units)

CSEN (COEN) 275. Object-Oriented Analysis, Design, and Programming
Four important aspects of object-oriented application development are covered: fundamental concepts of the OO paradigm, building analysis and design models using UML, implementation using Java/C++/C#, and testing object-oriented systems. Prerequisite: CSEN(COEN) 79. (4 units)

CSEN (COEN) 277. Human-Computer Interaction
Fundamentals of human cognition and perception applied to user interfaces. Core concepts, methods, and techniques of user research, human-computer interaction, usability, and user centered design. User experience evaluation methods and associated metrics. User interface and interaction design heuristics, guidelines, principles, theories, techniques, and applications. Prerequisite: CSEN(COEN) 12 or 912C or equivalent. (4 units)

CSEN (COEN) 278. Advanced Web Programming
Advanced topics in Web Application Development; Development with Web Frameworks (Ruby with Rails), implement web services and management of web security. Prerequisites: CSEN(COEN) 60 and 161 or demonstrated proficiency. (4 units)

CSEN (COEN) 279. Design and Analysis of Algorithms
Techniques of design and analysis of algorithms: proof of correctness; running times of recursive algorithms; design strategies: brute-force, divide and conquer, dynamic programming, branch-and-bound, backtracking, and greedy technique; max flow/ matching. Intractability: lower bounds; P, NP, and NP-completeness. Also listed as AMTH 377. Prerequisite: CSEN(COEN) 912C or equivalent. (4 units)

CSEN (COEN) 280. Database Systems
Data models. Relational databases. Database design (normalization and decomposition). Data definition and manipulation languages (relational algebra and calculus). Architecture of database management systems. Transaction management. Concurrency control. Security, distribution, and query optimization. Prerequisites: CSEN(COEN) 12 or 912C or Data Structures class and CSEN(COEN) 283 or equivalent. (4 units)

CSEN (COEN) 281. Pattern Recognition and Data Mining
Provides an overview of data analytics methods, including data representation and preprocessing, proximity, finding nearest neighbors, exploratory analysis, dimensionality reduction, association analysis and sequential patterns, supervised inference and prediction, classification, regression, model selection and evaluation, overfitting, clustering, and advanced topics. Students will analyze real-world data using state-of-the-art data science libraries. Prerequisites: AMTH 210 and 245 or equivalent, CSEN(COEN) 12 or 912C or equivalent. (4 units)

CSEN (COEN) 282. Energy Management Systems
Energy Management Systems (EMS) is a class of control systems that electric utility companies utilize for three main purposes: monitoring, engagement and reporting. Monitoring tools allow electric utility companies to manage their

assets to maintain the sustainability and reliability of power generation and delivery. Engagement tools help in reducing energy production costs, transmission and distribution losses by optimizing utilization of resources and/or power network elements. Reporting tools help track operational costs and energy obligations. Also listed as ECEN(ELEN) 288. (2 units)

CSEN (COEN) 283. Operating Systems
Fundamentals of operating systems. Processes, Memory, I/O, and File Systems. Implementation and performance issues. Security, multimedia systems, multiple-processor systems. Prerequisites: CSEN(COEN) 12 or 912C and 20 or 920C or equivalent. (4 units)

CSEN/COEN 285. Software Engineering
Systematic approaches to software design, project management, implementation, documentation, and maintenance. Software design methodologies: SA/SD, OOA/OOD. Software quality assurance; testing. Reverse engineering and re-engineering. CASE. Term project. (4 units)

CSEN (COEN) 286. Software Quality Assurance and Testing
Social factors. Configuration management. Software complexity measures. Functional and structuring testing. Test coverage. Mutation testing. Trend analysis. Software reliability. Estimating software quality. Testing OOPs. Confidence in the software. Software quality control and process analysis. Managerial aspects. Prerequisite: CSEN(COEN) 285 or equivalent. (2 units)

CSEN (COEN) 287. Software Development Process Management
Management of the software development process at both the project and organization levels. Interrelationship of the individual steps of the development process. Management techniques for costing, scheduling, tracking, and adjustment. Prerequisite: CSEN(COEN) 285 or equivalent. (2 units)

CSEN (COEN) 288. Software Ethics
Broad coverage of ethical issues related to software development. Formal inquiry into normative reasoning in a professional context. Application of ethical theories to workplace issues, viz., cost-benefit analysis, externalities, individual and corporate responsibility, quality and authorship of product. Case studies and in-class topics of debate include computer privacy, encryption, intellectual property, software patents and copyrights, hackers and break-ins, freedom of speech and the internet, error-free code, and liability. (2 units)

CSEN (COEN) 290. Computer Graphics
Raster and vector graphics image generation and representation. Graphics primitives, line and shape generation. Scan conversion anti-aliasing algorithms. Simple transformation, windowing and hierarchical modeling. Interactive input techniques. 3D transformations and viewing, hidden surface removal. Introduction to surface definition with B-spline and Bezier techniques. Surface display with color graphics. Prerequisites: AMTH 245 and CSEN(COEN) 12 or 912C. (4 units)

CSEN (COEN) 291 Computational Creativity
Computational Creativity is a subfield of Artificial Intelligence that intersects with the arts, philosophy, and cognitive psychology. The goal of computational creativity is to model, simulate or replicate creativity using computer systems, through the creation of either autonomous creative systems or collaborative systems that engage with humans on creative tasks. The course will enable students to critically analyze questions concerning the creative capabilities of computer systems and the impact of computing on the arts and society at large, and prepare students to contribute to research in this field. Prerequisites: Good programming skills (4 units)

CSEN (COEN) 296A. Topics in Computer Science and Engineering
Various subjects of current interest. May be taken more than once if topics differ. (2 units)

CSEN (COEN) 296B. Topics in Computer Science and Engineering
Various subjects of current interest. May be taken more than once if topics differ. (4 units)

CSEN (COEN) 303. Logic Design Using HDL

Algorithmic approach to design of digital systems. Use of hardware description languages for design specification. Structural, register transfer, and behavioral, view of HDL. Simulation and synthesis of systems descriptions. Also listed as ECEN(ELEN) 603. Prerequisite: ECEN(ELEN)/CSEN(COEN) 127 or equivalent. (2 units).

CSEN (COEN) 305. VLSI Physical Design

Physical design is the phase that follows logic design, and it includes the following steps that precede the fabrication of the IC logic partitioning: cell layout, floor planning, placement, routing. These steps are examined in the context of very deep submicron technology. Effects of parasitic devices and packaging are also considered. Power distribution and thermal effects are essential issues in this design phase. Also listed as ECEN(ELEN) 389. Prerequisites: CSEN(COEN) 204/ECEN(ELEN) 388 or equivalent. (2 units)

CSEN (COEN) 307. Digital Computer Arithmetic

Fixed-point and floating-point number representation and arithmetic. High-speed addition and subtraction algorithms and architectures. Multiplication and division algorithms and architectures. Decimal arithmetic. Serial vs. parallel arithmetic circuits. Residue number arithmetic. Advanced arithmetic processing units. High-speed number crunchers. Arithmetic codes for error detection. VLSI perspective and reliability issues. Signed-digit (SD) representation of signed numbers. Prerequisite: CSEN(COEN) 210. (2 units)

CSEN (COEN) 308. Design for Testability

Principles and techniques of designing circuits for testability. Concept of fault models. The need for test development. Testability measures. Ad hoc rules to facilitate testing. Easily testable structures, PLAs. Scan-path techniques, full and partial scan. Built-in self-testing (BIST) techniques. Self-checking circuits. Use of computer-aided design (CAD) tools. Also listed as ECEN(ELEN) 608. Prerequisite: CSEN(COEN) 200 or equivalent. (2 units)

CSEN (COEN) 313. Advanced Computer Architecture

Advanced system architectures. Overview of different computer architecture paradigms. Hardware-supported instruction level parallelism, VLIW architectures, multithreaded processors. Performance and correctness issues (coherency, consistency, and synchronization) for different multiprocessor configuration alternatives (UMA, NUMA). SIMD architecture alternatives. Warehouse massive-scale computing. Prerequisite: CSEN (COEN 210). (4 units)

CSEN (COEN) 315. Web Architecture and Protocols

History and overview of World Wide Web technology. Web clients and browsers. State management, session persistence, and cookies. Spiders, bots, and search engines. Web proxies. Web servers and server farms. HTTP and web protocols. Web caching and content distribution. Load balancing. Web security and firewalls. Web workload and traffic characterization. Future of web technology. Prerequisite: CSEN(COEN) 233 or equivalent. (4 units)

CSEN (COEN) 317. Distributed Systems

Fundamental algorithms for distributed system architectures, inter-process communications, data consistency and replication, distributed transactions and concurrency control, distributed file systems, network transparency, fault tolerant distributed systems synchronization, reliability. Prerequisites: CSEN(COEN) 233 and 283 or equivalent. (4 units)

CSEN (COEN) 318. Parallel Computation Systems

Introduction to parallel processing. Parallel system classifications. Parallel computation models and algorithms. Performance analysis and modeling. Interconnection networks. Vector processors. SIMD and MIMD architectures and their hybrid. Systolic arrays. Dataflow architectures. Introduction to parallel languages and parallelizing compilers. Prerequisites: CSEN(COEN) 210 and AMTH 247 or instructor approval. (4 units)

CSEN (COEN) 319. Parallel Computing

How to effectively program parallel computers, from smartphones to large clusters. Types of parallel architectures, routing, data parallel, shared-memory, and message-passing parallel programming, load balancing, evaluation of parallel algorithms, advanced topics. Students will implement select parallel algorithms for solving real-world data analytics problems, including parallel algorithms for sparse matrix and graph operations. Prerequisites: CSEN(COEN) 12 or 912C or CSCI 61 or equivalent. (4 units)

CSEN (COEN) 320. Computer Performance Evaluation

Measurement, simulation, and analytic determination of computer systems performance. Workload characterization. Bottleneck analysis tuning. Prerequisites: CSEN(COEN) 210 and AMTH 211. (4 units)

CSEN (COEN) 329. Network Technology

Advanced technologies and protocols for broadband LAN, MAN, WAN, L2 VPN, and L3 VPN, Pseudo Wire, VPLS (Virtual Private LAN Services). Current technologies: tunneling, QoS and security in content delivery, PON (Passive Optical Networks), support for multimedia communication, server farms, server redundancy, GMPLS (Generalized Multi-Protocol Label Switching). Hot Standby Router Protocol. Emerging technologies, e.g., Carrier Ethernet. Prerequisite: CSEN(COEN) 233 or equivalent. (4 units)

CSEN (COEN) 331. Wireless and Mobile Networks

TCP/IP architecture. Fundamentals of wireless transmission. IEEE 802.11 architecture and protocols. Bluetooth protocol stack. BLE. IEEE 802.15.4 and ZigBee. Real-time networks. Cellular communication fundamentals. Long-Term Evolution (LTE). Software-defined networking. 5G. Prerequisite: CSEN(COEN) 233 or equivalent. (4 units)

CSEN (COEN) 332. Wireless/Mobile Multimedia Networks

This course will cover IMS (Internet Protocol Multimedia Subsystem), an architectural framework for providing IP-based real-time traffic, such as voice and video, in wireless networks. IMS aims at the convergence of data, speech, fixed, and mobile networks and provides real-time services on top of the UMTS (Universal Mobile Telecommunication System) packet-switched domain. Prerequisite: CSEN(COEN) 331. (4 units)

CSEN (COEN) 335. High-Performance Networking

Understanding the concepts and technologies of high-speed networks designed for HPC, big data processing, and cloud computing. Layer-2 and layer-3 switching. Infiniband and Ethernet. Network topologies. Edge computing. Software-defined networking to manage high-performance networking. Offloading and network virtualization. Integrating high-performance networking and 5G. Prerequisite: CSEN(COEN) 233 or equivalent. (2 units)

CSEN (COEN) 337. Internet Architecture and Protocols

In-depth and quantitative study of Internet algorithms, protocols, and services. Topics include: scheduling and buffer/queue management, flow/congestion control, routing, traffic management, support for multimedia/real-time communication. Prerequisite: CSEN(COEN) 233 or equivalent. (4 units)

CSEN (COEN) 338. Image and Video Compression

Image and video compression. Entropy coding. Prediction. Quantization. Transform coding and 2-D discrete cosine transform. Color compression. Motion estimation and compensation. Digital video. Image coding standards such as JPEG, BPG, and JPEG family. Video coding standards such as the MPEG series and the H.26x series. H.264/MPEG-4 AVC coding. HEVC/H.265/MPEG-H Part 2 coding. VVC/H.266/MPEG-I Part 3 coding. Rate-distortion theory and optimization. Visual quality and coding efficiency. Brief intro to 3D video coding and 3D-HEVC. Deep learning approaches. Screen content coding. Video coding for machines. Applications. Also listed as ECEN(ELEN) 641. Prerequisites: AMTH 108, AMTH 245 and basic knowledge of algorithms. (4 units)

CSEN (COEN) 339 Audio and Speech Compression

Audio and speech compression. Digital audio signal processing fundamentals. Non-perceptual coding. Perceptual coding. Psychoacoustic model. High-quality audio coding. Audio coding standards. Brief introduction to speech coding and speech coding standards. Machine learning for audio and speech coding. Also listed as ECEN(ELEN) 639. Prerequisites: AMTH 108, AMTH 245 and CSEN(COEN) 279 or equivalent. (2 units)

CSEN (COEN) 340. Digital Image Processing I

Digital image representation and acquisition, color representation; point and neighborhood processing; image enhancement; morphological filtering; Fourier, cosine, and wavelet transforms. Also listed as ECEN(ELEN) 640. Prerequisite: CSEN(COEN) 201 or equivalent. (2 units)

CSEN (COEN) 341. Information Theory

Introduction to the fundamental concepts of information theory. Source models. Source coding. Discrete channel without memory. Continuous channel. Alternate years. Also listed as ECEN(ELEN) 244. Prerequisites: ECEN(ELEN) 241 and AMTH 211. (2 units)

CSEN (COEN) 342. Deep Learning

Deep neural networks and their applications to various problems, e.g., speech recognition, image segmentation, and natural language processing. Will cover the underlying theory of various types of neural networks including feed-forward, convolutional, and recurrent neural networks, the range of applications to which it has been applied, and current trends in the field. Prerequisite: CSEN(COEN) 240 or CSEN(COEN) 281. (4 units)

CSEN (COEN) 343. Digital Image Processing II

Image restoration using least squares methods in image and spatial frequency domain; matrix representations; blind deconvolution; reconstructions from incomplete data; image segmentation methods; three-dimensional models from multiple views. Also listed as ECEN(ELEN) 643. Prerequisite: CSEN(COEN) 340). (2 units)

CSEN (COEN) 344. Computer Vision I

Introduction to image understanding, feature detection, description, and matching; feature based alignment; structure from motion; stereo correspondence. Also listed as ECEN(ELEN) 644. Prerequisites: CSEN(COEN) 340 and knowledge of linear algebra. (2 units)

CSEN (COEN) 345 Computer Vision II

Learning and inference in vision; regression models; deep learning for vision; classification strategies; detection and recognition of objects in images. Also listed as ECEN(ELEN) 645. Prerequisites: CSEN(COEN) 340 and knowledge of probability. (2 units)

CSEN (COEN) 346. Natural Language Processing

Natural language processing (NLP) is the art and science of extracting insights from large amounts of natural language. It is one of the most important technologies of the information age. Applications of NLP are everywhere because people communicate almost everything in language: web search, recommendation, emails, customer service, language translation, virtual agents, medical reports, politics, etc. This course presents an introduction to NLP and covers the main models, algorithms, and applications of NLP. A key emphasis of this course is on statistical analysis of large text corpora, and distilling useful structured knowledge from large collections of unstructured documents. Prerequisites: CSEN(COEN) 240 or CSEN(COEN) 281. CSEN(COEN) 342 is optional but recommended. (4 units)

CSEN (COEN) 347. Advanced Image and Video Coding

Advanced topics in image and video coding, selected from: Wavelet transform and compression. Sparse coding. Compressive sensing. Standards such as JPEG 2000, JPEG XT, JPEG PLENO, VVC, and HEVC extensions such as SHVC, MV-HEVC, 3D-HEVC, and SCC. Scalable video coding. Multiview and 3D video coding. Screen content coding. High dynamic range HDR. Light-field, point-cloud, and holographic imaging. Distributed video coding. Video communications systems. Congestion control. Rate control. Error control. Transcoding. Machine and deep learning approaches. Image/video coding for machines. Other advanced topics. Prerequisite: CSEN(COEN) 338 or ECEN(ELEN) 641. (4 units)

CSEN (COEN) 348. Speech Processing I

Review of sampling and quantization. Introduction to digital speech processing. Elementary principles and applications of speech analysis, synthesis, and coding. Speech signal analysis and modeling. The LPC Model. LPC parameter quantization using line spectrum pairs (LSPs). Digital coding techniques: quantization, waveform coding, predictive coding, transform coding, hybrid coding, and sub-band coding. Applications of speech coding in various systems. Standards for speech and audio coding. Also listed as ECEN(ELEN) 421. Prerequisite: ECEN(ELEN) 233 and/or ECEN(ELEN) 334 or equivalent. (2 units)

CSEN (COEN) 349. Speech Processing II

Advanced aspects of speech analysis and coding. Analysis-by-Synthesis (AbS) coding of speech, Analysis-as-Synthesis (AaS) coding of speech. Code-excited linear prediction speech coding. Error-control in speech transmission. Application of coders in various systems (such as wireless phones). International standards for speech (and audio) coding. Real-time DSP implementation of speech coders. Speech recognition and biometrics. Research project on speech processing. Also listed as ECEN(ELEN) 422. Prerequisite: ECEN(ELEN) 421. (2 units)

CSEN (COEN) 351. Internet and E-Commerce Security

Special security requirements of the internet. Secure electronic business transactions. Email security. CGI scripts, cookies, and certified code. Intrusion prevention strategies. Designing secure E-commerce systems. AGENT technologies. Legal requirements for E-Commerce. Prerequisite: CSEN (COEN 253). Co-requisite: CSEN(COEN) 351L. (3 units)

CSEN (COEN) 351L. Laboratory for CSEN (COEN) 351

Co-requisite: CSEN(COEN) 351. (1 unit)

CSEN (COEN) Advanced Topics in Information Assurance

Topics may include advanced cryptology, advanced computer forensics, secure business transaction models, or other advanced topics in information assurance. May be repeated for credit if topics differ. Prerequisites: AMTH 387 and CSEN(COEN) 250. (2 units)

CSEN (COEN) 353. Trust and Privacy in Online Social Network

This course will introduce fundamental concepts in trustworthy computing and privacy; discuss classic (1) trust models, such as direct/indirect model, belief theory-based model, entropy-based model, fuzzy model, and (2) privacy models, such as k-anonymity, l-diversity, t-closeness models; investigate evolution of trust/privacy attacks and defenses in online social networks; and discuss state-of-the-art trust/privacy researches in online social networks. Prerequisites: AMTH 108 or AMTH 210, and CSEN(COEN)179 or 279. (4 units)

CSEN (COEN) 354. Social Network Analysis and Risk

Social network analysis. Cybersecurity risks. Network measurement. Centrality. Random networks. Submodularity. Diffusion models. Community detection. Sybil defense. Adaptive crawling. Influence maximization. Misinformation containment. Prerequisites: AMTH 108 or AMTH 210, and CSEN(COEN) 179 or 279. (4 units)

CSEN (COEN) 359. Design Patterns

Software design patterns and their application in developing reusable software components. Creational, structural, and behavioral patterns are studied in detail and are used in developing a software project. Prerequisite: CSEN(COEN) 275. (4 units)

CSEN (COEN) 376. Expert Systems

Overview of tools and applications of expert systems, as well as the theoretical issues: What is knowledge, can it be articulated, and can we represent it? Stages in the construction of expert systems: problem selection, knowledge acquisition, development of knowledge bases, choice of reasoning methods, life cycle of expert systems. Basic knowledge of representation techniques (rules, frames, objects) and reasoning methods (forward-chaining, backward-chaining, heuristic classification, constraint reasoning, and related search techniques). Requires completion of an expert systems project. Prerequisite: CSEN(COEN) 266 and a course including predicate logic and lambda calculus. (4 units)

CSEN (COEN) 379. Advanced Design and Analysis of Algorithms

Amortized and probabilistic analysis of algorithms and data structures: disjoint sets, hashing, search trees, suffix arrays and trees. Randomized, parallel, and approximation algorithms. Also listed as AMTH 379. Prerequisite: AMTH 377/CSEN(COEN) 279. (4 units)

CSEN (COEN) 380. Advanced Database Systems

Database system design and implementation. Disk and file organization. Storage and indexes; query processing and query optimization. Concurrency control; transaction management; system failures and recovery. Parallel and

distributed databases. MapReduce. Prerequisite: CSEN(COEN) 280 or equivalent. (4 units)

CSEN (COEN) 383. Advanced Operating Systems
Advanced topics beyond the fundamentals of operating systems, including a look at different systems software concepts within different components of a modern operating system, and applications beyond the scope of an individual operating system. Prerequisite: CSEN(COEN) 283 or equivalent. (4 units)

CSEN (COEN) 385. Formal Methods in Software Engineering
Specification, verification, validation. Notations and the models they support. Classes of specification models: algebraic, state machine, model theoretic. Appropriate use of formal methods: requirements, design, implementation, testing, maintenance. Data and program specification and design using Z or any other modern formal method. Case studies. Prerequisites: course including predicate logic and lambda calculus. (2 units)

CSEN (COEN) 386. Software Architecture
Understanding and evaluating software systems from an architectural perspective. Classification, analysis, tools, and domain-specific architectures. Provides intellectual building blocks for designing new systems using well-understood architectural paradigms. Examples of actual system architectures that can serve as models for new designs. Prerequisite: CSEN(COEN) 385. (2 units)

CSEN (COEN) 389. Energy-Efficient Computing
This course covers energy-efficient software practices. Historically, software has always been written to run faster and faster, and energy has always been considered a plentiful resource. However, it has been shown that computers use a lot of energy, which may not always be so plentiful, leading to the redesign of traditional software solutions in different areas. The focus of the course will be on operating systems, networks, compilers, and programming. Prerequisites: CSEN (COEN) 233 or equivalent and CSEN(COEN) 283 or equivalent. (2 units)

CSEN (COEN) 396A. Advanced Topics in Computer Science and Engineering
Various subjects of current interest. May be taken more than once if topics differ. See department website for current offerings and descriptions. (2 units)

CSEN (COEN) 396B. Advanced Topics in Computer Science and Engineering
Various subjects of current interest. May be taken more than once if topics differ. See department website for current offerings and descriptions. (4 units)

CSEN (COEN) 400. Computer Science and Engineering Graduate Seminar
Regularly scheduled seminars on topics of current interest in the field of computer science and engineering. May apply a maximum of 1 unit of credit from CSEN(COEN) 400 to any graduate degree in the Department of Computer Science and Engineering. Consult the department for additional information. Prerequisite: Completion of 12 or more graduate units at SCU. P/NP grading. (1 unit)

CSEN (COEN) 485. Software Engineering Capstone
A capstone course in which the student applies software engineering concepts and skills to a software engineering project. Team projects are strongly encouraged. Projects will cover all aspects of the software life-cycle: specification of requirements and functionality; project planning and scoping; system and user interface definition; analysis of architectural solutions; detailed system design; implementation and integration; testing and quality assurance; reliability, usability, and performance testing, documentation, evolution, and change management. The course is typically restricted only to MSSE students. Students enrolled must complete three one-quarter (preferably consecutive) sections. Prerequisites: CSEN(COEN) 286 and CSEN(COEN) 386. (2 units)

CSEN (COEN) 490. Mathematical Reasoning in Computer Science
(Seminar Style) Short introduction to the praxis of mathematical proofs. Students will write and present proofs and papers on instructor-approved topics related to computer science and engineering. Stress is on mathematical exactness. Maximum enrollment of 10. Enrollment is by preference to Ph.D. students, but is open to other students as space allows. Prerequisite: Open to Ph.D. students or with instructor approval. (2 units)

CSEN (COEN) 493. Directed Research

Special research directed by a faculty member. By arrangement. Research must be directed by a tenure-track faculty member in computer science and engineering. Limited to master's and Ph.D. students in computer science and engineering. Must be supervised by a regular CSE full-time faculty. Prerequisite: Registration requires the faculty member's and department chair approval. (1–6 units per quarter, for a total of maximum 6 units combining CSEN(COEN) 493 and 499 for master's students)

CSEN (COEN) 497. Master's Thesis Research

By arrangement. Research must be directed by a tenure-track faculty member in computer science and engineering. Limited to master's students in computer science and engineering. Must be supervised by a regular CSE full-time faculty. Prerequisite: Registration requires the faculty member's and department chair approval. (1–9 units per quarter, for a total of at least 8 units)

CSEN (COEN) 498. Ph.D. Thesis Research

By arrangement. Research must be directed by a tenure-track faculty member in computer science and engineering. Limited to Ph.D. students in computer science and engineering. Must be supervised by a regular CSE full-time faculty Prerequisite: Registration requires the faculty member's and department chair approval. (1–15 units per quarter, for a total of 36 units)

CSEN (COEN) 499. Independent Study

Special problems. By arrangement. Work must be directed by a full-time faculty member. Limited to computer science and engineering majors. Prerequisite: Registration requires the faculty member's approval. (1–6 units per quarter, for a total of maximum 6 units combining CSEN(COEN) 493 and 499 for master's students)

CSEN (COEN) 912C. Abstract Data Types and Data Structures

Intense coverage of topics related to abstract data types and data structures. Data abstraction: abstract data types, information hiding, interface specification. Basic data structures: stacks, queues, lists, binary trees, hashing, tables, graphs; implementation of abstract data types in the C language. Internal sorting: review of selection, insertion, and exchange sorts; quicksort, heapsort; recursion. Analysis of run-time behavior of algorithms; Big-O notation. Introduction to classes in C++. Foundation course not for graduate credit. Prerequisite: A grade of B or higher in a programming language course. (2 units)

CSEN (COEN) 920C. Embedded Systems and Assembly Language

Intense coverage of topics related to embedded systems and assembly language. Introduction to computer organization: CPU, registers, buses, memory, I/O interfaces. Number systems: arithmetic and information representation. Assembly language programming: addressing techniques, arithmetic and logic operations, branching and looping, stack operations, procedure calls, parameter passing, and interrupts. C language programming: pointers, memory management, stack frames, interrupt processing. Foundation course not for graduate credit. Prerequisite: A grade of B or higher in a programming language course. (2 units)

CSEN (COEN) 921C. Logic Design

Intense coverage of topics related to logic design. Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flip-flops; timing; registers; counters. Programmable logic, PLD, and FPGA. Use of industry quality CAD tools for schematic capture and HDL in conjunction with FPGAs. Foundation course not for graduate credit. Also listed as ECEN(ELEN) 921C. (2 units)

Chapter 11: Department of Electrical and Computer Engineering

Professors Emeritus: Timothy J. Healy, Dragoslav D. Siljak, Sarah Kate Wilson
Thomas J. Bannan Professor: Shoba Krishnan (Chair)
Professors: Tokunbo Ogunfunmi, Sally L. Wood, Cary Y. Yang, Aleksandar Zecevic
Associate Professor: M. Mahmudur Rahman, Hoeseok Yang
Assistant Professors: Anoosheh Heidarzadeh, Maryam Khanbaghi, Maria Kyrarini, Kurt Schab, Dat Tran, S.J.

Overview

The field of Electrical and Computer Engineering covers the design, construction, testing, and operation of electrical components, circuits, and systems. Electrical and Computer Engineers work with information representation, processing and transmission; advancing integrated circuit design for digital, analog, and mixed signals systems; designing and characterizing antennas, RF, microwave and millimeter-wave Systems; new devices and architectures, energy systems and renewable energy; nanotechnology; and all the areas of information circuits and systems that have traditionally supported these efforts. This includes all phases of the digital or analog transmission of information, such as in mobile communications and networks, radio, television, telephone systems, fiber optics, and satellite communications, as well as control and robotics, electric power, information processing and storage.

The Electrical and Computer Engineering Programs are supported by the facilities of the University's Academic Computing Center, as well as by the Engineering Computing Center. The department supports 10 major teaching and research laboratories, five additional laboratories used only for teaching, and a laboratory dedicated to the support of design projects. The five teaching laboratories cover the fields of digital systems, electric circuits, electronics, systems, and RF and communication and signal processing and control systems, logic design and digital systems, In addition, the program has a laboratory dedicated to senior design projects.

Master's Degree Program and Requirements

The master's degree will be granted to degree candidates who complete a program of studies approved by a faculty advisor. The degree does not require a thesis, but students may include a thesis in their program with up to nine units for their thesis work. The program must consist of no less than 46 units. In addition, a 3.0 cumulative GPA (B average) must be earned in all coursework taken at Santa Clara University. Residence requirements are met by completing no less than 37 units of the graduate program at Santa Clara University. A maximum of nine quarter units (six-semester units) of graduate-level coursework may be transferred from other accredited institutions at the discretion of the student's advisor. All units applied toward the degree, including those transferred from other institutions, must be earned within six years from initial enrollment.

Students must develop a program of studies with an academic advisor and file the approved program during their first term of enrollment at Santa Clara University. The program of studies must contain a minimum of 46 units of graduate-level engineering courses which include at least 27 units of courses offered within the electrical and computer department and no more than four units of engineering management courses.

The program of studies must include the following:

1. Graduate Core-Enrichment Experience (minimum 8 units): Students must take a minimum of 8 units of the Graduate Core Enrichment Experience.

    - A minimum of 4 units must be from the Graduate Core which requires at least two courses from the three

areas (Emerging Topics in Engineering, Engineering and Business/Entrepreneurship, and Engineering and Society).

  - The remaining 4 units can be accumulated by the following a) Taking one or more major technical electives, b) Taking additional classes from the Graduate Core, c) Taking Cooperative Education course and d) combining courses from a, b and c. For additional information please see Chapter 6, Enrichment Experience and Graduate Core Requirements.

2. Applied Mathematics (4 units)

3. Electrical and Computer Engineering primary focus area (minimum 6 units). Students must select and meet the requirements of one of the six focus areas listed below.

4. Power Systems and Control Either (236 or 281A) and two courses selected from (211, 232, 281B, 333)

5. IC Design and Technology Three courses selected from (252, 261, 270, 387)
6. RF and Applied Electromagnetics 201 and two courses selected from (202, 203, 204, 624, 701, 706)
7. Signal Processing and Machine Learning 233 and two courses selected from (234, 421, 431, 520, 640, 644)
8. Digital Systems 501, 511, and 603
9. Communications 241 and 243, and one course selected from (244, 444, 446)

10. Electrical and Computer Engineering breadth: (minimum 4 units) Two other focus areas must be selected as breadth areas. For each breadth area, one course must be taken from the list of required courses for that area.

11. Additional graduate courses recommended and approved by the graduate program advisor.

These M.S. degree requirements may be adjusted by the advisor based on the student's previous graduate work.

An advisor may approve selected undergraduate classes that do not duplicate course content of graduate courses in the program of studies. No more than 15 units of electives may be selected from the following upper-division undergraduate courses: 105, 112, 116, 117, 118, 130, 133, 141, 144, 151, 152, 156, 160, 164, 183 and 184.

Alterations in the approved program, consistent with the above departmental requirements, may be requested at any time by a petition initiated by the student and approved by the advisor.

Students with relevant technical backgrounds may be admitted to the master's program without an undergraduate degree in Electrical or Electrical and Computer Engineering from an accredited program. In order to guarantee prerequisites for graduate courses, those students must take sufficient additional courses beyond the 46-unit minimum to ensure coverage of all areas of the undergraduate EE core requirements. A student who has earned a Fundamentals of Electrical and Computer Engineering Certificate will have satisfied these background requirements.

Undergraduate Core Courses

- ECEN (ELEN) 21 Introduction to Logic Design
- ECEN (ELEN) 50 Electric Circuits I
- ECEN (ELEN) 100 Electric Circuits II
- ECEN (ELEN) 115 Electronic Circuits I
- ECEN (ELEN) 120 Microprocessor System Design

The advisor will determine which courses must be taken to meet these requirements. Undergraduate core courses will not be included in the 46 units required for the master's degree.

Please Note: In general, no credit will be allowed for courses that duplicate prior coursework, including courses listed above as degree requirements. (However, graduate-level treatment of a topic is more advanced than an undergraduate course with a similar title.) Students should discuss any adjustments of these requirements with their academic advisor before filing their program of studies. In all cases, prerequisite requirements should be interpreted to mean the course specified or an equivalent course taken elsewhere.

Engineer's Degree Program and Requirements

The program leading to the Engineer's Degree is particularly designed for the education of the practicing engineer. The degree is granted on completion of an approved academic program and a record of acceptable technical achievement in the candidate's field of engineering. The academic program consists of a minimum of 46 quarter units beyond the master's degree. Courses are selected to advance competence in specific areas relating to the engineering professional's work. Evidence of technical achievement must include a paper principally written by the candidate and accepted for publication by a recognized engineering journal prior to the granting of the degree. A letter from the journal accepting the paper must be submitted to the department chair. In certain cases, the department may accept publication in the peer-reviewed proceedings of an appropriate national or international conference.

Electrical and Computer Engineering courses at the introductory Master of Science level (e.g., ECEN (ELEN) 210, 211, 212, 230, 231, 236, 241, 250, 261; and AMTH 210, 211, 220, 221, 230, 231, 235, 236, 240, 245, 246) are not generally acceptable in an Engineer's Degree program of studies. However, with the approval of the advisor, the student may include up to three of these courses in the Engineer's Degree program. The department also requires that at least 15 units of the program of studies be in topics other than the student's major field of concentration. Candidates admitted to the Electrical and Computer Engineering Program who have M.S. degrees in fields other than electrical and computer engineering must include in their graduate programs (M.S. and Engineer's Degree combined) a total of at least 46 units of graduate-level electrical and computer engineering coursework approved by an academic advisor.

Ph.D. Program and Requirements

The Doctor of Philosophy (Ph.D.) degree is conferred by the School of Engineering primarily in recognition of competence in the subject field and the ability to investigate engineering problems independently, resulting in a new contribution to knowledge in the field. The work for the degree consists of engineering research, the preparation of a thesis based on that research, publication of the research, and a program of advanced studies in engineering, mathematics, and related physical sciences.

Preliminary Examination

The preliminary examination shall be written and shall include subject matter deemed by the major department to represent sufficient preparation in depth and breadth for advanced study in the major. Only those who pass the written examination may take any required oral preliminary examination.

Students currently studying at Santa Clara University for a master's degree who are accepted for the Ph.D. program and who are at an advanced stage of the M.S. program may, with the approval of their academic advisor, take the preliminary examination before completing the M.S. degree requirements. Students who have completed the M.S. degree requirements and have been accepted for the Ph.D. program should take the preliminary examination as soon as possible but not more than two years after beginning the program.

Only those students who pass the preliminary examination shall be allowed to continue in the doctoral program. The preliminary examination may be repeated only once, and then only at the discretion of the thesis advisor.

General Requirements

Thesis Advisor

It is the student's responsibility to obtain consent from a full-time faculty member in the student's major department to serve as his/her prospective thesis advisor.

It is strongly recommended that Ph.D. students find a thesis advisor before taking the preliminary examination. After passing the preliminary examination, Ph.D. students should have a thesis advisor before the beginning of the next quarter following the preliminary examination. Students currently pursuing a master's degree at the time of their preliminary examination should have a thesis advisor as soon as possible after being accepted as a Ph.D. student.

The student and the thesis advisor jointly develop a complete program of studies for research in a particular area. The complete program of studies (and any subsequent changes) must be filed with the Graduate Programs Office and approved by the student's doctoral committee. Until this approval is obtained, there is no guarantee that courses taken will be acceptable toward the Ph.D. course requirements.

Doctoral Committee

After passing the Ph.D. preliminary exam, a student requests his or her thesis advisor to form a doctoral committee. The committee consists of at least five members, each of whom must have earned a doctoral degree in a field of engineering or a related discipline. This includes the student's thesis advisor, at least two other current faculty members of the student's major department at Santa Clara University, and at least one current faculty member from another appropriate academic department at Santa Clara University. The committee reviews the student's program of study, conducts an oral comprehensive exam, conducts the dissertation defense, and reviews the thesis. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, dissertation defense, and thesis itself meet with the approval of all committee members.

Residence

The doctoral degree is granted based on achievement, rather than on the accumulation of units of credit. However, the candidate is expected to complete a minimum of 72 quarter units of graduate credit beyond the master's degree. Of these, 36 quarter units may be earned through coursework and independent study, and 36 through the thesis. All Ph.D. thesis units are graded on a Pass/No Pass basis.

Ph.D. students must undertake a minimum of four consecutive quarters of full-time study at the University; spring and fall quarters are considered consecutive. The residency time shall normally be any period between passing the preliminary examination and completion of the thesis. For this requirement, full-time study is interpreted as a minimum registration of eight units per quarter during the academic year and four units during the summer session. Any variation from this requirement must be approved by the doctoral committee.

Comprehensive Examinations and Admission to Candidacy

After completion of the formal coursework approved by the doctoral committee, the student shall present his/her research proposal as part of a comprehensive oral examination on the coursework and the subject of his/her research work. The student should make arrangements for the comprehensive examinations through the doctoral committee. A student who passes the comprehensive examinations is considered a degree candidate. The comprehensive examinations typically must be completed within four years from the time the student is admitted to the doctoral program. Comprehensive examinations may be repeated once, in whole or in part, at the discretion of the doctoral committee.

Thesis Research and Defense

The period following the comprehensive examinations is devoted to research for the thesis, although such research may begin before the examinations are complete. After successfully completing the comprehensive examinations, the student must pass an oral examination on his/her research and thesis, conducted by the doctoral committee and whomever they appoint as examiners. The thesis must be made available to all examiners one month prior to the examination. The oral examination shall consist of a presentation of the results of the thesis and the defense. This examination is open to the public, but only members of the doctoral committee have a vote.

Thesis and Publication

At least one month before the degree is to be conferred, the candidate must submit to the Office of the Dean of Engineering two copies of the final version of the thesis describing the research in its entirety. The thesis will not be considered as accepted until approved by the doctoral committee and one or more refereed articles based on it are accepted for publication in a first-tier professional or scientific journal approved by the doctoral committee. All doctoral theses must also be archived in the University library.

Time Limit for Completing Degree

All requirements for the doctoral degree must be completed within eight years following initial enrollment in the Ph.D. program. This includes any leave of absences/withdrawals. Extensions will be allowed only in unusual circumstances and must be recommended in writing by the student's doctoral committee and approved by the dean of engineering in consultation with the Graduate Program Leadership Council.

Additional Graduation Requirements

The requirements for the doctoral degree in the School of Engineering have been made to establish the structure in which the degree may be earned. Upon written approval of the provost, the dean of the School of Engineering, the doctoral committee, and the chair of the major department, other degree requirements may be established. The University reserves the right to evaluate the undertakings and the accomplishments of the degree candidate in total, and award or withhold the degree as a result of its deliberations.

Certificate Programs

General Information

Certificate programs are designed to provide an intensive background in a narrow area at the graduate level. At roughly one-third of the units of a master's degree program, the certificate is designed to be completed in a much shorter period of time. These certificate programs are appropriate for students working in the industry who wish to update their skills or those interested in changing their career path. Students can only take courses that are required for the certificate.

Admission

To be accepted into a certificate program, the applicant must have a bachelor's degree and meet any additional requirements for the specific certificate. Exceptions based on work experience may be granted for the Certificate in Fundamentals of Electrical and Computer Engineering. Admitted students are responsible for ensuring that they have the prerequisites for all courses they take in the Certificate Program.

Grade Requirements

Students must receive a minimum grade of C in each course and have an overall GPA of 3.0 or better to earn a certificate.

Continuation for a Master's Degree

Santa Clara University graduate courses applied to the completion of a certificate program earn graduate credit that may also be applied toward a graduate degree. Students who wish to continue for such a degree must submit a separate application and satisfy all normal admission requirements. The general GRE test requirement for graduate admission to the master's degree will be waived for students who complete a certificate program with a GPA of 3.5 or higher.

Academic Requirements

Digital System Design

Advisor: Dr. Hoeseok Yang

This certificate program has a triple purpose: (a) to increase design skills in digital system development, (b) to strengthen fundamental knowledge of computer architecture, digital design and embedded systems; and (c) to introduce the digital system designer to state-of-the-art tools and techniques. The program consists of the courses listed below totaling 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (6 units)

- ECEN (ELEN) 501 (Embedded Systems) 2 units
- ECEN (ELEN) 511 Advanced Computer Architecture (2 units)
- ECEN (ELEN) 603 Logic Design Using HDL (2 units)

Elective Courses (10 units)

- ECEN (ELEN) 387 VLSI Design I (2 units)
- ECEN (ELEN) 388 VLSI Design II (2 units)
- ECEN (ELEN) 500 Logic Analysis and Synthesis (2 units)
- ECEN (ELEN) 502 Real Time Systems (2 units)
- ECEN (ELEN) 503 Hardware-Software Co-design (2 units)
- ECEN (ELEN) 512 Advanced Computer Architecture II (2 units)
- ECEN (ELEN) 513 Parallel System Architectures (2 units)
- ECEN (ELEN) 530 Hardware Security and Trust (2 units)
- ECEN (ELEN) 608 Design for Testability (2 units)
- ECEN (ELEN) 613 SoC (System-on-Chip) Verification (2 units)

Integrated Circuit Design and Technology

Advisors: Dr. Shoba Krishnan, Dr. Cary Yang, Dr. Mahmudur Rahman

The study of integrated circuits consists of three interconnected areas: Design, Devices and Process Technology. This certificate provides the necessary fundamentals in these areas and advanced concepts and applications in integrated circuit design, devices, and process technology. The program will also introduce the IC designer to state-of-the-art tools and techniques. The program consists of the courses listed below; students are required to complete a total of 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (8 units)

- ECEN (ELEN) 252 Analog Integrated Circuits I (2 units)
- ECEN (ELEN) 261 Fundamentals of Semiconductor Physics (2 units)
- ECEN (ELEN) 270 Introduction to IC Materials (2 units)
- ECEN (ELEN) 387 VLSI Design I (2 units)

Elective Courses (8 units)

- ECEN (ELEN) 251 Transistor Models for IC Design (2 units)
- ECEN (ELEN) 253 Analog Integrated Circuit Design (2 units)
- ECEN (ELEN) 254 Advanced Analog Integrated Circuit Design
- ECEN (ELEN) 264 Semiconductor Device Theory I (2 units)
- ECEN (ELEN) 265 Semiconductor Device Theory II (2 units)
- ECEN (ELEN) 267 Device Electronics for IC Design (4 units)
- ECEN (ELEN) 271 Microsensors: Components and Systems (2 Units)
- ECEN (ELEN) 274 Integrated Circuit Fabrication Processes I (2 units)
- ECEN (ELEN) 275 Integrated Circuit Fabrication Processes II (2 units)
- ECEN (ELEN) 351 RF Integrated Circuit Design (2 units)
- ECEN (ELEN) 352 Mixed Signal IC Design for Data Communications (2 units)
- ECEN (ELEN) 353 DC to DC Power Conversion (2 units)
- ECEN (ELEN) 361 Nanoelectronics
- ECEN (ELEN) 388 VLSI Design II (2 units)

Digital Signal Processing and Machine Learning

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a basic understanding of digital signal processing theory, machine learning and modern implementation methods as well as advanced knowledge of at least one specific application area. Digital signal processing and machine learning have become important across many areas of engineering, and this certificate prepares students for traditional or novel applications. This certificate can be earned with a combination of in-person and on-line courses.

Required Courses (11 units minimum)

- ECEN (ELEN) 233 Digital Signal Processing I (2 units)
- ECEN (ELEN) 520 and ECEN (ELEN) 520L Introduction to Machine Learning (3 units)
- At least one course from: AMTH 210 Probability I or AMTH 245 Linear Algebra I or AMTH 370 Optimization Techniques (2 units)
- At least one course from: ECEN (ELEN) 223 Digital Signal Processing System Development (4 units) or ECEN (ELEN) 226 Machine Learning and Signal Processing Using FPGAs (2 units) or ECEN(ELEN) 234 Digital Signal Processing II (2 units)
- At least one course from: ECEN (ELEN) 421 Speech Processing I or ECEN (ELEN) 640 Digital Image Processing I (2 units) or both ECEN (ELEN) 521 Deep Learning (2 units) and 521L Deep Learning Laboratory (1 unit) *Note: ECEN (ELEN) 233E Digital Signal Processing I, II (4 units) is equivalent to both ECEN (ELEN) 233 and ECEN (ELEN) 234.*

Elective Courses (Additional courses to make a total of 16 units) selected from the list below or from any courses in the list above that are not used to meet the specified certificate requirements:

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ECEN (ELEN) 243 Digital Communications Systems (2 units)
- ECEN (ELEN) 244 Information Theory (2 units)
- ECEN (ELEN) 334 Introduction to Statistical Signal Processing (2 units)
- ECEN (ELEN) 422 Speech Coding II (2 units)
- ECEN (ELEN) 431 Adaptive Signal Processing I (2 units)
- ECEN (ELEN) 522 Reinforcement Learning (2 units)
- ECEN (ELEN) 523 Natural Language Processing with Deep Learning (2 units)
- ECEN (ELEN) 643 Digital Image Processing II (2 units)
- ECEN (ELEN) 644 Computer Vision I (2 units) or ECEN (ELEN) 645 Computer Vision II (2 units)

Digital Signal Processing Theory

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a firm theoretical grounding in fundamentals of digital signal processing (DSP) technology and its applications. It is appropriate for engineers involved with any application of DSP who want a better working knowledge of DSP theory and its applications. A novel feature of the program is a hands-on DSP hardware/software development laboratory course in which students design and build systems for various applications using contemporary DSP hardware and development software.

Required Courses (8 units)

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ECEN (ELEN) 233E or ECEN (ELEN) 233 and 234 Digital Signal Processing I, II (4 units)
- ECEN (ELEN) 334 Introduction to Statistical Signal Processing (2 units)

Elective Courses (8 units)

- ECEN (ELEN) 223 Digital Signal Processing System Development (4 units)
- ECEN (ELEN) 226 Machine Learning and Signal Processing Using FPGAs (2 units)
- ECEN (ELEN) 235 Estimation I (2 units)

- ECEN (ELEN) 241 Introduction to Communications (2 units)
- ECEN (ELEN) 244 Information Theory (2 units)
- ECEN (ELEN) 336 Detection (2 units)
- ECEN (ELEN) 431 Adaptive Signal Processing I (2 units)
- ECEN (ELEN) 640 Digital Image Processing I (2 units)
- ECEN (ELEN) 641 Image and Video Compression (2 units)
- ECEN (ELEN) 643 Digital Image Processing II (2 units

Fundamentals of Electrical and Computer Engineering

Advisor: Dr. Shoba Krishnan

This certificate has been designed for those individuals who have significant work experience in some area of electrical and computer engineering and wish to take graduate-level courses but may lack some prerequisite knowledge because they have not earned a BS degree in electrical and/or computer engineering. This one-year program consists of 16 to 28 units, depending on the background of the individual student, and covers electrical and computer engineering core areas. Units from courses at or above the 200 level may be credited toward the Master of Science Degree in Electrical and Computer Engineering after successful completion of the certificate.

The specific required courses for a certificate are selected with the help of the program advisor according to the student's background.

- ECEN (ELEN) 21 Introduction to Logic Design (5 units)
- ECEN (ELEN) 50 Electric Circuits I (5 units)
- ECEN (ELEN) 100 Electric Circuits II (5 units)
- ECEN (ELEN) 104 Electromagnetics I (5 units)
- ECEN (ELEN) 110 Linear Systems (5 units) or ECEN (ELEN) 210 (2 units)
- ECEN (ELEN) 115 Electronic Circuits I (5 units) or ECEN (ELEN) 250 (2 units)
- ECEN (ELEN) 120 Microprocessor System Design (5 units)

RF and Applied Electromagnetics

Advisor: Dr. Kurt Schab

The purpose of this certificate is to meet the increasing need for the knowledge in microwave, antenna and RF integrated circuits in existing electronic products. This program is offered for students who have a B.S. in Electrical Engineering. Students are expected to have knowledge of multivariate calculus and preferably partial differential equations and they must ensure that they have prerequisites for the courses in their program.

The curriculum consists of 16 units: two required courses (4 units) and 12 units of elective courses listed below:

Required Courses (4 units)

- ECEN (ELEN) 201 Electromagnetic Field Theory I (2 units)
- ECEN (ELEN) 701 Microwave System Architecture (2 units)

Elective Courses (12 units)

- ECEN (ELEN) 202 Computational Electromagnetics (2 units)
- ECEN (ELEN) 203 Bio-Electromagnetics (2 units)
- ECEN (ELEN) 204 Magnetic Circuits for Electric and Autonomous Vehicles (2 units)
- ECEN (ELEN) 351 RF Integrated Circuit Design or ECEN (ELEN) 354 Advanced RFIC Design (2 units each)
- ECEN (ELEN) 624 Signal Integrity in IC and PCB Systems (2 units)
- ECEN (ELEN) 706 Microwave Circuit Analysis and Design (2 units) (Passive Component)
- ECEN (ELEN) 711 Active Microwave Devices I or ECEN (ELEN) 712 Active Microwave Devices II (2 units each)

(Active Components)
- ECEN (ELEN)715 Antennas I or ECEN (ELEN) 716 Antennas II (2 units each)
- ECEN (ELEN) 726 Microwave Measurements, Theory and Tech (3 units) (Laboratory Oriented)

Substitutions for these courses are only possible with the approval of the certificate advisor and the chair.

Electrical and Computer Engineering Laboratories

The Electrical and Computer Engineering program is supported by a set of well-equipped laboratories. Some are dedicated solely for lower division courses such as circuits and electronics. In addition, the department has a diversity of research and teaching laboratories listed next.

The ***Electromagnetics and Communications Laboratory*** provides a full range of modern RF measurement capabilities up to 22 GHz, including a number of vector network analyzers, spectrum analyzers, and antenna measurement systems. This lab also includes complete production facilities for prototyping printed microwave circuits and antennas. Further, the lab has extensive computer-aided design and simulation capability, including both commercial packages and research-grade in-house solvers. In both research and teaching, connections between physical hardware measurements and computer simulations are stressed.

The ***Computer Systems Laboratory*** offers various research projects in hardware-software co-design of digital systems. Examples of target designs include Internet-of-Things (IoTs), wearable devices, wireless sensor networks (WSNs), satellite on-board computers, neural network (NN) accelerators, and so on. Non-functional design concerns such as real-timeness, low-power, thermal behavior, security, or privacy are also important research topics studied in the Computer Systems Laboratory. The lab supports both graduate and undergraduate student research and has the following facilities to support student research: various FPGAs, MPSoC prototyping boards, GPU workstations (for NN training), and power monitoring tools.

The ***IC Design and Technology Laboratory*** is dedicated to teaching and research topics on electronic materials and devices, integrated circuit design, and IC manufacturing technologies. Current research topics include modeling complex electronic devices using variational methodologies, materials and device characterizations, fabrication and experimental studies of photovoltaic devices, emission free smart infrastructure, and optimizing energy infrastructure.

The ***Complex Systems and Control Laboratory*** provides an experimental environment for students in the area of control system and power engineering. The lab includes computer-controlled DC motors. These motors provide students with a range of qualitative and quantitative experiments such as inverted pendulum for learning the utility and versatility of feedback in computer-controlled systems. Additionally, the lab is equipped with a state-of-the-art robotic arm mounted on a mobile robot. The students can learn how to program the robot to perform collaborative tasks with human teammates. The lab also has a Linux-based workstation with GPUs for simulating brain-inspired architectures using emergent memory nanodevices (memristors and memcapacitors) as synapses for artificial neural networks.

The ***Latimer Energy Laboratory (LEL)*** supports a very wide range of activities relating to solar energy, more specifically photovoltaics (PV) and management of renewable energy sources, from K-12 outreach through graduate engineering. The laboratory focuses on two major directions: 1) measurement and characterization of different renewable energy sources; and 2) integration of renewable energy into the electric grid. The lab has instrumentation such as pyranometers, VIS-IR spectrometers, metallurgical microscopes, source meters, grid simulator software and related computers.

The ***Thermal and Electrical Nanoscale Transport (TENT) Laboratory*** provides teaching and research facilities for modeling, simulation, and characterization of devices and circuits in the nanoscale. Ongoing research topics include silicon heterostructures, thin dielectrics, high-frequency device and circuit parameter extraction, carbon nanostructures used as electrical interconnect and thermal interface materials, and compact modeling of transistors

and interconnects for large-scale circuit simulation. This laboratory is located inside NASA Ames Research Center in Moffett Field, California, and was established to conduct, promote, and nurture nanoscale science and technology interdisciplinary research and education activities at the University.

The *Information Systems and Machine Learning Laboratory* supports research in theoretical algorithm development in digital signal processing, adaptive and nonlinear signal processing, machine learning, deep learning, coding and information theory, private information retrieval, private function computation, secure and fault-tolerant distributed computing, group testing, and compressed sensing. Application areas include speech, audio, image and video processing for computer vision, communications, biological testing and diagnostics, artificial intelligence (AI), cloud computing, machine learning in the cloud, distributed storage systems, cache networks, and server-based and peer-to-peer networking.

The *Human-Machine Interaction & Innovation (HMI2) Laboratory* supports research in Human-Robot Interaction, Assistive Robotics, Intelligent Systems and Assistive Technologies with a special focus on enhancing Human Performance. The lab is equipped with several robotic systems, including mobile manipulators and humanoid robots. Additionally, the lab has several wearable sensors, such as electroencephalogram (EEG) and electrocardiogram (ECG), in order to develop AI-based intelligent systems that improve interactions between machines and humans.

Course Descriptions

Lower-Division Undergraduate Courses

ECEN (ELEN) 20. Emerging Areas in Electrical and Computer Engineering
Introduction to new frontiers in electrical and computer engineering. Hands-on activities and visits to research and production facilities in Silicon Valley companies to learn how the fundamentals of electrical and computer engineering are enabling new emerging technologies. (2 units)

ECEN (ELEN) 21. Introduction to Logic Design
Boolean functions and their minimization. Combinational circuits: adders, multipliers, multiplexers, decoders. Sequential logic circuits: latches and flip-flops, registers, counters. Memory. Busing. Programmable logic. Use of industry quality CAD tools for schematic capture and HDL in conjunction with FPGAs. Also listed as CSEN (COEN) 21. Co-requisite: ECEN (ELEN) 21L. (4 units)

ECEN (ELEN) 21L. Logic Design Laboratory
Laboratory for ELEN (ECEN) 21. Also listed as CSEN (COEN) 21L. Co-requisite: ECEN (ELEN) 21. (1 unit)

ECEN (ELEN) 49. Fundamentals of Electricity for Civil Engineers
Transducers. Motors, generators, and efficiency. DC and AC circuits. One and three-phase power systems. Sources of electricity. Hydroelectric power, generation, and pumps. Electrical diagrams and schematics. (4 units)

ECEN (ELEN) 50. Electric Circuits I
Physical basis and mathematical models of circuit components and energy sources. Circuit theorems and methods of analysis are applied to DC and AC circuits. Co-requisite: ECEN (ELEN) 50L, PHYS 33. (4 units)

ECEN (ELEN) 50L. Electric Circuits I Laboratory
Laboratory for ECEN (ELEN) 50. Co-requisite: ECEN (ELEN) 50. (1 unit)

Upper-Division Undergraduate Courses

ECEN (ELEN) 100. Electric Circuits II
Continuation of ELEN (ECEN) 50. Sinusoidal steady state and phasors, transformers, resonance, Laplace analysis, transfer functions. Frequency response analysis. Bode diagrams. Switching circuits. Prerequisite: ECEN (ELEN) 50 with a grade of C− or better, or PHYS 70. Co-requisite: ECEN (ELEN) 100L, AMTH 106. (4 units)

ECEN (ELEN) 100L. Electric Circuits II Laboratory

Laboratory for ECEN (ELEN) 100. Co-requisite: ECEN (ELEN) 100. (1 unit)

ECEN (ELEN) 104. Electromagnetics I

Vector analysis and vector calculus. The laws of Coulomb, Lorentz, Faraday, and Gauss. Dielectric and magnetic materials. Energy in electric and magnetic fields. Capacitance and inductance. Maxwell's equations. Wave equation. Poynting vector. Wave propagation and reflection in transmission lines. Radiation. Prerequisites: PHYS 33 and ECEN (ELEN) 50 with a grade of C− or better. Co-requisite: ECEN (ELEN) 104L. (4 units)

ECEN (ELEN) 104L. Electromagnetics I Laboratory

Laboratory for ECEN (ELEN) 104. Co-requisite: ECEN (ELEN) 104. (1 unit)

ECEN (ELEN) 105. Electromagnetics II

In-depth study of several areas of applied electromagnetics such as transmission lines circuits including microstrip and strip lines, Smith Chart and bounce diagram, magnetic circuits, antennas, and antenna arrays. Prerequisite: ECEN (ELEN) 104. Co-requisite: ECEN (ELEN) 105L. (4 units)

ECEN (ELEN) 105L. Electromagnetics II Laboratory

Laboratory for ECEN (ELEN) 105. Co-requisite: ECEN (ELEN) 105. (1 unit)

ECEN (ELEN) 110. Linear Systems

Signals and system modeling. Laplace transform. Transfer function. Convolution. Discrete systems. Frequency analysis. Fourier series and transform. Filtering. State-Space models. Prerequisite: ECEN (ELEN) 100. Co-requisite: ECEN (ELEN) 110L. (4 units)

ECEN (ELEN) 110L. Linear Systems Laboratory

Laboratory for ECEN (ELEN) 110. MATLAB laboratory/problem sessions. Co-requisite: ECEN (ELEN) 110. (1 unit)

ECEN (ELEN) 112. Modern Network Synthesis and Design

Approximation and synthesis of active networks. Filter design using positive and negative feedback biquads. Sensitivity analysis. Fundamentals of passive network synthesis. Design project. Prerequisite: ECEN (ELEN) 110. Co-requisite: ECEN (ELEN) 112L. (4 units)

ECEN (ELEN) 112L. Modern Network Synthesis and Design Laboratory

Laboratory for ECEN (ELEN) 112. Co-requisite: ECEN (ELEN) 112. (1 unit)

ECEN (ELEN) 115. Electronic Circuits I

Study of basic principles of operation, terminal characteristics, and equivalent circuit models for diodes and transistors. Analysis and design of diode circuits, transistor amplifiers, and inverter circuits. Prerequisite: ECEN (ELEN) 50 with a grade of C− or better. Co-requisite: ECEN (ELEN) 115L. (4 units)

ECEN (ELEN) 115L. Electronic Circuits I Laboratory

Laboratory for ECEN (ELEN) 115. Co-requisite: ECEN (ELEN) 115. (1 unit)

ECEN (ELEN) 116. Analog Integrated Circuit Design

Design and analysis of multistage analog amplifiers. Study of differential amplifiers, current mirrors, and gain stages. Frequency response of cascaded amplifiers and gain-bandwidth considerations. Concepts of feedback, stability, and frequency compensation. Prerequisite: ECEN (ELEN) 115. Co-requisite: ECEN (ELEN) 116L. (4 units)

ECEN (ELEN) 116L. Analog Integrated Circuit Design Laboratory

Laboratory for ECEN (ELEN) 116. Co-requisite: ECEN (ELEN) 116. (1 unit)

ECEN (ELEN) 117. Advanced Analog Integrated Circuits

Design and analysis of BJT and MOSFET analog ICs. Study of analog circuits such as comparators, sample/hold amplifiers, and switched capacitor circuits. Architecture and design of analog to digital and digital to analog converters. Reference and biasing circuits. Study of noise and distortion in analog ICs. Prerequisite: ECEN (ELEN) 116. Co-requisite: ECEN (ELEN) 117L. (4 units)

ECEN (ELEN) 117L. Advanced Analog Integrated Circuits Laboratory
Laboratory for ECEN (ELEN) 117. Co-requisite: ECEN (ELEN) 117. (1 unit)

ECEN (ELEN) 118. Fundamentals of Computer-Aided Circuit Simulation
Introduction to algorithms and principles used in circuit simulation packages (such as SPICE). Formulation of equations for linear and nonlinear circuits. Detailed study of the three different types of circuit analysis (AC, DC, and transient). Discussion of computational aspects, including sparse matrices, Newton's method, numerical integration, and parallel computing. Applications to electronic circuits, active filters, and CMOS digital circuits. Course includes a number of design projects in which simulation software is written in MATLAB and verified using SPICE. Prerequisites: ECEN (ELEN) 21, with a grade of C− or better; ECEN (ELEN) 100 and 115. Co-requisite: ECEN (ELEN) 118L. (4 units)

ECEN (ELEN) 118L. Fundamentals of Computer-Aided Circuit Simulation Laboratory
Laboratory for ECEN (ELEN) 118. Co-requisite: ECEN (ELEN) 118. (1 unit)

ECEN (ELEN) 119. Current Topics in Electrical and Computer Engineering
Subjects of current interest. May be taken more than once if topics differ. (4 units)

ECEN (ELEN) 120. Microprocessor System Design
Design and analysis of microprocessor-based systems for embedded applications. Assembly Language programming. Integration of digital and analog input/output devices with microprocessor hardware and software. Low-level programming techniques specialized for hardware interfacing and precise control of timing. Structure and operation of embedded computing platforms. Prerequisites: A grade of C- or better in ECEN (ELEN) 21 and CSEN (COEN) 11. Co-requisite: ECEN (ELEN) 120L. (4 units)

ECEN (ELEN) 120L. Microprocessor System Design
Lab projects based on an embedded computer module to practical applications that reinforce class concepts and provide some opportunities for creative design. Prerequisites A grade of C- or better in ECEN (ELEN) 21 and CSEN (COEN) 11. Co-requisite: ECEN (ELEN) 120 (1 unit)

ECEN (ELEN) 121. Real-Time Embedded Systems
Computing systems that measure, control, and interact. Real-time principles (multitasking, scheduling, synchronization), interfacing sensors, actuators and peripherals, implementation trade-offs, low-power high-performance systems (code profiling and optimization) embedded software (exception handling, loading, mode-switching, programming embedded systems). Real-time multimedia. Prerequisites: A grade of C- or better in ECEN (ELEN) 120. Co-requisite: ECEN (ELEN) 121L. (4 units)

ECEN (ELEN) 121L. Real-Time Embedded Systems Lab
Lab projects based on an embedded computer module to practical applications that reinforce class concepts and provide some opportunities for creative design. Prerequisites: A grade of C- or better in ECEN (ELEN) 120. Co-requisite: ECEN (ELEN) 121. (1 unit)

ECEN (ELEN) 122. Computer Architecture
Application of logic design concepts to computer architecture. Computation state machines. Computer instruction definition and formatting, the use of opcodes and operands. Memory, and how it is used to store instructions and data. Instruction execution, control transfer. Application of critical path concepts and pipelining. Hazards. Caches. Hardware support for virtual memory. Prerequisites: A grade of C- or better in either CSEN (COEN) or ECEN (ELEN) 21. Co-requisite: ECEN (ELEN) 122L. (4 units)

ECEN (ELEN) 122L. Computer Architecture Lab
Laboratory for ECEN (ELEN) 122. Co-requisite: ECEN (ELEN) 122. (1 unit)

ECEN (ELEN) 123. Mechatronics
Introduction to behavior, design, and integration of electromechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and

integration of transducers, microcontrollers, and actuators. Also listed as CSEN (COEN) 123 and MECH 143. Prerequisite: ECEN (ELEN) 50 with a grade of C− or better and CSEN (COEN) 11. Co-requisite: ECEN (ELEN) 123L. (4 units)

ECEN (ELEN) 123L. Mechatronics Laboratory

Laboratory for ECEN (ELEN) 123. Also listed as CSEN (COEN) 123L and MECH 143L. Co-requisite: ECEN (ELEN) 123. (1 unit)

ECEN (ELEN) 127. Advanced Logic Design

Contemporary design of finite-state machines as system controllers using FPGA devices. Minimization techniques, performance analysis, and modular system design. HDL simulation and synthesis. Also listed as COEN (CSEN) 127. Prerequisite: ECEN (ELEN) 21 with a grade of C− or better. Co-requisite: ECEN (ELEN) 127L. (4 units)

ECEN (ELEN) 127L. Advanced Logic Design Laboratory

Laboratory for ECEN (ELEN) 127. Design, construction, and testing of controllers from verbal specs. Use of CAD design tools. Also listed as CSEN (COEN) 127L. Co-requisite: ECEN (ELEN) 127. (1 unit)

ECEN (ELEN) 130. Control Systems

Applications of control systems in engineering. Principle of feedback. Performance specifications: transient and steady-state response. Stability. Design of control systems by frequency and root locus methods. Computer-controlled systems. State-variable feedback design. Also listed as ECEN (ELEN) 230. Prerequisite: ECEN (ELEN) 110. Co-requisite: ECEN (ELEN) 130L. (4 units)

ECEN (ELEN) 130L. Control Systems Laboratory

Laboratory for ECEN (ELEN) 130. Co-requisite: ECEN (ELEN) 130. (1 unit)

ECEN (ELEN) 131. Introduction to Robotics

Overview of robotic systems and application areas. Kinematic Analysis of Robotic Manipulators. Joint-space trajectory planning. Linear PID control for manipulators. Prerequisite: AMTH 106. Co-requisite: ECEN (ELEN) 131L (4 units)

ECEN (ELEN) 131L. Introduction to Robotics Laboratory

Laboratory for Robot Programming using Python and Robot Operating System (ROS): Prerequisite: Basic Programming. Co-requisite: ECEN (ELEN) 131. (1 unit)

ECEN (ELEN) 132 Design of Assistive Technologies

Accessible and Interactive Design. Design of Assistive Technologies. Prototype Development. Data Gathering. Data Analysis, Interpretation, and Representation. Project-based course. Prerequisites: AMTH 108 or equivalent. Also listed as ECEN (ELEN) 532. Corequisite: ECEN (ELEN) 132L. (4 units)

ECEN (ELEN) 132L. Design of Assistive Technologies Laboratory

Laboratory for ECEN (ELEN) 132. Corequisite: ECEN (ELEN) 132. (1 unit)

ECEN (ELEN) 133. Digital Signal Processing

Discrete signals and systems. Difference equations. Convolution summation. Z-transform, transfer function, system response, stability. Model based digital filter design and implementation. Frequency domain analysis. Discrete Fourier transform and FFT. Introduction to adaptive filter design and CNN architectures. Audio, video, and communication applications. Prerequisites: ECEN (ELEN) 110 or both ECEN (ELEN) 50 with a grade of C- or better, and CSEN (COEN) 19. Co-requisite: ECEN (ELEN) 133L. (4 units)

ECEN (ELEN) 133L. Digital Signal Processing Laboratory

Laboratory for ECEN (ELEN) 133. Laboratory for analysis, design, and simulation using MATLAB. Co-requisite: ECEN (ELEN) 133. (1 unit)

ECEN (ELEN) 134. Applications of Signal Processing

Current applications of signal processing. Topics may vary. Example topics include Speech Coding, Speech Recognition, and Biometrics. Prerequisite: ECEN (ELEN) 133, MATLAB. Co-requisite: ECEN (ELEN) 134L. (4 units)

ECEN (ELEN) 134L. Applications of Signal Processing Laboratory

Laboratory for ECEN (ELEN) 134. Co-requisite: ECEN (ELEN) 134. (1 unit)

ELEN (ECEN) 139. Special Topics in Signals and Systems

Subjects of current interest. May be taken more than once if topics differ. (4 units)

ECEN (ELEN) 141. Communication Systems

Modulation and demodulation of analog and digital signals. Baseband to passband conversion. Baseband and passband communications. Random processes, signal-to-noise ratio, and bandwidth considerations. Prerequisites: ECEN (ELEN) 110 and AMTH 108. Corequisite: ECEN (ELEN) 141L. (4 units)

ECEN (ELEN) 141L. Communication Systems Laboratory

Laboratory for ECEN (ELEN)141. Co-requisite: ECEN (ELEN) 141. (1 unit)

ECEN (ELEN) 142. Communications and Networking

Networking in different media. Effects of the media on data rate. Error/erasure detection and correction. Routing algorithms. Collision and retransmission in networks. Network coding algorithms. Prerequisite: AMTH 108 with a grade of C- or better; or its equivalent. Co-requisite: ECEN (ELEN) 142L (4 units)

ECEN (ELEN)142L. Communications and Networking Lab

Lab component; Networking in different media. Effects of the media on data rate. Error detection and correction. Routing algorithms. Collision and retransmission in networks. Prerequisite: AMTH 108 with a grade of C- or better; or its equivalent. Co-requisite: ECEN (ELEN) 142. (1 unit)

ECEN (ELEN) 144. RF and Microwave Components

The fundamental characteristics of passive and active electrical components. Parasitics, models, and measurements. Modeling of circuit interconnects. Study of crosstalk in high-speed digital circuits, matching circuits, power dividers, and microwave filters. Prerequisite: ECEN (ELEN) 105. Co-requisite: ECEN (ELEN) 144L. (4 units)

ECEN (ELEN) 144L. RF and Microwave Components Laboratory

Laboratory for ECEN (ELEN) 144. Co-requisite: ECEN (ELEN) 144. (1 unit)

ECEN (ELEN) 151. Device Electronics for IC Design

Properties of materials, crystal structure, and band structure of solids. Carrier statistics and transport; p-n junction electrostatics, I-V characteristics, equivalent circuits. Metal-semiconductor contacts, Schottky diodes. MOS field-effect transistors, bipolar junction transistors. This course covers the essential device concepts necessary for analog, digital, and/or mixed signal circuit design. Credit not allowed for both ECEN (ELEN) 151 and ECEN (ELEN) 267. Prerequisite or Co-requisite: ECEN (ELEN) 104. Co-requisite: ECEN (ELEN) 151L. (4 units)

ECEN (ELEN) 151L. Device Electronics Laboratory

Laboratory for ECEN (ELEN) 151. Co-requisite: ECEN (ELEN) 151. (1 unit)

ECEN (ELEN) 152. Integrated Circuit Fabrication Process Technology

Fundamental principles of processes essential for fabricating micro- and nanoelectronic hardware ranging from Integrated circuits, MEMS and biosensors to power, control and optoelectronic devices. Physical and chemical models of semiconductor crystal growth, thermal oxidation and diffusion, ion implantation, Lithography, etching and cleaning, epitaxy, chemical and physical vapor deposition, metallization, etc. Process integration and simulation using TCAD. (4 units). Also listed as ECEN (ELEN) 276. (4 units)

ECEN (ELEN) 152L. Integrated Circuit Fabrication Process Technology Laboratory

Laboratory for ECEN (ELEN)152. Also listed as ECEN (ELEN) 276L. (1 unit)

ECEN (ELEN) 153. Digital Integrated Circuit Design

Introduction to VLSI design and methodology. Study of basic principles, material for CMOS transistors. Study of CMOS digital integrated circuits and technology scaling. Physical design and layout principles. Interconnect modeling. Semiconductor memories. Use of state-of-the-art CAD tools. Prerequisites: ECEN (ELEN)/CSEN (COEN) 21 and ECEN (ELEN) 50 with a grade of C− or better. Co-requisite: ECEN (ELEN) 153L. (4 units)

ECEN (ELEN) 153L. Digital Integrated Circuit Design Laboratory
Laboratory for ECEN (ELEN) 153. Co-requisite: ECEN (ELEN) 153. (1 unit)

ECEN (ELEN) 156. Introduction to Nanotechnology
Introduction to the field of nanoscience and nanotechnology. Properties of nanomaterials and devices. Nanoelectronics: from silicon and beyond. Measurements of nanosystems. Applications and implications. Laboratory experience is an integral part of the course. Also listed as MECH 156. Prerequisites: PHYS 33 and either PHYS 34 or MECH 15. Co-requisite: ECEN (ELEN) 156L. (4 units)

ECEN (ELEN) 156L. Introduction to Nanotechnology Laboratory
Laboratory for ECEN (ELEN) 156. Also listed as MECH 156L. Co-requisite: ECEN (ELEN) 156. (1 unit)

ECEN (ELEN) 160. Chaos Theory, Metamathematics and the Limits of Science: An Engineering Perspective on Religion
Limitations of science are examined in the framework of nonlinear system theory and metamathematics. Strange attractors, bifurcations, and chaos are studied in some detail. Additional topics include an introduction to formal systems and an overview of Godel's theorems. The mathematical background developed in the course is used as a basis for exploring the relationship between science, aesthetics, and religion. Particular emphasis is placed on the rationality of faith. Also listed as ECEN (ELEN) 217. Prerequisites: AMTH 106 (or an equivalent course in differential equations), and a basic familiarity with MATLAB. Co-requisite: ECEN (ELEN) 160L. (4 units)

ECEN (ELEN) 160L. Chaos Theory, Metamathematics and the Limits of Science: An Engineering Perspective on Religion Laboratory
Laboratory for ECEN (ELEN) 160. Co-requisite: ECEN (ELEN) 160. (1 unit)

ECEN (ELEN) 161. The Beauty of Nature and the Nature of Beauty
Beauty is examined from an interdisciplinary perspective, taking into account insights from mathematics, physics, engineering, neuroscience, and psychology, as well as philosophy, art history, and theology. Technical topics include information theory, quantum computing, fractal geometry, complex systems, cellular automata, Boolean networks, and set theory. Prerequisite: AMTH 106 (or equivalent). Familiarity with basic concepts in probability theory is expected, as is some experience with MATLAB. Co-requisite: ECEN (ELEN) 161L. (4 units)

ECEN (ELEN) 161L. The Beauty of Nature and the Nature of Beauty Laboratory
Laboratory for ECEN (ELEN) 161. Co-requisite: ECEN (ELEN) 161. (1 unit)

ECEN (ELEN) 162 Quantum and Parallel Algorithms for Scientific Computing
Quantum and parallel computing are explored as paradigms for high performance scientific computing. Particular emphasis is placed on quantum algorithms and graph-theoretic methods for parallelizing the solution of large sparse systems of equations. Since a proper understanding of these topics requires a background in matrix theory, functional analysis, cryptology and number theory, these areas are covered in some detail. Prerequisites: MATH 53 or equivalent, and familiarity with MATLAB. Co-requisite: ECEN (ELEN) 162L. (4 units)

ECEN (ELEN) 162L Quantum and Parallel Algorithms for Scientific Computing Lab
Laboratory for ECEN (ELEN) 162. Co-requisite: ECEN (ELEN) 162. (1 unit)

ECEN (ELEN) 164. Introduction to Power Electronics
Power and efficiency computations, rectifiers, power devices, DC-to-DC converters, AC-to-DC converters, and DC-to-AC inverters. Prerequisite: ECEN (ELEN) 115. Co-requisite: ECEN (ELEN) 164L. (4 units)

ECEN (ELEN) 164L. Introduction to Power Electronics Laboratory
Laboratory for ECEN (ELEN) 164. Co-requisite: ECEN (ELEN) 164. (1 unit)

ECEN (ELEN) 167. Medical Imaging Systems
Overview of medical imaging systems including sensors and electrical interfaces for data acquisition, mathematical models of the relationship of structural and physiological information to sensor measurements, resolution, and accuracy limits, and the conversion process from electronic signals to image synthesis. Analysis of the specification

and interaction of the functional units of imaging systems and the expected performance. Focus on MRI, CT, and ultrasound, PET, and impedance imaging. Also listed as BIOE 167, BIOE 267. Prerequisite: BIOE 162 or ECEN (ELEN) 110 or MECH 142. (4 units)

ECEN (ELEN) 180. Introduction to Information Storage

Storage hierarchy. Design of memory and storage devices, with a particular emphasis on magnetic disks and storage-class memories. Error detection, correction, and avoidance fundamentals. Disk arrays. Storage interfaces and buses. Network attached and distributed storage, interaction of economy, and technological innovation. Also listed as COEN (CSEN) 180. Prerequisites: ECEN (ELEN) 21 or CSEN (COEN) 21, and CSEN (COEN) 20; CSEN (COEN) 122 is recommended. (4 units)

ECEN (ELEN) 182. Energy Systems Design

Introduction to alternative energy systems with emphasis on those utilizing solar technologies; system analysis including resources, extraction, conversion, efficiency, and end-use; project will design power system for a house off or on grid making best use of renewable energy; system design will include power needs, generation options, storage, back-up power. Prerequisite: ECEN (ELEN) 50. (4 units)

ECEN (ELEN) 183. Power Systems Analysis

Analysis, design, and optimization of power systems for traditional and renewable power generation. Balanced three-phase circuits. Transformers and transmission lines. Also listed at ECEN (ELEN) 281E. Prerequisite: ECEN (ELEN) 100 or PHYS 12. Co-requisite: ECEN (ELEN) 183L. (4 units)

ECEN (ELEN) 183L. Power Systems Analysis Laboratory

Laboratory for ECEN (ELEN) 183. Co-requisite: ECEN (ELEN) 183. (1 unit)

ECEN (ELEN) 184. Power System Stability and Control

Examine power system stability and power system control, including load frequency control, economic dispatch, and optimal power flow. Also listed as ECEN (ELEN) 231. Prerequisite: ECEN (ELEN) 183 or equivalent. (4 units)

ECEN (ELEN) 188. Co-op Education

Integration of classroom study and practical experience in a planned program designed to give students practical work experience related to their academic field of study and career objectives. The course alternates (or parallels) periods of classroom study with periods of training in industry or government. Satisfactory completion of the assignment includes preparation of a summary report on co-op activities. P/NP grading. May be taken twice. May not be taken for graduate credit. (2 units)

ECEN (ELEN) 189. Co-op Technical Report

Credit is given for a technical report on a specific activity such as a design or research project, etc., after completing the co-op assignment. Letter grades based on content and presentation quality of report. May be taken twice. May not be taken for graduate credit. Prerequisite: ECEN (ELEN) 188. Approval of department co-op advisor required. (2 units)

ECEN (ELEN) 192. Introduction to Senior Design Project

Junior preparation for senior project. An introduction to project requirements and participation in the coordination of the senior conference. Tentative project selection. (2 units)

ECEN (ELEN) 194. Design Project I

Specification of an engineering project, selected with the mutual agreement of the student and the project advisor. Complete initial design with sufficient detail of target specification. Incorporation of relevant engineering standards and appropriate realistic constraints. Initial draft of the project report. Co-requisite: ENGL 181. (2 units)

ECEN (ELEN) 195. Design Project II

Implementation, construction, and testing of the project, system, or device. Sustainability analysis. Demonstration of project and formal design review. Prerequisite: ECEN (ELEN) 194. (2 units)

ECEN (ELEN) 196. Design Project III

Continued design, implementation, and testing of the project, system, or device to improve function and add capability. Reliability analysis. Formal public presentation of results. Final report. Prerequisite: ECEN (ELEN) 195. (1 unit)

ECEN (ELEN) 199. Directed Research/Reading

Investigation of an approved engineering problem and preparation of a suitable project report. Open to electrical engineering and computer majors only. (1–6 units)

* Eligible for graduate credit in electrical and computer engineering

Graduate Courses

Some graduate courses may not apply toward certain degree programs. As early as possible, preferably during the first quarter of study, students are urged to discuss in detail with their faculty advisor the program of study they wish to pursue.

ECEN (ELEN) 200. Electrical and Computer Engineering Graduate Seminars

Regularly scheduled seminars on topics of current interest in the fields of electrical and computer engineering and computer engineering. Consult the department office for detailed information. P/NP grading. (1 or 2 units)

ECEN (ELEN) 201. Electromagnetic Field Theory I

Time-varying electromagnetic field concepts starting with Maxwell's equations. Wave propagation in free space and in lossy media. Near and far-field effects. Fundamental theorems in electromagnetics. Transmission line propagation of harmonic waves and of pulse and transient signals. Dispersion effects. Prerequisites: An undergraduate electromagnetic field course. (2 units)

ECEN (ELEN) 202. Computational Electromagnetics

Numerical solution of Maxwell's Equations for engineering problems. Foundations and mathematical development of finite difference time domain (FDTD) and method of moments (MoM) solvers. Methods for numerical validation and robust simulation-based experiment design. Prerequisite: ECEN (ELEN) 201. (2 units)

ECEN (ELEN) 203. Bio-Electromagnetics

Fundamentals of bioelectromagnetics. Tissue characterization, dielectrophoresis electrodes, RF/Microwave Interaction mechanisms in biological materials. Electromagnetic field absorption, and SAR, Power transfer in biological environment, On-body and implant antennas, microwave hyperthermia. Also listed as BIOE 203. Prerequisite: ECEN (ELEN) 201 (or equivalent) or BIOE 168/268. (2 units)

ECEN (ELEN) 204. Magnetic Circuits for Electric and Autonomous Vehicles

Fundamentals of magnetic circuits, transformers, DC motors, induction motors, transducers, stationary and mobile wireless charging. Prerequisite: Introduction to Electromagnetic Field Theory. (2 units)

ECEN (ELEN) 210. Signals, Circuits, and Systems

Continuous and discrete signals. Circuit equations and time response. Laplace transform. Difference equations and discrete systems. Z-transform. Convolution. Transfer function. Frequency response. Fourier series and transform. Matrix representations of circuits and systems. The notion of state. State transition matrix. State and output response. Equivalent to ECEN (ELEN) 110. May not be included in the minimum required units of Electrical and Computer Engineering courses. (2 units)

ECEN (ELEN) 211. Modern Network Analysis I

Graph theory and its applications to network matrix equations. Network component magnitude and frequency scaling. Network topology, graph theory, graph matrices, oriented and non-oriented graphs. Fundamental network laws. Topologically dependent matrix equations. Circuit simulation. N Planar and dual graphs. Nondegenerate network state equations. Prerequisites: AMTH 246 and knowledge of Laplace transforms. (2 units)

ECEN (ELEN) 216. Modern Network Synthesis and Design

Approximation and synthesis of active networks. Filter design using positive and negative feedback biquads. Sensitivity analysis. Fundamentals of passive network synthesis. Credit not allowed for both 112 and 216. Prerequisite: ECEN (ELEN) 210 or its undergraduate equivalent of ECEN (ELEN) 110. (4 units)

ECEN (ELEN) 217. Chaos Theory, Metamathematics and the Limits of Knowledge: A Scientific Perspective on Religion

Limitations of science are examined in the framework of nonlinear system theory and metamathematics. Strange attractors, bifurcations, and chaos are studied in some detail. Additional topics include an introduction to formal systems and an overview of Godel's theorems. The mathematical background developed in the course is used as a basis for exploring the relationship between science, aesthetics, and religion. Particular emphasis islaced on the rationality of faith. Also listed as ECEN (ELEN) 160. Prerequisites: AMTH 106 or an equivalent course in differential equations, and a basic familiarity with MATLAB. (4 units)

ECEN (ELEN) 218. Quantum and Parallel Algorithms for Scientific Computing

Quantum and parallel computing are explored as paradigms for high performance scientific computing. Particular emphasis is placed on quantum algorithms and graph-theoretic methods for parallelizing the solution of large sparse systems of equations. Since a proper understanding of these topics requires a background in matrix theory, functional analysis, cryptology and number theory, these areas are covered in some detail. Also listed as ECEN (ELEN) 162. Prerequisites: AMTH 246 or equivalent, and familiarity with MATLAB. (4 units)

ECEN (ELEN) 219. Fundamentals of Computer-Aided Circuit Simulation

Introduction to the algorithms and principles used in circuit simulation packages (such as SPICE). Formation of equations for linear and nonlinear circuits. Detailed study of three different types of circuit analysis (AC, DC, and transient). Discussion of computational aspects, including sparse matrices, Newton's method, numerical integration, and parallel computing. Applications to electronic circuits, active filter, and CMOS digital circuits. Course includes a number of design projects in which simulation software is written in Matlab and verified using SPICE. Credit not allowed for both 118 and 219. Prerequisites: ECEN (ELEN) 21, ECEN (ELEN) 100, and ECEN (ELEN) 115. (4 units)

ECEN (ELEN) 223. Digital Signal Processing System Development

Hands-on experience with hardware and software development for real-time DSP applications. Students design, program, and build a DSP application from start to finish. Such applications include image processing, speech/audio/video compression, multimedia, etc. The development environment includes Texas Instruments TMS320C6X development systems. Prerequisites: ECEN (ELEN) 234 or ECEN (ELEN) 233E and knowledge of "C" programming language. (4 units)

ECEN (ELEN) 226. Machine Learning and Signal Processing using FPGAs

Implementation of machine learning inference pipelines in an FPGA; signal processing and hardware architecture to take a trained network through to a hardware realization; overview of the latest generation FPGA technology and C++ High Level Synthesis (HLS) FPGA design flows. Students will learn how to implement, in fixed-point arithmetic, in hardware, the linear-algebra operations that are at the center of virtually all ML networks such as GoogleNet, ResNet and other well-known network architectures. Implementation of the common linear algebra functions and nonlinear functions that form the core components of many common networks will be covered. FPGA implementation of a multi-layer perceptron network and a CNN (convolutional neural network) accelerator using a HLS design flow. Prerequisites: ECEN (ELEN) 133, ECEN (ELEN) 233E or ECEN (ELEN) 234) and ECEN (ELEN) 127 or the equivalent and C++ programming experience. (2 units)

ECEN (ELEN) 229. Topics in Network Theory

Various topics. (2 units)

ECEN (ELEN) 230. Introduction to Control Systems

Applications of control systems in engineering. Principle of feedback. Performance specifications: transient and steady-state response. Stability. Design of control systems by frequency and root-locus methods. Computer-controller

systems. State-variable feedback design. Credit not allowed for both ECEN (ELEN) 130 and ECEN (ELEN) 230. Prerequisite: ECEN (ELEN) 210 or its undergraduate equivalent of ECEN (ELEN) 110. (4 units)

ECEN (ELEN) 231. Power System Stability and Control
Examine power system stability and power system control, including load frequency control, economic dispatch and optimal power flow. Also listed as ECEN (ELEN) 184. Prerequisite: ECEN (ELEN) 183 or equivalent. (4 units)

ECEN (ELEN) 232. Introduction to Nonlinear Systems
This course is an Introduction to nonlinear systems. Topics include introducing some nonlinear phenomena, phase-plane analysis including phase portraits, singular points, linearization, limit cycles, Poincare-Bendixson criteria, Lyapunov stability theorems, LaSalle's invariance principle, stability analysis of linear system via Lyapunov stability theorem, Lyapunov stability analysis of nonautonomous, and linear time-varying systems. Also listed as MECH 423. Prerequisite: MECH 323/ ECEN (ELEN) 236 or its equivalent. (2 units)

ECEN (ELEN) 233. Digital Signal Processing
Description of discrete signals and systems. Z-transform. Convolution and transfer functions. System response and stability. Fourier transform and discrete Fourier transform. Sampling theorem. Digital filtering. Also listed as CSEN (COEN) 201. Prerequisite: ECEN (ELEN) 210 or its undergraduate equivalent of ECEN (ELEN) 110. (2 units)

ECEN (ELEN) 233E. Digital Signal Processing I and II
Same description as ECEN (ELEN) 233 and ECEN (ELEN) 234. Credit not allowed for both ECEN (ELEN) 133 and 233E. Also listed as CSEN (COEN) 201E (4 units)

ECEN (ELEN) 234. Digital Signal Processing II
Continuation of ECEN (ELEN) 233. Digital FIR and IIR filter design and realization techniques. Multirate signal processing. Fast Fourier transform. Quantization effects. Also listed as CSEN (COEN) 202. Prerequisite: ECEN (ELEN) 233. (2 units)

ECEN (ELEN) 235. Estimation I
Introduction to Classical estimation. Minimum Variance Unbiased Estimator (MVUE) from Cramer-Rao theorem, sufficient statistics, and linear estimator constraint. Maximum Likelihood Estimation (MLE) method. Least Square (LS) methods. Prerequisites: AMTH 211 or AMTH 212, AMTH 246 or AMTH 247, familiarity with MATLAB. (2 units)

ECEN (ELEN) 236. Modern Control Systems I
Concept of state-space descriptions of dynamic systems. Relations to frequency domain descriptions. State-space realizations and canonical forms. Stability. Controllability and observability. State feedback and observer design. Also listed as MECH 323. Prerequisite: ECEN (ELEN) 130 or its undergraduate equivalent. (2 units)

ECEN (ELEN) 237. Optimal Control I
Introduction to the principles and methods of the optimal control approach: performance measure criteria including the definition of minimum-time, terminal control, minimum-control effort, tracking and regulator problems, calculus of variation applied to optimal control problems including Euler-Lagrange equation, transversality condition constraint, Pontryagin's minimum principle (PMP), linear quadratic regulator (LQR) and tracking control problems. Also listed as MECH 429. Prerequisite: ECEN (ELEN) 236. Students are expected to be proficient in MATLAB/Simulink. (2 units)

ECEN (ELEN) 238. Model Predictive Control
Review of state-space model in discrete time, stability, optimal control, prediction, Kalman filter. Measurable and unmeasurable disturbance, finite and receding horizon control, MPC formulation and design. Also listed as MECH 420. Prerequisite: ECEN (ELEN) 237 or MECH 324 or equivalent. (2 units)

ECEN (ELEN) 239A. Topics in Systems Theory
Various topics. (2 units)

ECEN (ELEN) 239B. Topics in Systems Theory
Various topics. (4 units)

ECEN (ELEN) 241. Introduction to Communication

Power spectral density and correlation; bandwidth; random processes; carrier frequency, modulation and baseband versus passband modulation. Prerequisite: ECEN (ELEN) 210 or its undergraduate equivalent of ECEN (ELEN) 110. (2 units)

ECEN (ELEN) 241E. Modern Communications

Power spectral density and correlation; bandwidth; carrier frequencies, baseband vs. passband, random processes and noise; digital modulation techniques including QAM, PAM, PSK, and FSK; matched-filter receivers; maximum-likelihood and maximum a priori detection; Signal-to-Noise ratio evaluation and its impact on error rate. If students have taken ECEN (ELEN) 241 or ECEN (ELEN) 243, credit is not allowed for 241E. Similarly, if a student has taken 241E, credit is not allowed for 241 or 243. Prerequisites: ECEN (ELEN) 110 or its equivalent and AMTH 108 or its equivalent. (4 units)

ECEN (ELEN) 243. Digital Communication Systems

Digital modulation techniques including: QAM, PSK, FSK; matched-filter receivers; maximum-likelihood and maximum a priori detection. Signal-to-Noise ratio evaluation and its impact on error rate. Prerequisite: ECEN (ELEN) 241 or equivalent. (2 units)

ECEN (ELEN) 244. Information Theory

Introduction to the fundamental concepts of information theory. Source models. Source coding. Discrete channel without memory. Continuous channel. Alternate years. Also listed as CSEN (COEN) 341. Prerequisite: AMTH 211. (2 units)

ECEN (ELEN) 247. Communication Systems Modeling Using Simulink I

The objective of this course is for students to acquire and consolidate their practical skills of digital communication systems design through building simulation of some carefully selected prototype systems using MATLAB® and Simulink.® Examples include communication systems. The components and the principle of operation of each system will be presented in a lecture, together with key simulation techniques required. Topics include digital modulation and synchronization. Prerequisites: ECEN (ELEN) 233 and 243. (2 units)

ECEN (ELEN) 248. Communication Systems Modeling Using Simulink II

Continuation of ECEN (ELEN) 247. Prerequisite: ECEN (ELEN) 247. (2 units)

ECEN (ELEN) 249. Topics in Communication

Various topics. (2 units)

ECEN (ELEN) 250. Electronic Circuits

Introductory presentation of semiconductor circuit theory. The p-n junction, bipolar junction transistors (BJT), field-effect transistors and circuit models for these devices. DC biasing required of small-signal amplifier circuits. Analysis and design of small-signal amplifiers. The ideal operational amplifier and circuit applications. May not be taken for credit by a student with an undergraduate degree in electrical engineering. Not for graduate credit. Prerequisite: ECEN (ELEN) 50 or equivalent. (2 units)

ECEN (ELEN) 251. Transistor Models for IC Design

Semiconductor device modeling methods based upon device physics, process technology, and parameter extraction. Model derivation for bipolar junction transistors and metal-oxide-semiconductor field-effect transistors for use in circuit simulators. Model parameter extraction methodology utilizing linear regression, data fitting, and optimization techniques. Prerequisite: ECEN (ELEN) 265 or ECEN (ELEN) 267. (2 units)

ECEN (ELEN) 252. Analog Integrated Circuits I

Design and analysis of multi-stage BJT and CMOS analog amplifiers. Study of differential amplifiers, current mirrors, and gain stages. Frequency response of cascaded amplifiers and gain-bandwidth considerations. Concepts of feedback, stability, and frequency compensation. Prerequisite: ECEN (ELEN) 115 or equivalent. (2 units)

ECEN (ELEN) 253. Analog Integrated Circuits II

Design of operational amplifiers and wideband amplifiers. Design of output stages and power amplifiers. Reference and biasing circuits. Study of noise and distortion in analog ICs and concepts of low noise design. Selected applications of analog circuits such as comparators. Prerequisite: ECEN (ELEN) 252. (2 units)

ECEN (ELEN) 254. Advanced Analog Integrated Circuit

Design and analysis of BJT and MOSFET analog ICs. Study of analog circuits such as comparators, sample/hold amplifiers, and continuous time switch capacitor filters. Architecture and design of analog to digital and digital to analog convertors. Reference and biasing circuits. Study of noise and distortion in analog ICs. Prerequisite: ECEN (ELEN) 116. Co-requisite: ECEN (ELEN) 117L. (4 units)

ECEN (ELEN) 259. Topics in Circuit Design

Various topics. (2 units)

ECEN (ELEN) 261. Fundamentals of Semiconductor Physics

Wave mechanics. Crystal structure and energy band structure of semiconductors. Carrier statistics and transport. Electrical and optical properties. (2 units)

ECEN (ELEN) 264. Semiconductor Device Theory I

Physics of semiconductor materials, junctions, and contacts as a basis for understanding all types of semiconductor devices. Prerequisite: ECEN (ELEN) 261 or ECEN (ELEN) 151 or equivalent. (2 units)

ECEN (ELEN) 265. Semiconductor Device Theory II

Continuation of ECEN (ELEN) 264. MOSFET basics, short-channel and high-field effects, CMOS, bipolar junction transistors. Prerequisite: ECEN (ELEN) 264. (2 units)

ECEN (ELEN) 266. Semiconductor Device Theory I and II

Same description as ECEN (ELEN) 264 and 265. Prerequisite: ECEN (ELEN) 261 or ECEN (ELEN) 151 or equivalent. Credit allowed for either ECEN (ELEN) 264 and 265, or ECEN (ELEN) 266. (4 units)

ECEN (ELEN) 267. Device Electronics for IC Design

Properties of materials, crystal structure, and band structure of solids. Carrier statistics and transport; p-n junction electrostatics, I-V characteristics, equivalent circuits. Metal-semiconductor contacts, Schottky diodes. MOS field-effect transistors, bipolar junction transistors. This course covers the essential device concepts necessary for analog, digital, and/or mixed signal circuit design. Credit not allowed for both ECEN (ELEN) 151 and ECEN (ELEN) 267. Prerequisite or Co-requisite: ECEN (ELEN) 104 or basic knowledge of electrostatics. (4 units)

ECEN (ELEN) 270. Introduction to IC Materials

Materials issues in IC, classification of IC materials, Historical perspective. IC materials electrical conductivity, high-k, low-k materials. IC processing materials; solid liquid, gaseous dopants, chemicals and gases for etching and cleaning; IC lithography materials; photo-, e-beam-, x-ray resists, resist developers; IC packaging materials; IC thin film materials; adhesion, thermal conductivity and stress, electrical conductivity and sheet resistance. (2 units)

ECEN (ELEN) 271. Microsensors: Components and Systems

Microfabrication technologies, bulk and surface micromachining, sensor fundamentals, electronic, chemical, and mechanical components as sensors, system level issues, technology integration; application and examples of sensors. (2 units)

ECEN (ELEN) 274. Integrated Circuit Fabrication Processes I

Fundamental principles of silicon-integrated circuit fabrication processes. Practical and theoretical aspects of microelectronic fabrication. Basic materials properties, including crystal structure and crystallographic defects; physical and chemical models of crystal growth; and doping, thermal oxidation, diffusion, and ion implantation. Prerequisite: ECEN (ELEN) 270. (2 units)

ECEN (ELEN) 275. Integrated Circuit Fabrication Processes II

Physical and chemical models of etching and cleaning, epitaxy, deposited films, photolithography, and metallization. Process simulation and integration. Principles and practical aspects of fabrication of devices for MOS and bipolar integrated circuits. Prerequisite: ECEN (ELEN) 270. (2 units)

ECEN (ELEN) 276. Integrated Circuit Fabrication Process Technology

Fundamental principles of processes essential for fabricating micro- and nanoelectronic hardware ranging from Integrated circuits, MEMS and biosensors to power, control and optoelectronic devices. Physical and chemical models of semiconductor crystal growth, thermal oxidation and diffusion, ion implantation, Lithography, etching and cleaning, epitaxy, chemical and physical vapor deposition, metallization, etc. Process integration and simulation using TCAD. Also listed as ECEN (ELEN) 152. Prerequisite: ECEN (ELEN) 270. (4 units)

ECEN (ELEN) 276L. Integrated Circuit Fabrication Process Technology Laboratory

Laboratory for ECEN (ELEN) 276. Also listed as ECEN (ELEN) 152L. (1 unit)

ECEN (ELEN) 277. IC Assembly and Packaging Technology

IC assembly techniques, assembly flow, die bond pad design rules, eutectic bonding and other assembly techniques, package types and materials, package thermal and electrical design and fabrication, special package considerations, future trends, and package reliability. Prerequisite: ECEN (ELEN) 201. (2 units)

ECEN (ELEN) 279. Topics in Semiconductor Devices and Processing

Various topics. (2 units)

ECEN (ELEN) 280. Introduction to Alternative Energy Systems

An introduction to such alternative energy systems with an emphasis on those utilizing solar technologies. Learn how the technologies work to provide electrical power today and the capabilities foreseen for the future. The material is designed to be suitable for both undergraduate and graduate students in engineering and related applied sciences. Also listed as MECH 287. (2 units)

ECEN (ELEN) 281A. Power Systems: Generation and Transmission

Electricity is the most versatile and widely used form of energy, and as such, it is the backbone of today's and tomorrow's global society. The course deals with the power system structure and components, electric power generation, transmission, and distribution. It also examines how these components interact and are controlled to meet the requirement of capacity, energy demand; reliabilityy, availability, and quality of power delivery; efficiency, minimization of power loss; sustainability, and integration of low carbon energy sources. Prerequisite: ECEN (ELEN) 100 or equivalent. (2 units)

ECEN (ELEN) 281B. Power Systems: Distribution

The objective of this course is to cover the fundamental as well as wider aspects of Electric Power Transmission and Distribution networks including monitoring and control application tools typically provided by Energy Management Systems that enable electric utility companies to manage these assets to achieve their goals. Prerequisite: ECEN (ELEN) 281A. (2 units)

ECEN (ELEN) 282. Photovoltaic Devices and Systems

This course begins with a discussion of the sun as a source of energy, emphasizing the characteristics of insolation which then leads to a study of solar cells, their performance, their models, and the effects on their performance of factors such as atmospheric attenuation, incidence angle, shading, and others. Cells are connected together to become modules, which in turn are connected in arrays. This leads to a discussion of power electronic devices used to control and condition the DC solar voltage, including charge controllers, inverters, and other devices. Energy storage is studied. These components are then collected together in a solar PV system. The course concludes with a discussion of system sizing. (2 units)

ECEN (ELEN) 283. Characterization of Photovoltaic Devices

This course consists of five pre-lab lectures and five experiments exploring different aspects of photovoltaic cells and modules, including cell characterization under controlled conditions using a solar simulator; determining the spectral

response and quantum efficiency of cells; measurement of solar irradiance and insolation; characterization of photovoltaic modules under real sun conditions; study of solar-related power electronics. Prerequisite: ECEN (ELEN) 282 or equivalent. (2 units)

ECEN (ELEN) 284. Solar Cell Technologies & Simulation Tools
Review of concepts needed to understand function, design, and manufacturing of PV cells and modules. PV cell physics leading to derivation of the I-V curve and equivalent circuit, along with contact and optical design, and use of computer-aided design tools. Manufacturing processes for silicon and thin film cells and modules. Cell measurements, including simulators, quantum efficiency, and parameter extraction. Cell types include silicon, thin film, organics, and concentrators. Markets, drivers, and LCOE (levelized cost of electricity) are surveyed. (2 units)

ECEN (ELEN) 284L. Solar Cell Technologies and Simulation Tools Laboratory
Co-requisite: ELEN (ECEN) 284. (1 unit)

ECEN (ELEN) 285. Introduction to the Smart Grid
The smart grid initiative calls for the construction of a 21st-century electric system that connects everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It is envisioned that it will seamlessly integrate many types of generation and storage systems with a simplified interconnection process analogous to "plug and play." This course describes the components of the grid and the tools needed to realize its main goals: communication systems, intelligent meters, and appropriate computer systems to manage the grid. (2 units)

ECEN (ELEN) 286. Introduction to Wind Energy Engineering
Introduction to renewable energy, history of wind energy, types and applications of various wind turbines, wind characteristics and resources, introduction to different parts of a wind turbine including the aerodynamics of propellers, mechanical systems, electrical and electronic systems, wind energy system economics, environmental aspects and impacts of wind turbines, and the future of wind energy. Also listed as MECH 286. (2 units)

ECEN (ELEN) 287. Energy Storage Systems
Energy storage systems play an essential role in the utilization of renewable energy. They are used to provide reserve power under different circumstances and needs such as peak shaving, load leveling, and ancillary services. Power electronics equipment converts the battery power into usable grid power. The course will survey batteries, pumped storage, flywheels, ultracapacitors, etc., with an analysis of the advantages and disadvantages, and uses of each. Also listed as ENGR 339. (2 units)

ECEN (ELEN) 288. Energy Management Systems
Energy Management Systems (EMS) is a class of control systems that electric utility companies utilize for three main purposes: monitoring, engagement, and reporting. Monitoring tools allow electric utility companies to manage their assets to maintain the sustainability and reliability of power generation and delivery. Engagement tools help in reducing energy production costs, transmission and distribution losses by optimizing utilization of resources and/or power network elements. Reporting tools to track operational costs and energy obligations. Also listed as CSEN (COEN) 282. (2 units)

ECEN (ELEN) 289. Topics in Energy Systems
Various topics (2 units)

ECEN (ELEN) 296. Independent Study
Supervised study of specialized and/or advanced topics not covered by current course offerings. By arrangement. (1-6 units)

ECEN (ELEN) 297. Master's Thesis Research
By arrangement. Limited to department majors only (1–9 units)

ECEN (ELEN) 298. Ph.D. Thesis Research
By arrangement. Limited to department Ph.D. students only. A nominal number of 36 units is expected toward the Ph.D. degree. (1–15 units per quarter)

ECEN (ELEN) 299. Directed Research
Supervised research not requiring a thesis. Limited to department majors only. By arrangement. (1–6 units)

ECEN (ELEN) 329. Introduction to Intelligent Control
Intelligent control, AI, and system science. Adaptive control and learning systems. Artificial neural networks and Hopfield model. Supervised and unsupervised learning in neural networks. Fuzzy sets and fuzzy control. Also listed as MECH 329. Prerequisite: ECEN (ELEN) 236. (2 units)

ECEN (ELEN) 330. Introduction to Stochastic Control for Supply and Demand Network
Managing inventories plays an important role in supply and demand network optimization. This course covers basic inventory models. The foundations needed to characterize optimal policies using deterministic and stochastic control strategies. Markov chain. Optimal control. Stochastic control. Prerequisites: Statistics, Probability, ECEN (ELEN) 238 or equivalent. (2 units)

ECEN (ELEN) 331. Autonomous Driving Systems
This course introduces students to autonomous driving systems. Through lectures, labs, and assignments, students will gain hands-on experience on the major modules of the system including localization, sensor fusion, perception, detection, segmentation, scene understanding, tracking, prediction, path planning, control, routing, and decision making. Prerequisites: First-year graduate standing in ECEN, CSEN or MECH and knowledge of programming. (2 units)

ECEN (ELEN) 331L. Autonomous Driving Systems Lab
Lab for Autonomous Driving Systems, ECEN (ELEN) 331. (1 unit)

ECEN (ELEN) 333. Digital Control Systems
Difference equations. Sampling. Quantization. Z-transform. Transfer functions. State-Space models. Controllability and observability. Stability. Pole-placement by feedback. Frequency response methods. Prerequisites ECEN (ELEN) 230 or 236. (2 units)

ECEN (ELEN) 334. Introduction to Statistical Signal Processing
Introduction to statistical signal processing concepts. Random variables, random vectors, and random processes. Second-moment analysis, estimation of first and second moments of a random process. Linear transformations; the matched filter. Spectral factorization, innovation representations of random processes. The orthogonality principle. Linear predictive filtering; linear prediction and AR models. Levinson algorithm. Burg algorithm. Prerequisites: AMTH 211 and ECEN (ELEN) 233 or ECEN (ELEN) 233E. (2 units)

ECEN (ELEN) 335. Estimation II
Introduction to Bayesian estimation. Minimum mean square error estimator (MMSE), Maximum a posteriori estimator (MAP). Wiener filter and Kalman filter. Prerequisite: ECEN (ELEN) 235. (2 units)

ECEN (ELEN) 336. Detection
Hypothesis testing. Neyman-Pearson lemma. Generalized matched filter. Detection of deterministic and random signals in Gaussian and non-Gaussian noise environments. Prerequisite: AMTH 362, ECEN (ELEN) 243, or ECEN (ELEN) 335. (2 units)

ECEN (ELEN) 337. Robotics I
Overview of robotics: control, AI, and computer vision. Components and structure of robots. Homogeneous transformation. Forward kinematics of robot arms. Denavit-Hartenberg representation. Inverse kinematics. Velocity kinematics. Manipulator Jacobian. Singular configurations. Euler Lagrange equations. Dynamic equations of motion of manipulators. Task planning, path planning, and trajectory planning in the motion control problem of robots. Also listed as MECH 337. Prerequisite: AMTH 245. (2 units)

ECEN (ELEN) 338. Robotics II
Joint-based control. Linear control of manipulators. PID control and set-point tracking. Method of computer-torque in trajectory following control. Also listed as MECH 338. Prerequisites: ECEN (ELEN) 236 and 337. (2 units)

ECEN (ELEN) 339. Robotics III

Intelligent control of robots. Neural networks and fuzzy logic in robotic control. Selected topics of current research in robotics. Also listed as MECH 339. Prerequisite: ECEN (ELEN) 338. (2 units)

ECEN (ELEN) 345. Phase-Locked Loops

Basic loop. Components. Describing equations. Stability. Transients. Modulation and demodulation. Prerequisite: ECEN (ELEN) 130. (2 units)

ECEN (ELEN) 347. Advanced Digital Communication Systems

Receiver design, equalizers, and maximum likelihood sequence detection. Modulation and receiver design for wireline and wireless communications. Particular emphasis on intersymbol interference and equalizers. Offered every other year. Prerequisite: ECEN (ELEN) 243. (2 units)

ECEN (ELEN) 348. FPGA for Communications Applications

This course is a project-based course to introduce students to architectures and implementations of Field-Programmable Gate Arrays (FPGAs) for DSP for communications applications. Examples of a final project include implementing a significant application in communications such as Software-Defined Radio (SDR) or, Wi-Fi. Prerequisites: ECEN (ELEN) 226 and 247. (2 units)

ECEN (ELEN) 351. RF Integrated Circuit Design

Introduction to RF terminology, technology tradeoffs in RFIC design. Architecture and design of radio receivers and transmitters. Low noise amplifiers, power amplifiers, mixers, oscillators, and frequency synthesizers. Prerequisites: ECEN (ELEN) 252 and 387. (2 units)

ECEN (ELEN) 352. Mixed Signal IC Design for Data Communications

Design and analysis of mixed-signal circuits for data communications. Introduction to data communications terminology and signaling conventions. Data transmission media, noise sources. Data transceiver design: Signal coding/decoding, transmit signal waveshaping, receive equalization. Timing Circuits: Clock generation and recovery techniques. Prerequisites: ECEN (ELEN) 252 and 387. (2 units)

ECEN (ELEN) 353. DC to DC Power Conversion

Basic buck, boost, and buck-boost DC to DC converter topologies in both continuous and discontinuous conduction modes (CCM and DCM). Analog and digital controlled pulse width modulation techniques. Efficiency and control loop stability analysis. Critical MOSFET parameters and non-ideal circuit behavior will be studied using time and frequency domain computer modeling. Prerequisites: ECEN (ELEN) 230 and ECEN (ELEN) 252 or 116. (2 units)

ECEN (ELEN) 354. Advanced RFIC Design

Design and analysis of passive circuits (filters, splitters, and couplers), Gilbert cell mixers, low phase noise VCOs, frequency translators, and amplifiers. Advanced simulation methods, such as envelope and time domain simulations. Class project designed to meet specifications, design rules, and device models of RFIC foundry. Prerequisite: ECEN (ELEN) 351. (2 units)

ECEN (ELEN) 359. Advanced Topics in Circuit Design

Various topics. (2 units)

ECEN (ELEN) 360. Nanomaterials

Physics, chemistry, and materials science of materials in the nanoscale. Thin films, inorganic nanowires, carbon nanotubes, and quantum dots are examples covered in detail as well as state-of-the-art synthesis processes and characterization techniques for these materials as used in various stages of technology development. Also listed as ENGR 262. Prerequisites: ENGR 260 and ECEN (ELEN) 261. (2 units)

ECEN (ELEN) 361. Nanoelectronics

Silicon-based technology in the sub-90nm regime. General scaling trend and ITRS Roadmap. Novel device architectures, logic and memory nanodevices, critical enabling device design and process technologies, interconnects, molecular electronics, and their potential usage in future technology nodes. Prerequisite: ECEN (ELEN) 265 or ECEN (ELEN) 267. (2 units)

ECEN (ELEN) 375. Semiconductor Surfaces and Interfaces

Structural and electronic properties of semiconductor surfaces, semiconductor/oxide interfaces, and metal/semiconductor interfaces. Relationship between interface morphology/composition and electrical properties. Modern techniques for characterizing surfaces and interfaces. Derivation of interface properties from electrical characterization of devices. Prerequisite: ECEN (ELEN) 265 or ECEN (ELEN) 267. (2 units)

ECEN (ELEN) 379. Topics in Micro/Nanoelectronics

Various Topics. (2 units)

ECEN (ELEN) 380. Economics of Energy

The focus of the course is the finances of power and energy, including applications of blockchain ledgers, and transactive energy. Roles of policy, regulation and markets that govern production and supply of electricity will be examined. Operational aspects of making and moving electricity are discussed and Levelized Cost of Energy (LOCE) models are developed. Distributed resource management, power flow optimization and integration of large-scale renewables will be considered. Prerequisite: ECEN (ELEN) 183 or ECEN (ELEN) 281A and ECEN (ELEN) 281B. (2 units)

ECEN (ELEN) 387. VLSI Design I

Introduction to VLSI design and methodology. Analysis of CMOS integrated circuits. Circuit modeling and performance evaluation supported by simulation (SPICE). Ratioed, switch, and dynamic logic families. Design of sequential elements. Full-custom layout using CAD tools. Also listed as CSEN (COEN) 203. Prerequisite: CSEN (COEN)/ECEN (ELEN) 127 or equivalent. (2 units)

ECEN (ELEN) 388. VLSI Design II

Continuation of VLSI design and methodology. Design of arithmetic circuits and memory. Comparison of semi-custom versus fully custom design. General concept of floor planning, placement, and routing. Introduction of signal integrity through the interconnect wires. Also listed as COEN (CSEN) 204. Prerequisite: CSEN (COEN) 203/ECEN (ELEN) 387 or equivalent, or ECEN (ELEN) 153. (2 units)

ECEN (ELEN) 389. VLSI Physical Design

Physical design is the phase that follows logic design, and it includes the following steps that precede the fabrication of the IC logic partitioning: cell layout, floor planning, placement, routing. These steps are examined in the context of very deep submicron technology. Effects of parasitic devices and packaging are also considered. Power distribution and thermal effects are essential issues in this design phase. Also listed as CSEN (COEN) 305. Prerequisite: CSEN (COEN) 204/ECEN (ELEN) 388 or equivalent. (2 units)

ECEN (ELEN) 390. Semiconductor Device Technology Reliability

Reliability challenges in device design, fabrication technology, and test methodology. Device design issues such as design tolerances for latch-up, hot carrier injection, and electromigration. Fabrication technology challenges for sub-micron processes. Test methodology in terms of design feasibility and high-level test/fault coverage. IC yield models and yield enhancement techniques. (2 units)

ECEN (ELEN) 391. Process and Device Simulation with Technology Computer Aided Design (TCAD)

Review of semiconductor technology fundamentals. TCAD tools and methods as a design aid for visualizing physical device quantities at different stages of design and influencing device process parameters and circuit performance. Introduction to numerical simulation and TCAD, 2D process and device simulation, CMOS process flow and device design, device characterization and parameter extraction, circuit simulation. Introduction to virtual IC factory concept, integration of process, device and circuit simulation tools. The concept of process variation, statistical analysis and modeling methods, such as Monte Carlo sampling, correlation analysis, response surface modeling. Prerequisite: ECEN (ELEN) 274. (2 units)

ECEN (ELEN) 421. Speech Coding I

Review of sampling and quantization. Introduction to Digital Speech Processing. Elementary principles and applications of speech analysis, synthesis, and coding. Speech signal analysis and modeling. The LPC Model. LPC Parameter quantization using Line Spectrum Pairs (LSPs). Digital coding techniques: Quantization, Waveform coding.

Predictive coding, Transform coding, Hybrid coding, and Sub-band coding. Applications of speech coding in various systems. Standards for speech and audio coding. Also listed as CSEN (COEN) 348. Prerequisite: ECEN (ELEN) 233 and/or 334 or equivalent. (2 units)

ECEN (ELEN) 422. Speech Coding II

Advanced aspects of speech analysis and coding. Analysis-by-Synthesis (AbS) coding of speech, Analysis-as-Synthesis (Aas) coding of speech. Code-Excited Linear Prediction speech coding. Error-control in speech transmission. Application of coders in various systems (such as wireless phones). International Standards for Speech (and Audio) Coding. Real-Time DSP implementation of speech coders. Speech recognition and Biometrics. Research project on speech processing. Also listed as CSEN (COEN) 349. Prerequisite: ECEN (ELEN) 421. (2 units)

ECEN (ELEN) 423. Introduction to Voice-over-IP

Overview of voice encoding standards relevant to VoIP: G.711, G.726, G.723.1, G.729, G.729AB. VoIP packetization and signaling protocols: RTP/RTCP, H.323, MGCP/MEGACO, SIP. VoIP impairments and signal processing algorithms to improve QoS. Echo cancellation, packet loss concealment, adaptive jitter buffer, Decoder clock synchronization. Network convergence: Soft-switch architecture, VoIP/PSTN, interworking (Media and Signaling Gateways), signaling translation (SS7, DTMF/MF, etc.), fax over IP. Prerequisite: ECEN (ELEN) 233 or knowledge of basic digital signal processing concepts. (2 units)

ECEN (ELEN) 431. Adaptive Signal Processing I

Theory of adaptive filters, Wiener filters, the performance surface, gradient estimation. The least-mean-square (LMS) algorithm, other gradient algorithms, transform-domain LMS adaptive filtering, block LMS algorithm. IIR adaptive filters. The method of least squares. Recursive least squares (RLS) adaptive transversal filters; application of adaptive filters in communications, control, radar, etc. Projects. Prerequisites: ECEN (ELEN) 233 and ECEN (ELEN) 334 or AMTH 362 or knowledge of random processes. (2 units)

ECEN (ELEN) 431E. Adaptive Signal Processing I and II

Same description as ECEN (ELEN) 431 and ECEN (ELEN) 432. Prerequisite: ECEN (ELEN) 334 or AMTH 362 or knowledge of random processes. (4 units)

ECEN (ELEN) 432. Adaptive Signal Processing II

Linear prediction. Recursive least squares lattice filters. Applications of Kalman filter theory to adaptive transversal filters. Performance analysis of different algorithms. Fast algorithms for recursive least squares adaptive transversal filters. Applications of adaptive filters in communications, control, radar, etc. Projects. Offered in alternative years. Prerequisite: ECEN (ELEN) 431. (2 units)

ECEN (ELEN) 439. Topics in Adaptive Signal Processing

Various topics. (2 units)

ECEN (ELEN) 441. Communications Satellite Systems Engineering

Satellite systems engineering considerations. Spacecraft. Satellite link design. Communication systems techniques for satellite links. Propagation on satellite-earth paths. Earth station technology. Prerequisite: ECEN (ELEN) 243 or equivalent. (2 units)

ECEN (ELEN) 444. Error-Correcting Codes

Theory and implementation of error-correcting codes. Linear block codes, cyclic codes. Encoding and decoding techniques and implementations analysis of code properties and error probabilities. Offered in alternate years. Prerequisite: Knowledge of probability. (2 units)

ECEN (ELEN) 446. Introduction to Wireless Communication Systems

Overview of digital communications. Topics include bit rate and error performance. Long-term and short-term propagation effects. Link budgets. Diversity techniques. Prerequisite: Knowledge of random processes, AMTH 210, ECEN (ELEN) 241 or its equivalent. (2 units)

ECEN (ELEN) 446E Wireless Communications and Networking

This course combines the topics found in ECEN (ELEN) 446 and ECEN (ELEN) 447 into one 4-unit course. (4 units)

ECEN (ELEN) 447. Wireless Network Architecture

Issues in wireless management. Topics include: multiple access techniques, cellular and local area network standards, scheduling of users, handoff and channel assignment. Prerequisite: ECEN (ELEN) 446 or equivalent. (2 units)

ECEN (ELEN) 460. Advanced Mechatronics I

Theory of operation, analysis, and implementation of fundamental physical and electrical device components: basic circuit elements, transistors, op-amps, sensors, electro-mechanical actuators. Application to the development of simple devices. Also listed as MECH 207. Prerequisite: MECH 141 or ECEN (ELEN) 100. (3 units)

ECEN (ELEN) 461. Advanced Mechatronics II

Theory of operation, analysis, and implementation of fundamental controller implementations: analog computers, digital state machines, microcontrollers. Application to the development of closed-loop control systems. Also listed as MECH 208. Prerequisites: ECEN (ELEN) 460 or MECH 207, and MECH 217. (3 units)

ECEN (ELEN) 462. Advanced Mechatronics III

Electro-mechanical modeling and system development. Introduction to mechatronic support subsystems: power, communications. Fabrication techniques. Functional implementation of hybrid systems involving dynamic control and command logic. Also listed as MECH 209. Prerequisite: MECH 208 or ECEN (ELEN) 461. (2 units)

ECEN (ELEN) 500. Logic Analysis and Synthesis

Analysis and synthesis of combinational and sequential digital circuits with attention to static, dynamic, and essential hazards. Algorithmic techniques for logic minimization, state reductions, and state assignments. Decomposition of state machine, algorithmic state machine. Design for test concepts. Also listed as CSEN (COEN) 200. Prerequisite: ECEN (ELEN) 127C or equivalent. (2 units)

ECEN (ELEN) 501. Embedded Systems

Embedded Systems are computing systems that measure, control, and interact. This course considers cost, speed, and power optimizations in design. The course and accompanying lab will create real systems with physical device interfaces and consider real-time behaviors. The course will design with embedded development environments, and explore bare-metal programming and debugging techniques, and embedded system validation. Co-requisite: ECEN (ELEN) 501L. (2 units)

ECEN (ELEN) 501L. Embedded Systems Lab

Lab projects based on an embedded computer module to practical applications that reinforce class concepts and provide some opportunities for creative design. Co-requisite: ECEN (ELEN) 501. (1 unit)

ECEN (ELEN) 502. Real-Time Systems

Formal methods and practical solutions related to embedded computing systems with time-critical deadlines. This includes hard real-time systems such as vehicular control and industrial machinery as well as soft real-time systems such as audio streaming or video games. Distributed real-time, timing analysis, and adaptation. Prerequisites: A grade of C- or better in ECEN (ELEN) 501 or equivalent. (2 units)

ECEN (ELEN) 503. Hardware-Software Codesign

The design, analysis, and verification of mixed hardware-software systems focusing on underlying modeling concepts, the design of hardware-software interfaces, hardware/software partitioning, and the trade-offs between hardware and software components. Real-time operating systems, hardware/software project management, and documentation. Co-simulation and mixed-mode testing and verification. Prerequisite: A grade of C- or better in ECEN (ELEN) 502 or equivalent. (2 units)

ECEN (ELEN) 510. Computer Architecture Fundamentals

Computer instruction definition and formatting, the use of opcodes and operands. Instruction execution, control transfer. Pipelining. Hazards. Caches. Prerequisites: A grade of C- or better in either CSEN (COEN) or ECEN (ELEN) 21, or equivalent. (2 units)

ECEN (ELEN) 511. Advanced Computer Architecture

Advanced architectural concepts built upon fundamentals. Superscalar and out-of-order execution. Memory system implementation concepts. DMA and virtual memory. Multiprocessing, including multi-core and multi-threaded architectures. Shared memory and cache coherence. Prerequisite: ECEN (ELEN) 122 or CSEN (COEN) 122 or ECEN (ELEN) 510 or equivalent. (2 units)

ECEN (ELEN) 512. Advanced Computer Architecture II

Continuation of advanced architectural concepts. Hardware support for virtualization. CPU microarchitecture concepts such as branch prediction and non-blocking caches. More on cache coherence protocols. Multi-level cache hierarchies. Memory consistency and synchronization. Prerequisite: ECEN (ELEN) 511 or equivalent. (2 units)

ECEN (ELEN) 513. Parallel System Architectures

Exploration of alternative computing architectures and their uses. SIMD computing. GPUs. Deep Learning accelerators. Warehouse-scale computing. Prerequisite: ECEN (ELEN) 511 or equivalent. (2 units)

ECEN (ELEN) 519. Special Topics in Advanced Computer Architecture

Support for virtual memory, shared memory synchronization, transactional memory, multithreading, chip multiprocessors, deep learning, SIMD, warehouse-scale computing. (2 units)

ECEN (ELEN) 520. Introduction to Machine Learning

Classification models, cross-validation; supervised learning, linear and logistic regression, support vector machines; unsupervised learning, dimensionality reduction methods; tree-based methods, and kernel methods, principal component analysis, K-means; reinforcement learning. Prerequisites: Python programming, elementary statistics. Co-requisites: ECEN (ELEN) 520L, (2 units)

ECEN (ELEN) 520L. Introduction to Machine Learning Laboratory

Laboratory component of ECEN (ELEN) 520. Co-requisite: ECEN (ELEN) 520. (1 unit)

ECEN (ELEN) 521. Deep Learning

Convolutional neural networks; analysis of selected architectures: GoogleNet, ResNet, Moblenet, Capsule networks; transfer learning; recurrent neural networks and applications; autoencoders; adversarial generative networks. Prerequisite: ECEN (ELEN) 520. Co-requisite: ECEN (ELEN) 521L. (2 units)

ECEN (ELEN) 521L. Deep Learning Laboratory

Laboratory component of ECEN (ELEN) 521. Co-requisite: ECEN (ELEN) 521. (1 unit)

ECEN (ELEN) 522. Reinforcement Learning

Introduction to the foundational ideas of reinforcement learning, which provides a way to model the interaction of autonomous agents with the world and emphasizes learning without supervision, and often without any knowledge of the rules of the task it is trying to learn; Markov decision processes, value functions, Monte Carlo estimation, dynamic programming, temporal difference learning, function approximation, scaling to large domains. Prerequisite: ECEN (ELEN) 521. (3 units)

ECEN (ELEN) 523. Natural Language Processing with Deep Learning

Computational properties of natural language; simple word level to syntactic level; design and implementation of neural network models used in NLP for applications such as question answering, language translation, language understanding, and natural language generation. Prerequisite: ECEN (ELEN) 521. (2 units)

ECEN (ELEN) 530. Hardware Security and Trust

New techniques for securing hardware from malicious attacks. Hardware security primitives. Hardware Trojan detection and prevention. Hardware-based obfuscation techniques. Side-channel attacks and countermeasures. Cryptographic algorithms. FPGA security. Hardware Metering. Watermarking. IP piracy. IoT security. Counterfeit detection and prevention. Prerequisite: ECEN (ELEN) 127 OR ECEN (ELEN) 603 with a grade of C- or better. (2 units)

ECEN (ELEN) 601. Low Power Designs of VLSI Circuits and Systems

Design of digital circuits for reduced power consumption. Sources of power consumption in ICs and analysis algorithms for their estimation at different stages of design. Various power reduction techniques and their trade-offs with performance, manufacturability, and cost are analyzed. Project to design a digital circuit with power reduction as the primary objective. Prerequisite: ECEN (ELEN) 387. (2 units)

ECEN (ELEN) 602. Modern Time Analysis

Analysis in logic design review of background materials and introduction of concepts of false path, combinational delay, and minimum cycle time of finite state machines. Study of efficient computational algorithms. Examination of retiming for sequential circuits, speed/area trade-off. Prerequisite: ECEN (ELEN) 500. (2 units)

ECEN (ELEN) 603. Logic Design Using HDL

Algorithmic approach to design of digital systems. Use of hardware description languages for design specification. Structural, register transfer, and behavioral views of HDL. Simulation and synthesis of systems descriptions. Also listed as CSEN (COEN) 303. Prerequisite: ECEN (ELEN) 127 or equivalent. (2 units)

ECEN (ELEN) 608. Design for Testability

Principles and techniques of designing circuits for testability. Concept of fault models. The need for test development. Testability measures. Ad hoc rules to facilitate testing. Easily testable structures, PLAs. Scan-path techniques, full and partial scan. Built-in self-testing (BIST) techniques. Self-checking circuits. Use of computer-aided design (CAD) tools. Also listed as CSEN (COEN) 308. Prerequisite: ECEN (ELEN) 500 or equivalent. (2 units)

ECEN (ELEN) 609. Mixed-Signal DA and Test

Mixed-Signal test techniques using PLL and behavioral testing as major examples. Overview of the IEEE 1149.4 Mixed-Signal standard. Mixed-Signal DFT and BIST techniques with emphasis on test economics. Most recent industrial mixed-signal design and test EDA tools and examples of leading state-of-the-art SoCs. Prerequisites: ECEN (ELEN) 500 or CSEN (COEN) 200 and ECEN (ELEN) 387 or CSEN (COEN) 203. (2 units)

ECEN (ELEN) 613. SoC (System-on-Chip) Verification

This course presents various state-of-the-art verification techniques used to ensure the corrections of the SoC (System-on-Chip) design before committing it to manufacturing. Both Logical and Physical verification techniques will be covered, including Functional Verification, Static Timing, Power, and Layout Verification. Also, the use of Emulation, Assertion-based Verification, and Hardware/Software Co-Verification techniques will be presented. Also listed as COEN 207. Prerequisites: ECEN (ELEN) 500 or CSEN (COEN) 200 and ECEN (ELEN) 603 or equivalent. (2 units)

ECEN (ELEN) 617. Storage Systems – Technology and Architecture

The course will address the developments in storage systems. Increase in data storage has led to an increase in storage needs. This arises from the increase of mobile devices as well as increase in internet data storage. This course will provide the students good knowledge of different storage systems as well as challenges in data integrity. A discussion of the next generation of storage devices and architectures will also be done. (2 units)

ECEN (ELEN) 620. Digital Systems Design Project

By arrangement. An individual or group project that progresses through multiple phases of a complete design flow, leveraging and applying concepts learned in other courses. Projects can be pure hardware designs, or hardware/software co-designs. Prerequisites: ECEN (ELEN) 501, ECEN (ELEN) 511, ECEN (ELEN) 603. (1-6 units)

ECEN (ELEN) 624 Signal Integrity in IC and PCB Systems

Analysis, modeling, and characterization of interconnects in electronic circuits; Transmission line theory; losses and frequency dependent parameters. Signal Integrity issues in high-speed/high-frequency circuits; means of identifying signal integrity problems. Reflection and crosstalk; analysis of coupled-line systems. Power distribution networks in VLSI and PCB environments and power integrity. Signal/Power integrity CAD. Prerequisite: ECEN (ELEN) 201. (2 units)

ECEN (ELEN) 639. Audio and Speech Compression

Audio and speech compression. Digital audio signal processing fundamentals. Non-perceptual coding. Perceptual coding. Psychoacoustic model. High-quality audio coding. Parametric and structured audio coding. Audio coding standards. Scalable audio coding. Speech coding. Speech coding standards. Also listed as CSEN (COEN) 339. Prerequisites: AMTH 245 and CSEN (COEN) 279 or equivalent. (2 units)

ECEN (ELEN) 640. Digital Image Processing I

Digital image representation and acquisition, color representation; point and neighborhood processing; image enhancement; morphological filtering; Fourier, cosine and wavelet transforms. Also listed as CSEN (COEN) 340. Prerequisite: ECEN (ELEN) 233 or equivalent. (2 units)

ECEN (ELEN) 641. Image and Video Compression

Image and video compression. Entropy coding. Prediction. Quantization. Transform coding and 2-D discrete cosine transform. Color compression. Motion estimation and compensation. Digital video. Image coding standards such as JPEG and JPEG family. Video coding standards such as the MPEG series and the H.26x series. H.264/MPEG-4 AVC coding. HEVC/H 265/MPEG-H Part 2 coding. VVC. Future JVET standard Rate-distortion theory and optimization. Visual quality and coding efficiency. Brief introduction to 3D video coding and 3D-HEVC. Deep learning approaches. Applications. Also listed as CSEN (COEN) 338. Prerequisites: AMTH 108, AMTH 245, basic knowledge of algorithms. (4 units)

ECEN (ELEN) 642. Computational and Medical Imaging

Algorithms for indirect image formation using both optimization and model-based methods. Application includes computed tomography, magnetic resonance imaging, microscopy, remote sensing, super-resolution. Fourier-based and sparse iterative algorithms. Analysis of accuracy and resolution of image formation based on measurement geometry and statistics. Offered in alternate years. Also listed as BIOE 642. Prerequisites: AMTH 211 and either ECEN (ELEN) 233 or AMTH 358 or equivalent. (2 units)

ECEN (ELEN) 643. Digital Image Processing II

Image restoration using least squares methods in image and spatial frequency domains; matrix representations; blind deconvolution; super-resolution methods; reconstructions from incomplete data; image segmentation methods, three-dimensional models from multiple views. Also listed as CSEN (COEN) 343. Prerequisite: CSEN (COEN) 340. (2 units)

ECEN (ELEN) 644. Computer Vision I

Introduction to image understanding, feature detection, description, and matching; feature based alignment; structure from motion stereo correspondence. Also listed as CSEN (COEN) 344. Prerequisites: ECEN (ELEN) 640 and knowledge of linear algebra. (2 units)

ECEN (ELEN) 645. Computer Vision II

Learning and inference in vision; regression models; deep learning for vision; classification strategies; detection and recognition of objects in images. Also listed as CSEN (COEN) 345. Prerequisites: ECEN (ELEN) 640 and knowledge of probability. (2 units)

ECEN (ELEN) 649. Topics in Image Processing and Analysis

Various topics. (2 units)

ECEN (ELEN) 701. RF and Microwave Systems

The purpose of this class is to introduce students to the general hardware components, system parameters, and architectures of RF and microwave wireless systems. Practical examples of components and system configurations are emphasized. Communication systems are used to illustrate the applications. Other systems, such as radar, the global positioning system (GPS), RF identification (RFID), and direct broadcast systems (DBS) are introduced. (2 units)

ECEN (ELEN) 706. Microwave Circuit Analysis and Design

Microwave circuit theory and techniques. Emphasis on passive microwave circuits. Planar transmission lines. Field problems formulated into network problems for TEM and other structures, scattering and transmission parameters,

Smith chart, impedance matching, and transformation techniques. Design of power dividers, couplers, hybrids and microwave filters. Microwave CAD. Prerequisite: ECEN (ELEN) 201. (4 units)

ECEN (ELEN) 711. Active Microwave Devices I
Scattering and noise parameters of microwave transistors, physics of silicon bipolar and gallium arsenide MOSFET transistors, device physics, models, and high-frequency limitations. Applications to microwave amplifier and oscillator designs. Prerequisite: ECEN (ELEN) 706. (2 units)

ECEN (ELEN) 712. Active Microwave Devices II
Continuation of ECEN (ELEN) 711. Nonlinear active circuits and computer-aided design techniques. Nonlinear models of diodes, bipolar transistors and FET's applied to the design of frequency converters, amplifiers, and oscillators. Techniques. Prerequisite: ECEN (ELEN) 711. (2 units)

ECEN (ELEN) 715. Antennas I
Fundamentals of radiation, antenna pattern, directivity and gain. Dipole and wire antennas. Microstrip Patch Antennas. Broadband antennas. Antennas as components of communications and radar systems. Antenna measurement. Antenna CAD. Prerequisite: ECEN (ELEN) 201. (2 units)

ECEN (ELEN) 715E Antenna Theory and Design
This course combines the topics found in ECEN (ELEN) 715 and ECEN (ELEN) 716 (both 2 unit courses) into one 4-unit course. Fundamentals of radiation, antenna pattern, directivity and gain. Dipole and wire antennas. Microstrip Patch Antennas. Broadband antennas. Antennas as components of communications and radar systems. Aperture antennas. Traveling-wave antennas. Antenna Arrays. Linear arrays with uniform and non-uniform excitations. Beam scanning and phased arrays; Planar arrays; Array Synthesis.

ECEN (ELEN) 716. Antennas II
Continuation of ECEN (ELEN) 715. Aperture antennas. Traveling-wave antennas. Antenna Arrays. Linear arrays with uniform and non-uniform excitations. Beam scanning and phased arrays; Planar arrays; Array Synthesis. Prerequisite: ECEN (ELEN) 715. (2 units)

ECEN (ELEN) 717. Antennas III
Continuation of ECEN (ELEN) 716. Reflector, and lens antennas. Large antenna design. High-frequency techniques. Geometrical optics. Physical optics. Diffraction. Antenna synthesis. Offered in alternate years. Prerequisite: ECEN (ELEN) 716. (2 units)

ECEN (ELEN) 725. Optics Fundamentals
Fundamental concepts of optics: geometrical and wave optics. Optical components—free space, lenses, mirrors, prisms. Optical field and beams. Coherent (lasers) and incoherent (LED, thermal) light sources. Elements of laser engineering. Optical materials. Fiber optics. Polarization phenomena and devices. Also listed as PHYS 113. Prerequisite: ECEN (ELEN) 201 or equivalent. (4 units)

ECEN (ELEN) 726. Microwave Measurements, Theory, and Techniques
Theory comprises six classroom meetings covering signal flow graphs, error models and corrections, S-parameter measurements, Vector analyzers, microwave resonator measurements, noise figure measurements, signal generation and characterization, spectrum analyzers, and phase noise measurements. Four laboratory meetings. Offered in alternate years. Prerequisite: ECEN (ELEN) 711. (3 units)

ECEN (ELEN) 729. Topics in Electromagnetics and Optics
Selected advanced topics in electromagnetic field theory. Prerequisite: As specified in class schedule. (2 units)

ECEN (ELEN) 809. Special Topics in Human-Machine Interaction
Selected advanced topics in Human-Machine Interaction. Prerequisite: As specified in class schedule. (4 units)

ECEN (ELEN) 921C. Introduction to Logic Design
Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flip-flops; timing; registers;

counters. Introduction to FPGAs and the need for the use of HDL. Taught in the graduate time format. Foundation course not for graduate credit. Also listed as CSEN (COEN) 921C. (2 units)

Chapter 12: Department of Engineering

The Graduate Core is one of the distinguishing features of the Master's program at Santa Clara University. Because of its breadth and interdisciplinary nature, the Core requires courses that transcend departmental boundaries, and address questions that relate to the societal impact of engineering, as well as ways in which this impact can be shaped. We offer a wide range of such courses, which are designated with the prefix ENGR (to emphasize the fact that they belong to the category of General Engineering).

Course Descriptions

ENGR 238 Critical Tools for Social and Environmental Projects

This class offers vital tools for completing projects in unfamiliar communities and/or cultures. Students will learn how to read and understand the human and environmental ecosystem where they and their projects are immersed and incorporate this information into their design process to develop solutions that are socially, economically, and environmentally appropriate. Students will also learn how to implement a quick "need assessment evaluation" to uncover the scope, depth, impact and local perception of the need they will solve, while familiarizing themselves with approaches and tools for problem-solving and innovation. Also listed as ENGR 138. Prerequisite: Graduate standing (2 units)

ENGR 245 Innovation, Entrepreneurship, and the Evolution of Silicon Valley

This course will explore technological innovation by studying the evolution of technologies and industries in Silicon Valley. We will review the development of fundamental technologies such as vacuum tubes, semiconductors, and biotechnology, and systems such as radar, communications, aerospace, personal computing, the internet, social media and platforms. This approach will help students to understand 1) the defining features of this region and how it has continued to lead in global technology development even as the fundamental technologies have changed, and 2) the complexity of the innovation process and the influence of the public sector, academia, investors, and other entities on innovation and entrepreneurship. Also listed as ENGR 145. (4 units)

ENGR 256. Introduction to NanoBioengineering

This course is designed to present a broad overview of diverse topics in nanobioengineering, with emphasis on areas that directly impact applications in biotechnology and medicine. Specific examples that highlight interactions between nanomaterials and various biomolecules will be discussed, as well as the current status and future possibilities in the development of functional nanohybrids that can sense, assemble, clean, and heal. Also listed as BIOE 256. (2 units)

ENGR 257. Introduction to Biofuels Engineering

This course will cover the basic principles used to classify and evaluate biofuels in terms of thermodynamic and economic efficiencies as well as environmental impact for resource recovery. Special emphasis will be placed on emerging applications, namely Microbial Fuel Cell Technology and Photo-bioreactors. Also listed as BIOE 157/257. Prerequisite: BIOE 21 or BIOL 1B, CHEM 13, PHYS 33. (2 units)

ENGR 260. Nanoscale Science and Technology

Overview of key elements of physics, chemistry, biology, and engineering underlying this interdisciplinary field. Bulk vs. surface properties of materials. Surface phenomena and quantum phenomena. Self-assembly and soft lithography. Nanoscale materials characterization. Carbon nanotubes, inorganic nanowires, organic molecules for electronics, biological and bio-inspired materials. Emerging applications of nanoscale materials. Prerequisite: Graduate standing. (2 units)

ENGR 261. Nanotechnology and Society

Addresses the fundamental scientific and technological underpinnings of the important new field of nanotechnology. Examines how our understanding and our technological capabilities have evolved over the past century, and how nanotechnology proposes new applications that can address social and economic goals. An appreciation of the interaction between these goals and the evolution of the technology is central to the course. Students will develop critical thinking about the prospects for nanotechnology in order to be able to assess the relevant ethical and social issues, and also the possibility and/or likelihood of the development of specific applications. (4 units)

ENGR 262. Nanomaterials

Physics, chemistry, and materials science of materials in the nanoscale. Thin films, inorganic nanowires, carbon nanotubes, and quantum dots are examples covered in detail as well as state-of-the-art synthesis processes and characterization techniques for these materials as used in various stages of technology development. Also listed as ECEN (ELEN) 360. Prerequisites: ENGR 260 and ECEN (ELEN) 261 or ECEN (ELEN) 151. (2 units)

ENGR 271. Energy Conservation

It is by no means clear that the shortage of carbon-free energy can be resolved by identifying alternative resources. As a result, conservation must play a key role in the development of new energy policies, both locally and globally. This course explores how conservation and sustainability relate to each other, with special emphasis on the value of cost-effective, innovative water recycling, and strategies for reducing the use of electrical energy. (2 units)

ENGR 272. Energy Public Policy

The class will survey the types of energy used historically from traditional biomass to coal, to natural gas, to nuclear and renewables, as well as the increasingly diverse possibilities for future use discussed in current policy debates. Coverage will also include a historical review of regulation and policy in the energy industry. The geographic scope will be international. The field of energy analysis and policy is inherently interdisciplinary. Prerequisite: ECEN (ELEN) 280/MECH 287. (2 units)

ENGR 273. Sustainable Energy and Ethics

This course explores the ethical implications of energy production, distribution, and consumption, with the aim of understanding those normative considerations that motivate public, institutional and private bodies to develop sustainable energy policies and practices. Through examination of texts and case studies, students will learn to critically analyze, develop and defend ethical judgments and practices with respect to energy. Topics include considerations of environmental justice; tension between global and local spheres of ethical concern; the rights and interests of potential stakeholders, both human and non-human; our duties with respect to prevention or mitigation of harms and management of risk; our ethical obligations to future generations; and the role of personal, civic and professional virtues in guiding sustainable energy practices. (2 units)

ENGR 288. Co-op Education

The primary purpose of Co-op education is to give students an opportunity to gain practical knowledge in their field of study. This course is designed to prepare them for such an experience, by providing the appropriate academic background that is required for an internship. It consists of a series of lectures on topics that will familiarize them with the Silicon Valley working environment and will enable them to relate their experience in the industry to their academic program. This course is required for all students who wish to enroll in ENGR 289 (Extended Co-op Education). Attendance is mandatory. (1 unit) Note: Engr 288 must be taken before you can start an internship and is not offered in the Summer quarter.

ENGR 289. MS Extended Co-op Education

Students who wish to do an academic internship must be enrolled in this class. The course may be taken for credit up to three times, and students are required to submit a final report in each quarter in which they are enrolled. The final report should focus on skills, experiences, and insights that they acquired in the current term. In order to get a passing grade, students must also submit a supervisor report, which evaluates their performance during the most recent ten-week period. Prerequisite: ENGR 288. (1 unit)

ENGR 293. Directed Research

Special research directed by a faculty member. By arrangement. Prerequisite: Registration requires the faculty member's approval. (1–6 units per quarter)

ENGR 302. Managing in the Multicultural Environment

Provides practical, theoretical, and experiential tools to manage a multicultural workforce. Cases from Silicon Valley engineering environments will be studied. Topics will include: (1) insights into various cultures' approaches to time, information, planning, decision making, relationships, power, and change; (2) developing leadership, motivation, and participation in multicultural teams; (3) creating an environment that maximizes the benefits of diversity and retains workers from a variety of cultural backgrounds; (4) resolving conflict when there are different cultural approaches; and (5) the role of corporate culture for multicultural and global companies. (2 units)

ENGR 303. Gender and Engineering

This course, based on brain science, culture, and communication, provides a foundation for managing the different worlds—the various cultural lenses, paradigms, and different competencies—many women and men bring to an engineering workplace. Gender Competence, effective management of differences increases "fire prevention," customer focus, and innovation in research, development, and marketing of products; and advancement of both women and men. (2 units)

ENGR 304. Building Global Teams

Challenges of working virtually and globally. Building global teams. Working across cultures and distance; achieving goals while managing differences. Diverse approaches to managing task, time, and hierarchy. Social interactions and decision-making. Culture's impact on teamwork. Global leader dimensions. Trust building. Empowering self and others. Business practices in China, India, Russia, and other countries. (2 units)

ENGR 306. Engineering and the Law

Exploration of legal issues affecting project engineers, contractors, and owners. Topics include structure of project teams, contracts, standard of care, insurance, and dispute resolution. Evolving legal issues with Integrated Project Delivery (IPD) and Building Information Modeling (BIM). (2 units)

ENGR 330. Law, Technology, and Intellectual Property

Study of available legal provisions for establishing, receiving, preserving, and enforcing intellectual property rights in research, development, engineering, and marketing of products. Includes a study of patents, trade secrets, copyrights, mask works, trademarks, and employer-employee contracts regarding intellectual property. (2 units)

ENGR 332. How Engineers, Businesspeople and Lawyers Communicate with Each Other

It can be challenging to communicate and collaborate effectively with people from different disciplines. This course will help students from business, engineering, and law learn to understand each other's perspectives, speak each other's language, and work together effectively in a collaborative environment. Students from different schools will be organized into teams to work together on a simulated project involving a technological matter, such as privacy/security or IP. Also listed as LAW 371. (3 units)

ENGR 334. Energy, Climate Change, and Social Justice

The field of climate ethics has emerged recently to negotiate the serious and complex ethical choices facing human society as we balance energy, environmental, and economic development needs. Social science and ethical lenses are used to examine energy use and climate disruption in light of the moral principle of social justice. This course gives graduate engineering students the background and skills to communicate these issues in several different modes. It consists of three main thematic parts: energy choices; social vulnerabilities; and difficult policy dilemmas. (2 units)

ENGR 336. Engineering for the Developing World

How does one innovate products and services for developing countries? How can complex problems be tackled with simple technologies and low-cost business models? This course presents a framework of engineering design and management techniques that are appropriate for developing markets. Topics such as "ruggedization," cost control, and local resource use will be explored through a variety of examples and case studies, which range from alternative energy and low-cost diagnostics to mobile applications and micro entrepreneurship. This course examines the potential social benefits that design, manufacturing, and business innovation can provide to address various challenges in the developing world. (2 units)

ENGR 337 Innovating with Impact - Social Entrepreneurship

Social Entrepreneurship is a rapidly growing discipline that harnesses the power of leadership, entrepreneurship, business, and social impact to address society's most pressing social challenges. This course is designed for students who want to explore and analyze social enterprises and gain in-depth insights into economic and social value creation across several different sectors including poverty alleviation, financial services, energy, and sustainability. In this class, students will also compare various social ventures and their approaches and learn to analyze and evaluate their impact, and formulate possible improvements to their models. Through case studies, lectures, classroom dialogue, and individual assignments, students will learn the root causes of social problems, and how to use the tools of business to create financial, social, and environmental value. (2 units)

ENGR 338. Mobile Applications for Emerging Markets

The mobile revolution is changing the lives of people across the globe, from Wall Street to Main Street to rural villages. This course will provide an overview of the technological innovation, including applications and instrumentation, which the mobile revolution is spawning, particularly in underserved communities globally. It will feature guest speakers from technology companies involved in Mobile R\&D, look at market and beneficiary needs, and discuss how to innovate products and services for these customers and how to tackle complex "life" problems with simple technologies, applications, and business models, using real-life case studies. (2 units)

ENGR 339. Energy Storage Systems

Energy storage systems play an essential role in the utilization of renewable energy. They are used to provide reserve power under different circumstances and needs such as peak shaving, load leveling, and ancillary services. Power electronics equipment converts the battery power into usable grid power. The course will survey batteries, pumped storage, flywheels, ultracapacitors, etc., with an analysis of the advantages and disadvantages, and uses of each. Also listed as ECEN (ELEN) 287. (2 units)

ENGR 340. Distributed & Renewable Energy

This course surveys energy engineering and entrepreneurship in emerging market countries, with an emphasis on strategies for coping with the absence of a grid. It analyzes strategies for energy generation, transmission, and storage at household, community and regional scales drawing from sector and case studies in the developing world. (2 units)

ENGR 341. Innovation, Design, and Spirituality

IDS provides opportunity for the SCU graduate engineering student to begin to integrate knowledge gained in other engineering coursework with innovation management, design thinking and spiritual development, particularly in entrepreneurial and intrapreneurial contexts, whether for commercial and/or social benefit. The 2-credit course assumes engineers play significant roles in innovation efforts in their future employments and deployments. As a result, IDS aims to deepen the engineering student's leadership character, competences and capacity, especially for these contexts and deployments. (2 units)

ENGR 342. 3D Print Technology and Society

This class is designed to introduce students to 3D print technology, which offers a range of exciting possibilities for product design, delivery, and democratization of entrepreneurship. Along with hands-on experience of the technology, students will be exposed to the ecosystem engaged by the technology. Implications for life sciences, career

opportunities, entrepreneurship, and restructuring of global markets and society will be examined. (2 units)

ENGR 350. Success in Global Emerging Markets

Strategies and tactics for moving new products and technologies into global emerging markets, comprehending cultural impact, and creating new markets. Understanding your company's objective, determining what is possible, and developing practical go-to-market strategies. Topics include new ventures, sustainability, social responsibility, risk assessment and mitigation. (2 units)

ENGR 351. New Paradigm for Technology-Global Mindfulness Leadership

The main purpose of this course is to examine the role that leadership and strategic vision play in a globalized interconnected business environment. Emphasis will be placed on developing critical thinking and collaborative skills through research projects and case studies. (2 units)

ENGR 371. Space Systems Design and Engineering I

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to orbital mechanics, power, command and data handling, and attitude determination and control. Note: ENGR 371 and 372 may be taken in any order. Also listed as MECH 371. (4 units)

ENGR 372. Space Systems Design and Engineering II

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to mechanical, thermal, software, and sensing elements. Note: ENGR 371 and 372 may be taken in any order. Also listed as MECH 372. (4 units)

ENGR 389. Ph.D. Extended Co-op Education

Ph.D. students who have passed their comprehensive examination and have the approval of their thesis advisor may enroll in this class. The course may be taken for credit up to three times, and students are required to submit a final report in each quarter in which they are enrolled. The final report should focus on skills, experiences, and insights that they acquired in the current term. In order to get a passing grade, students must also submit a new supervisor report, which evaluates their performance during the most recent ten-week period. P/NP grading. Prerequisite: ENGR 288 and Ph.D. Student status. (1 unit)

Chapter 13: Department of Engineering Management and Leadership

Dean's Executive Professor: Paul Semenza *(Department Chair)*
Adjunct Faculty: Michele Ellie Ahi, Octave Baker, Marlene Cole, Theresa Conefrey, Don Danielson, John Giddings, Pravin Jain, Mohammad Musa, Usha Parimi, Kern Peng, Dennis Segers

Overview

The Engineering Management and Leadership (EMGT) program is designed for both engineering students and professionals who wish to develop management and leadership skills while furthering their engineering education at the graduate level. EMGT students take core courses in organizational behavior, project management, systems engineering, finance, and marketing, augmented by additional courses in management and leadership. In parallel, students design a Technical Stem program to advance their knowledge in an advanced engineering discipline and round out their education with an Enrichment Experience. The combination of business and graduate-level engineering coursework prepares students for leadership roles in technologically sophisticated companies.

Master of Science Program Requirements

Admission to the Engineering Management and Leadership Program is open to those students who hold an undergraduate or graduate degree in engineering, mathematics, computer science, or engineering physics. The undergraduate degree must be from a four-year engineering program substantially equivalent to Santa Clara University's. Students holding undergraduate degrees other than bioengineering, civil engineering, computer engineering, electrical engineering or mechanical engineering must be prepared to select technical stem courses from these disciplines as listed in the Graduate Engineering Bulletin.

Requirements

Students are required to complete a minimum of 46 quarter units to complete the master's degree, following these guidelines:

- **Engineering Management Core (20 units)**
  - Required Courses (10 units): EMGT 255, 322, 330, 352, and 380
  - Leadership (at least 2 units): select from EMGT 269, 285, 324, 349, 358, 373, or 395
  - Project, Program, and Product Management (at least 2 units): select from EMGT 288, 296, 307, 308, 333, 335, 338, 339, 345, or 378
  - Operations/Innovation Management (at least 2 units): select from EMGT 249, 253, 289, 292, 323, or 357
  - Electives (as needed to reach 20 units): choose from any EMGT courses
- **Technical Stem (18 units)**
  - A focused set of courses from Graduate Engineering departments; see guidelines and restrictions below
- **Enrichment Experience (minimum 8 units)**
  - Graduate Core: A minimum of 4 units. One course each from the following areas:
    - Emerging Topics in Engineering
    - Engineering and Society
  - The additional 4 units can be satisfied by any combination of
    1. One or more technical electives
    2. Additional classes from Graduate Core List
    3. Cooperative Education courses (ENGR 288/289)

4. Combination of the 3 options above

> Please see Chapter 6 for additional information regarding the Enrichment Experience

Technical Stem Courses

Engineering Management and Leadership students are required to create a focused, coherent program of studies within a field of engineering. The following list areas of focus by department, which can be used as guidelines for developing the Technical Stem program.

- **Aerospace Engineering**
- **Bioengineering**: Biomolecular Engineering/Biotechnology; Biomaterials and Tissue Engineering; Microfluidics/Biosensors and Imaging; Computational Bioengineering; Translational Bioengineering
- **Civil, Environmental, and Sustainable Engineering**: Structural Engineering; General Civil Engineering; Construction Engineering and Management; Water and Environmental Engineering
- **Computer Science and Engineering**: Data Science; Internet of Things; Software Engineering; Information Assurance; Multimedia Processing; Computer Networks; Computer Architecture and Systems
- **Electrical and Computer Engineering**: Power Systems and Control; IC Design and Technology; RF and Applied Electromagnetics; Signal Processing and Machine Learning; Digital Systems; Communications
- **Mechanical Engineering**: Theoretical and Computational Mechanics; Dynamics and Controls; Materials Engineering; Mechanical Design; Robotics and Mechatronic Systems; Space Systems; Thermofluids
- **Power Systems and Sustainable Energy**
- **Robotics and Automation**

Interdisciplinary Technical Stem programs can be created to pursue areas of interest within engineering management. Examples include the following.

- **Industrial Engineering and/or Operations Research**: AMTH 210, 211, 245, 246, 362, 364, 370, 371 (optional: ECEN (ELEN) 235)
  - Mathematical Finance option: substitute AMTH 367 for 2 of the above
  - Network option: substitute ECEN (ELEN) 211 and/or 330 for 1 or 2 of the above
- **Machine Learning**: AMTH 245, 246, 370, 371; ECEN (ELEN) 520/L, 521/L, 522, 523

Courses for the Technical Stem of Engineering Management and Leadership are selected from the graduate course listings in the Graduate Bulletin. **However, not all graduate classes listed in the bulletin are considered technical in terms of fulfilling the technical stem requirements.** This is especially the case of ENGR courses. In addition, there are other limitations, some of which are listed below. Therefore, it is important that students complete a program of studies in their first term, to make sure all of the courses they select will fulfill the degree requirements.

- All courses applied to the Engineering Management and Leadership degree must be graded courses—no P/NP courses are allowed.
- Undergraduate courses cross-listed with graduate course numbers do not apply unless the student registers with the graduate course number.
- Graduate seminars and capstone courses in other departments (such as BIOE 200, 294, 295, 296; ECEN (ELEN) 200; CSEN (COEN) 400, 485; and MECH 261, 290, 297) are not applicable.
- The following courses do not count toward the technical stem: BIOE 210; CENG 208, 292; CSEN (COEN) 287,288; ECEN (ELEN) 217; all ENGR courses.
- Engineering Management and Leadership students are allowed to enroll in one unit of Independent Study or Directed Research under the direction of a full-time faculty member in the respective engineering department. Any additional units will not be counted toward graduation.
- New courses are often developed and offered during the academic year that are not listed in this bulletin. It is important that students check with their advisor prior to enrolling in those courses to make sure they will count

toward their degree.

All of the requirements for the engineering management and leadership degree must be completed within a six-year timeframe. In addition to the overall 3.0 GPA graduation requirement, engineering management and leadership degree candidates must earn a 3.0 GPA in those courses applied to their technical stem and a 3.0 GPA in their engineering management course stem. All courses in which a student is enrolled at Santa Clara are included in these calculations.

A completed program of studies for Engineering Management and Leadership degree candidates must be submitted to the chair of the Department of Engineering Management and Leadership during the first term of enrollment to ensure that all courses undertaken are applicable to the degree. Students who take courses that have not been approved for their program of studies by both the department chair and the Graduate Programs Office do so at their own risk, as they may not be counted toward completion of the degree.

A maximum of nine quarter units (six semester units) of graduate-level coursework may be transferred from other accredited institutions at the discretion of the student's advisor provided they have not been applied to a previous degree. However, in no case will the minimum units taken in the Department of Engineering Management and Leadership be fewer than 16. Extension classes, continuing education classes, professional development courses, or classes from international universities are not accepted for transfer credits.

Engineering Management and Leadership Five-Year Program

The School of Engineering offers qualified Santa Clara University undergraduates the opportunity to earn both a Bachelor of Science degree in their technical discipline and a Master of Science degree in Engineering Management and Leadership in five years. This is an excellent path to continue technical education while learning the essential skills required to manage technical projects and people. The degree program is open to students in computer science, engineering, engineering physics, and mathematics.

Students in this program will receive a B.S. degree after satisfying the standard undergraduate degree requirements. Students will then be matriculated to the Engineering Management and Leadership M.S. program and must then fulfill all requirements for the M.S. degree.

Notes

1. Course numbers below 200 indicate undergraduate courses, numbers of 200 and above indicate graduate courses. Students may take courses assigned both undergraduate and graduate numbers (same title used for both numbers) only once as an undergraduate or graduate student. All coursework applied to the M.S. degree must be at the 200 level or above and not applied to any other degree.
2. Students who are entering this program should meet with their Engineering Management and Leadership advisor to develop a program of studies to ensure that all graduate courses they plan to take are applicable to the Engineering Management and Leadership M.S. degree.

COURSE DESCRIPTIONS

EMGT 249. Civil Systems Engineering
Introduction to engineering systems analysis and management technologies and their applications to civil engineering problems, such as transportation, assignment, critical path, and maximum flow problems. Topics include linear programming, nonlinear programming, probability and queuing theory, as well as relevant applications to civil engineering problems. Also listed as CENG 149 and 249. (4 units)

EMGT 253. Operations and Production Systems

Provides the knowledge and techniques required to properly manage operations and production systems. Topics include operations strategies, process management, forecasting, location and layout decisions, capacity and resource planning, technology management, computer-integrated manufacturing. TQM, statistical process control, Lean, Just-in-Time, simulation, and supply-chain and inventory management. (2 units)

EMGT 255. Managerial Accounting for Operating Managers

This course provides an introductory survey to the underlying principles and applications of managerial accounting and financial analysis. Taken from the perspective of the recipient of accounting data, rather than the generator of reports, this course will equip operating managers with the skills to interpret the story behind the numbers to gain a more accurate understanding of the status of their business and to make more informed decisions. (2 units)

EMGT 269. Human Resource Development and the Engineering Manager

Provides concepts of human resource management in tech companies, including staffing, performance management, people development, compensation and benefit strategies. Also explores the meaning of work, the individual and organization behaviors, growth and learning, the manager's role in career/life management, corporate cultures, as well as the development of major management theories. (2 units)

EMGT 270. Effective Oral Technical Presentations

Role of communications in the workplace, persuasive communications, organizing and leading meetings, interviewing skills, delivering effective technical presentations to large and small groups. (2 units)

EMGT 271. Effective Written Technical Communication I

Cluster writing; pyramid technique; audience analysis; opening, body, and end of text; technical correspondence; abstracts and summaries; presentation patterns for reports and proposals; proposal presentation. (2 units)

EMGT 272. Effective Written Technical Communication II

Intensive writing practicum, overview of writing, mechanics of style, editing techniques, digital communications. (2 units)

EMGT 285. Managing Business Relationships

Leadership skills taught to develop and leverage key relationships in one's own organization, including person-to-person (manager), group-to-group (director), and company-wide (executive) relationship management strategies. Learn to develop and manage interaction models, dependency analyses, and team structures. Develop people skills and techniques to manage outsourcing, partnerships, joint development strategies, and change management. Calibration and driving key metrics as part of ability to influence across one's network. High class participation using group exercise, combined with practical training methods. (2 units)

EMGT 288. Engineering Decision and Risk Analysis

Epistemic and aleatory uncertainty, reliability and probabilistic risk assessment, risk management, decision trees, sensitivity analysis, optimization, reliability analysis (MCFOSM/FORM/SORM), Monte Carlo, Latin Hypercube and importance sampling, utility theory. Prerequisite: AMTH 108 or instructor's consent. Also listed as CENG 288 (4 units)

EMGT 289. Managing, Controlling, and Improving Quality

Management structure and statistical and analytical tools for quality success: total quality management, six-sigma and beyond, statistical inference (made simple), control charts (SPC), sampling procedures, designed experiments (DOE), and reliability. (2 units)

EMGT 292. Managing Capital Assets in the Smart Machine Era

Provides effective tactics in managing capital assets in technical firms. With Industry 4.0 and the development of a new generation of smart machines, the complexity and cost of capital equipment are increasing substantially. Prepares students to manage the new generation of machines with the applications of robotics, IoT, AI and ML. Covers approaches and practices in managing the lifespan of capital assets: development, introduction, sustaining, decommission. (2 units)

EMGT 295. Project Planning Under Conditions of Uncertainty

Managerial decision making in project management under conditions of varying knowledge about the future. Decisions relying on certainty and decisions based on probabilities and made under risk. Situations in which there is no basis for probabilities; decisions made under conditions of uncertainty. Use of applications of decision theory to help develop strategies for project selection and evaluation. (2 units)

EMGT 296. Project Risk Management

There are three fundamental steps: risk analysis, risk evaluation, and risk migration and management. The acceptable risk threshold is defined by the customer and management, and identifies the level above which risk reduction strategies will be implemented. (2 units)

EMGT 299. Directed Research

By arrangement. Limited to a single enrollment. (1 unit)

EMGT 307. Medical Device Product Development

The purpose of the course is to provide skills, knowledge, and confidence, to start or enhance a career in medical device product development. The course includes medical device examples, market data, product development processes, regulation, industry information, and intellectual property. Also listed as BIOE 107 and BIOE 307. (2 units)

EMGT 308. Solutions Architecture and the Cloud

System design foundation blocks, design considerations and best practices for cloud services; micro services to build sample systems. Hands-on labs to deploy applications on cloud platforms such as AWS, Azure and GCP. Review of cloud certification paths relevant to solutions architect roles at cloud infrastructure and platform companies. (2 units)

EMGT 318. Strategies for Career and Academic Success (for Foreign-born Technical Professionals)

Designed to help foreign-born engineers and technical professionals develop the knowledge and skills needed to be more effective in the American academic and corporate environments and to achieve career success. Focuses on key skills in career development, effective communication, interpersonal effectiveness, and building relationships with co-workers. Uses participatory, experiential training methods including role plays, simulations, and small group exercises. (2 units)

EMGT 319. Human Interaction I

Individuals interacting in groups to solve problems. Discusses a mix of electronic and personal elements to achieve goals. (2 units)

EMGT 320. Human Interaction II

A close look at communications. Personal limits. Electronic interfacing. The role of communication skills, attitudes, knowledge level, and culture in the communication process. (2 units)

EMGT 322. Organizational Behavior

This course will cover the skills required in transitioning from a technical contributor to a technical manager or team leader. This transition requires a new set of skills and knowledge in which engineers and scientists are typically not trained. These new skills will include "soft skills" from the areas of psychology, ethics, and interpersonal relationships, as well as the management processes essential to becoming an effective manager. This class blends the technical dialog with a more personal and social dialogue. Students will think introspectively about managerial roles and responsibilities through lectures and discussions. (2 units)

EMGT 323. Management of Technological Innovation: Opportunities and Challenges

Understanding innovation as the process of commercializing new technologies or applying them in new ways, at the levels of industries, markets, and the firm, including startups and incumbents. Sources, types and models of innovation, s-curves and disruptive innovation, dominant designs and standards, first-mover and other timing issues, network effects and platforms, intellectual property and markets for technology, and tools for selecting innovation projects. Focus will be on strategies and processes for capitalizing on innovations. (2 units)

EMGT 324. Engineering Leadership

This course is designed to facilitate successful transitions by individuals with technical backgrounds from team management to corporate leadership positions. Students will learn the attitudes and social approaches necessary for serving as an effective corporate leader. This will be accomplished through lectures and discussions with classroom participation exercises and topical essay homework. Prerequisite: EMGT 322. (2 units)

EMGT 329. Parallel Thinking

This workshop-style program will provide the tools and coaching engineering leaders need to be effective in harnessing the brainpower of groups. Draws heavily on the application of the research done at Stanford University on precision questioning, the work of Edward DeBono, and group processing work on high-performance systems. (2 units)

EMGT 330. Project Management Basics

Designed to provide the basic knowledge and techniques required to properly manage projects. Covers the fundamental concepts and approaches in project management, such as the triple constraints, project life cycle and processes, project organizations, project scheduling, budgeting, resource loading, project monitoring and controls, and project information systems. (2 units)

EMGT 331. Strategic Technology Management

Translating strategic plans into action plans and ensuring their implementation. Integration of a process that crosses all organizational boundaries. Performance objectives and priorities, change and discontinuities, managed growth, accelerated technology transfer. Analyzing competitive technical positions, collecting and utilizing user/customer information, and changing leadership. (2 units)

EMGT 333. Computer-Aided Project Management Scheduling and Control

This course covers defining project objectives, scheduling and budgeting, risk management, and project control using Microsoft Project for Gantt chart-based project management, and Jira for Agile project management using Kanban and Scrum methodologies. Customers, competition, technology, and financial realities are considered in order to develop project requirements. Project planning, resource allocation, and strategies for dealing with multiple projects; project tracking, including earned value analysis and taking corrective action. (2 units)

EMGT 335. Advanced Project Management and Leadership

A strategic view of project classification and project portfolio management. Covers the approaches and practices in creating the right environment and culture for overall project success. Highly interactive advanced course with in-class practice and situational analysis. While providing knowledge of project planning and managing techniques, it focuses on the development of project leadership, teamwork, and problem-solving skills. Prerequisite: EMGT 330. (2 units)

EMGT 336. Global Software Management (Introduction)

Discuss and understand the software development techniques and issues in view of offshore outsourcing. Discuss best practices, dos and don'ts in project management, and other techniques due to off-shoring and outsourcing. Case studies. (2 units)

EMGT 338. Software Product Management I

Introduction to product management, agile engineering planning and execution, customer analysis and value propositions, product vision, user testing, and product requirements mapping to a business model. A project-based course. (2 units)

EMGT 339. Software Product Management II: From Product to Company

Introduction to product management, agile engineering planning and execution, customer analysis and value propositions, product vision, user testing and product requirements mapping to a business model. Grading is based on a hands-on-project deliverable. Lecturer and Guest speakers will also cover product market fit, building a minimum viable product, early business model validation, hiring core team members, and fundraising strategies. Focus is on the transition from an idea to a fundable pre-seed or seed stage technology startup. (4 units).

EMGT 345. Program Management
Fundamentals of program and portfolio management and how they are applied to improve business results on programs of varying size, within all types of businesses, from small companies to large enterprises. Prerequisite: EMGT 330 (Project Management Basics) or equivalent experience. (2 units)

EMGT 346. Engineering Economics
Valuating and selecting engineering projects based on their characteristics of risk, available information, time horizon, and goals. Utilization of classical capital budgeting techniques, qualitative criteria, and financial option theory. Exploration of the value of individual projects on the company's total portfolio of projects. Introduction to decision theory as it applies to project evaluation. Prerequisite: Finance or familiarity with time value of money concepts such as net present value. (2 units)

EMGT 349. Ethical Decision Making for Technology Leaders
Designed to create a holistic understanding of leadership. Through readings, discussions, and case studies, students will learn to integrate key leadership concepts from psychology, ethics, political science, philosophy, and sociology. Students will be able to characterize their individual approaches to leadership and learn to adapt it to changes resulting from globalization and advancing technology. (2 units)

EMGT 352. Marketing of High-Tech Products and Innovations
This course is designed to give engineers and managers a working understanding of the strategic role marketing plays in the development and promotion of high-technology products and systems. Challenges to adoption of innovations and strategies for overcoming barriers will be explored. Students will learn marketing frameworks and apply them to case studies as well as by creating a marketing plan for an emerging technology or business. (2 units)

EMGT 353. Introduction to Total Quality Management
The basic tenets of TQM: customer focus, continuous improvement, and total participation. Particular emphasis on using TQM to enhance new product development. (2 units)

EMGT 354. Innovation, Creativity, and Engineering Design
Research, development, the process of discovery, recognizing a need, encouraging change, assuming risks, technological feasibility, marketability, and the environment for innovation. (2 units)

EMGT 357. Root Cause Analysis (RCA) Effective Problem Solving
Root cause analysis of problems is one of the main functions of engineering and is a critical component of organizational governance for engineering managers. This course will help problem solvers differentiate among the generic steps involved in (1) identifying a problem, (2) performing a diagnosis, (3) selecting and implementing solutions, and (4) leveraging and sustaining results. The major emphasis is placed on diagnosis, which at its core is logical, deductive analysis carried out using critical thinking. Cross-listed with BIOE 357 (2 units)

EMGT 358. Global Technology Development
Global markets present growth opportunities for both business and professionals. Approaches the development of global technology from the perspective of the engineering manager engaged as either part of a large corporate team or as an entrepreneur in a small business. Skills for characterizing, developing, and leveraging trending technology and risk management tools, as well as diversified cultures and global resources. Approaches include formal methodologies and practical lessons learned from industry. (2 units)

EMGT 360. Current Papers in Engineering Management and Leadership
Individual topics to be selected in concurrence with the instructor. (2 units)

EMGT 362. Topics in Engineering Management
Topics of current interest in engineering management and leadership. May be taken more than once as the topics change. (2 units)

EMGT 370. International (Global) Technology Operations
Examines methods and important issues in managing operations when customers, facilities, and suppliers are located across the globe. Topics include the global technology environment, international operations strategy and process

formulation, and issues on the location and coordination of overseas facilities. These and other course topics are examined through a combination of lectures, text material, and integrated case studies. (2 units)

EMGT 373. Technology Entrepreneurship

Designed for students who are interested in starting their own venture as well as those working for a start-up company. Students will discover the process of moving from an idea to making a profit. Topics will include idea development, intellectual property, forming a team, obtaining funding, start-up logistics, executing your plan, and finding customers. Understanding the steps, risks, and pitfalls to avoid in starting a high-tech business can help in being better prepared for launching a successful technology venture. (2 units)

EMGT 378. New Product Planning and Development

This course blends the perspectives of marketing, engineering, and manufacturing into a single approach to new product development - and consequentially product management - at various stages of the product life cycle. Students gain an appreciation for the realities of industrial practice, and the complex and essential roles played by team members led by product managers. For industrial practitioners in particular, the product planning and implementation methods can be put into immediate practice on development projects. (2 units)

EMGT 380. Introduction to Systems Engineering Management

Introduces the fundamental principles and methods of systems engineering and their application to complex systems. For the engineer, and project manager, it provides a basic framework for planning and assessing system development. For the non-engineer, it provides an overview of how a system is developed. (2 units)

EMGT 381. Managing System Conceptual Design

A continuation of EMGT 380 addressing in detail the system engineer's responsibilities and activities in the concept development stage of the system life cycle. Topics include needs and requirements analysis, system concept exploration and definition, and risk assessment. It concludes with a discussion of advanced development and the system engineer's role in planning and preparing for full-scale engineering development. Prerequisite: EMGT 380. (2 units)

EMGT 382. Managing System Design, Integration, Test and Evaluation

A continuation of EMGT 381 with a focus on the system engineer's responsibilities and activities in the engineering development and post-development stages of the system life cycle. Topics include engineering design, system integration and evaluation, and the systems engineer's role in preparing for full-scale manufacturing and subsequent deployment and support. Prerequisite: EMGT 380. (2 units)

EMGT 388. System Supportability and Logistics

The supportability of a system can be defined as the ability of a system to be supported in a cost-effective and timely manner, with a minimum of logistics support resources. The required resources might include test and support equipment, trained maintenance personnel, spare and repair parts, technical documentation, and special facilities. For large complex systems, supportability considerations may be significant and often have a major impact upon life cycle cost. It is therefore particularly important that these considerations be included early during the system design trade studies and design decision-making. (2 units)

EMGT 389. Design for Reliability, Maintainability, and Supportability

Provides the tools and techniques that can be used early in the design phase to effectively influence the design from the perspective of system reliability, maintainability, and supportability. Students will be introduced to various requirements, definition and analysis tools and techniques to include Quality Function Deployment, Input-Output Matrices, and Parameter Taxonomy. (2 units)

EMGT 390. System Architecture and Design

Fundamentals of system architecting and the architecting process, along with practical heuristics. The course has a strong "how-to" orientation, and numerous case studies are used to convey and discuss good architectural concepts as well as lessons learned. Adaptation of the architectural process to ensure the effective application of COTS will be addressed. (2 units)

EMGT 395. Intrapreneurship – Innovation from Within

Intrapreneurship is about creating an innovative business opportunity within the existing structure of an organization. Innovation and creativity, mixed with limited marketing and financial views that will create profitable new products, are critical components of intrapreneurship. Using small independent development teams, the concept incorporates product launch with an overview of marketing and customer views. The methods from this class are widely used by the most successful innovators in start-ups as well as established companies. (2 units)

Chapter 14: Department of Mechanical Engineering

Professor Emeritus: Terry E. Shoup
Associate Professor Emeritus: Timothy K. Hight
Professors: Christopher Kitts, Hohyun Lee (Department Chair), M. Godfrey Mungal
Associate Professors: Mohammad Ayoubi, Drazen Fabris, On Shun Pak, Panthea Sepehrband, Michael Taylor
Assistant Professors: Jun Wang
Renewable Term Lecturers: Robert Marks
Academic Year Adjunct Lecturers: Sthanu Mahadev, Michael Neumann, Nataliya Starostina, Peter Woytowitz

Overview

The Department of Mechanical Engineering is dedicated to delivering up-to-date, high-quality courses across a broad range of the discipline to meet the needs of both part- and full-time graduate students. These courses are concentrated in five emphases: (1) dynamics and controls; (2) design and manufacturing; (3) mechanics and materials; (4) mechatronic systems engineering; and (5) thermofluids and energy. Educational efforts are channeled to expand the skills of prospective and practicing engineers, not only in understanding fundamentals but also in developing competence in analyzing engineering systems. The department offers graduate degrees at the master, engineer, and doctorate levels, as well as certificates.

Master of Science Programs

An M.S. degree requires a minimum 46 units of study with an overall GPA of 3.0 or higher. The student must select one of the five areas of emphasis and develop a program of studies with an advisor. Courses taken to satisfy any particular requirement may be used to simultaneously satisfy additional requirements for which they are appropriate. Master of Science degrees must include the following:

- Engineering Core- Enrichment experience requirement as described in Chapter 6 (minimum of 8 units). Students must take a minimum of 4 units from at least two of the three areas:
  - Emerging Topics in Engineering,
  - Engineering and Business/Entrepreneurship
  - Engineering and Society

The remaining 4 units can be accumulated by,

a) taking one or more major technical electives,

b) additional classes from the Graduate Core list,

c) cooperative education courses (Engr 288, Engr 289) or

d) combining a, b, and c.

- Math requirement: 8 units composed of MECH 200 and 201, or MECH 202, and an approved two-course sequence or equivalent four-unit course in applied math
- Depth Requirement: 8 or more units depending on the chosen emphasis
- Breadth Requirement: 4 units in other emphases outside one's chosen emphasis. No double dip is allowed.
- At least 28 units from graduate courses in mechanical engineering.
- All emphases offer a culminating experience, which can be pursued by taking MECH 290 (Graduate Research/Project) and/or MECH 299 (Master's Thesis). Up to 6 units of MECH 290 can be taken and counted toward the 46-unit requirement. Those who write a thesis or publish an article in a peer-reviewed journal can take

6 more units of MECH 299. Some emphases may require the culminating experience.

The student may take any additional graduate courses, as needed, offered by the School of Engineering to meet the minimum 46-unit requirement.

Master of Science in Mechanical Engineering

Design and Manufacturing

Advisors: Dr. Sthanu Mahadev, Dr. Panthea Sepehrband, Dr. Calvin Tszeng, Dr. Jun Wang, Dr. Peter Woytowitz

The Design & Manufacturing (DM) emphasis in the Department of Mechanical Engineering allows students to develop abilities and skills in mechanical design and aspects of manufacturing in achieving competence in product development.

Core Courses (Students need to take at least 8 units out of these courses)

- MECH 251 Finite Element Methods I (4 units)
- MECH 275 Design for Competitiveness (2 units)
- MECH 281 Elasticity, Fracture, and Fatigue (4 units)
- MECH 285 Computer-Aided Design of Mechanisms (2 units)
- MECH 325 Computational Geometry for Computer-Aided Design and Manufacture (2 units)
- MECH 415 Optimization in Mechanical Design (2 units)

Other Related Courses

- MECH 252 Finite Element Methods II (4 units)
- MECH 257 Engineering Simulation and Modeling (4 units)
- MECH 276 Design for Manufacturability (2 units)
- MECH 293 Special Topics in Design & Manufacturing (2-4 units) (Tentative Topics: Designing with Plastic Materials; Processing Plastic Materials; CNC Machining; Additive/Hybrid Manufacturing; Advanced Manufacturing Lab)
- MECH 371/372 Space Systems Design and Engineering I, II (4 units each)

Dynamics and Controls

Advisors: Dr. Mohammad Ayoubi, Dr. Christopher Kitts

The Dynamics and Controls (D&C) emphasis in the Department of Mechanical Engineering provides a foundation for students to utilize the physics-based or data-driven techniques to model, identify, analyze, and regulate the behavior of dynamical systems. The important feature is to achieve the specified objectives in an optimal fashion while coping with the disturbances and model uncertainties.

Core Courses (Students need to take at least 8 units out of these courses)

- MECH 220 Orbital Mechanics (4 units)
- MECH 323/324 Modern Control Systems I, II (2 units each)
- MECH 429/430 Optimal Control I, II (2 units each)

Other Related Courses

- MECH 214 Advanced Dynamics (4 units)
- MECH 305 Advanced Vibrations (4 units)
- MECH 232 Multibody Dynamics (4 units)
- MECH 296 Special Topics in Dynamics and Controls
- MECH 337/338 Robotics I, II (2 units each)

Mechanics and Materials

Advisors: Dr. Sthanu Mahadev, Dr. Robert Marks, Dr. On Shun Pak, Dr. Panthea Sepehrband, Dr. Michael Taylor, Dr. Calvin Tszeng, Dr. Peter Woytowitz

The Mechanics & Materials (MM) emphasis in the Department of Mechanical Engineering allows students to explore the science of materials and how those materials move and deform in response to thermomechanical loading.

Core Courses (Students need to take at least 8 units out of these courses)

- MECH 251 Finite Element Methods I (4 units)
- MECH 281 Elasticity, Fracture, and Fatigue (4 units)
- MECH 330 Atomic Bonding, Crystal Structure, and Material Properties (4 units)
- MECH 331 Equilibrium Thermodynamics and Phase Transformations (4 units)
- MECH 377 Continuum Mechanics (4 units)

Other Related Courses

- MECH 230 Statistical Thermodynamics (2 units)
- MECH 252 Finite Element Methods II (4 units)
- MECH 293 Special Topics in Mechanics and Materials
- MECH 333 Experiments in Material Science (2 units)
- MECH 350 Composite Materials (4 units)

Mechatronic Systems Engineering

Advisor: Dr. Christopher Kitts

The Mechatronic Systems Engineering (MSE) emphasis in the Department of Mechanical Engineering focuses on the methods and techniques relating to the design, control and operation of complex modern engineering systems.

Core Courses (Students must complete 10 units of coursework as specified below in requirements A, B, and C.)

A- Mechatronics: Students will need to complete the 6 unit graduate mechatronic sequence:

- MECH 207 and 208 Advanced Mechatronics I, II (3 units each)

B- Systems: In addition, students will need to complete a minimum of 2 units of coursework from the following list of "systems" courses; additional courses may apply based on approval from faculty in the emphasis area.

- MECH 292 Special Topics in Mechatronic Systems Engineering (2-4 units) (Tentative Topics: UAV Systems; Marine Systems)
- MECH 311 Design and Control of Telerobotic Systems (4 units)
- MECH 337/338 Robotics I, II (2 units each)
- MECH 371/372 Space Systems Design and Engineering I, II (4 units each)
- MECH 379 Satellite Operations (1 unit)

C- Design Process: Students must also complete a 2-unit course in systems development. Some of these options may be used to also satisfy the degree's enrichment requirement. Courses that satisfy this requirement include:

- MECH 275 Design for Competitiveness (2 units)
- EMGT 380 Introduction to Systems Engineering (2 units)

Other Related Courses

- MECH 209/210 Advanced Mechatronics III, IV (2 units each)
- MECH 217 Introduction to Control (2 units)
- MECH 218/219 Guidance and Control I, II (2 units each)

- MECH 323/324 Modern Control System Design I, II (2 units each)
- MECH 345 Instrumentation and Design of Experiment (2 units)

Culminating experience (Required): Students must complete a culminating project in the form of a capstone project (4-6 units) or a research-based thesis. The experiences take a minimum of two quarters to complete and should be discussed with faculty members in the emphasis area.

Thermofluids and Energy

Advisors: Dr. Drazen Fabris, Dr. Hohyun Lee, Dr. Godfrey Mungal, Dr. On Shun Pak

The ThermoFluids and Energy (TFE) emphasis in the Department of Mechanical Engineering explores mechanisms and application of fluid motion at various scales and energy conversion.

Core Courses (Students need to take at least 8 units out of these courses)

- MECH 228 Energy Conversion and Conservation (4 units)
- MECH 241 Approximation and Design of Heat Transfer System (4 units)
- MECH 266 Viscous Flow & Advanced Fluid Mechanics (4 units)
- MECH 239 Solid State Power Generation and Energy Harvesting (4 units)

Other Related Courses

- MECH 225 Gas Dynamics (2 units)
- MECH 230 Statistical Thermodynamics (2 units)
- MECH 241 Advanced Heat Transfer (4 units)
- MECH 268 Computational Fluid Dynamics I (2 units)
- MECH 269 Computational Fluid Dynamics II (2 units)
- MECH 271 Turbulent and Convective Flow (4 units)
- MECH 295 Special Topics in Thermofluids & Energy (2-4 units) (Tentative Topics: Building Energy System Control (HVAC); Electronic Equipment Cooling; Microscale Fluid Mechanics; Water Purification & Desalination)
- MECH 345: Instrumentation and Design of Experiment (2 units)

Master of Science in Aerospace Engineering

Advisors: Dr. Mohammad Ayoubi, Dr. Christopher Kitts

Required Core Courses (minimum 8 units)

- MECH 214 Advanced Dynamics (4 units)
- MECH 251 Finite Element Methods I (4 units)
- MECH 281 Elasticity, Fracture, and Fatigue (4 units)
- MECH 305 Advanced Vibrations (4 units)
- MECH 323/324 Modern Control Systems I, II (2 units each)
- MECH 377 Continuum Mechanics (4 units)

Required Aerospace Engineering Courses (minimum 12 units)

- MECH 205/206 Aircraft Flight Dynamics and Control I, II (2 units each)
- MECH 220 Orbital Mechanics (4 units)
- MECH 222 Aircraft and Rotorcraft System Identification (2 units)
- MECH 313 Advanced Aerospace Structures (4 units)
- MECH 371 Space Systems Design and Engineering I (4 units)
- MECH 431 Spacecraft Dynamics and Control (4 units)

Elective Courses (recommended)

- MECH 232 Multibody Dynamics (4 units)
- MECH 290 Graduate Research/Project (1–6 units)
- MECH 299 Master's Thesis (1–3 units)
- MECH 355/356 Adaptive Control I, II (2 units each)
- MECH 372 Space Systems Design and Engineering II (4 units)
- MECH 420/ELEN 238 Model Predictive Control (2 units)
- MECH 423/424 Nonlinear Systems and Control I, II (2 units each)
- MECH 429/430 Optimal Control I and II (2 units each)

Doctor of Philosophy Program

The Doctor of Philosophy degree is conferred by the School of Engineering in recognition of competence in the subject field and the ability to investigate engineering problems independently, resulting in a new contribution to knowledge in the field.

See the section on Academic Regulations for details on admission and general degree requirements. The following departmental information augments the general School requirements.

Academic Advisor

A temporary academic advisor will be provided to the student upon admission. The student and advisor must meet prior to registration for the second quarter to complete a preliminary program of studies, which will be determined largely by the coursework needed for the preliminary exam.

Preliminary Exam

A preliminary written exam is offered at least once per year by the School of Engineering as needed. The purpose is to ascertain the depth and breadth of the student's preparation and suitability for Ph.D. work. Each student in mechanical engineering must take and pass an exam in mathematics as well as in two areas from the following list: Fluid Mechanics, Heat Transfer, Strength of Materials, Dynamics, Design, Controls, Vibrations, Finite Element Analysis, Material Science, and Thermodynamics. The advisor must approve the student's petition to take the exam. This exam should be taken within one year of starting the program.

Doctoral Committee

After passing the Ph.D. preliminary exam, a student requests his or her thesis advisor to form a doctoral committee. The committee consists of at least five members, each of which must have earned a doctoral degree in a field of engineering or a related discipline. This includes the student's thesis advisor, at least two other current faculty members of the student's major department at Santa Clara University, and at least one current faculty member from another appropriate academic department at Santa Clara University. The committee reviews the student's program of study, conducts an oral comprehensive exam, conducts the dissertation defense, and reviews the thesis. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, dissertation defense, and thesis itself meet with the approval of all committee members.

Time Limit for Completing Degree

All requirements for the doctoral degree must be completed within eight years following initial enrollment in the Ph.D. program. This includes leave of absence/withdrawals. Extensions will be allowed only in unusual circumstances and must be recommended in writing by the student's doctoral committee and approved by the dean of engineering in consultation with the Research Program Leadership Council.

Engineer's Degree Program

The Department of Mechanical Engineering offers an engineer's degree program. Details on admissions and requirements are shown in the Academic Regulations section. Students interested in this program should seek individual advice from the department chair prior to applying.

Certificate Programs

The Department of Mechanical Engineering offers a certificate in the five concentration areas (Design and Manufacturing; Dynamics and Controls; Mechanics and Materials; Mechatronic Systems Engineering; Thermofluids and Energy) as well as general mechanical engineering. The certificate program is designed for working professionals, who would like to deepen their understanding in disciplinary subjects and apply the knowledge toward real engineering problems. One can receive a certificate in Mechanical Engineering by taking 16 units of Mechanical Engineering graduate courses with a minimum GPA of 3.0 and grade above of C or better in each course. Candidates for a certificate in a specific concentration area must take at least 8 units of core courses from the concentration area, which is listed under the section "Master of Science in Mechanical Engineering". Applicants must have completed an accredited bachelor's degree program in Mechanical Engineering or a closely related field of engineering. Up to 16 units earned in a certificate can be transferred toward another advanced degree program at SCU if they are accepted to the M.S. or Ph.D. program.

Mechanical Engineering Laboratories

The mechanical engineering laboratories contain facilities for instruction and research in the fields of manufacturing, materials science, fluid mechanics, thermodynamics, heat and mass transfer, combustion, instrumentation, vibration and control systems, and robotic systems.

The *Materials Research Laboratory* supports interdisciplinary research efforts related to process-structure-property relations in engineering materials. Its principal activities focus on the characterization, quantitative analysis, and modeling of nano- and micro-structural evolution in materials during thermal and mechanical processing.

The *Robotic Systems Laboratory* is an interdisciplinary laboratory specializing in the design, control, and teleoperation of highly capable robotic systems for scientific discovery, technology validation, and engineering education. Laboratory students develop and operate systems that include spacecraft, underwater robots, aircraft, land rovers and robotic manipulators. These projects serve as ideal testbeds for learning and conducting research in mechatronic system design, guidance and navigation, command and control systems, and human-machine interfaces.

The *Energy System Design & Optimization Laboratory* explores topics related to energy sustainability, including building energy system control via Internet-of-Things (IoT); renewable energy; energy storage materials and system optimization; energy harvesting and conversion; and transactive energy (smart grid). Overarching goals of the various projects in the lab is to reduce our reliance on fossil fuel for a sustainable future. The Lab is also interested in making an impact for people in emerging markets, by providing sustainable and economically viable energy/water solutions: portable refrigerator for last mile delivery; clean cookstoves; and desalination.

The *Theoretical and Computational Mechanics Laboratory* explores emerging problems in fluid and solid mechanics utilizing the tools of applied mathematics and numerical simulation. Research areas include low Reynolds number flow, microswimmers, biological flows and membranes, thin film mechanics, fracture simulation, auxetic metamaterials, and parallel computing.

The *Micro Scale Heat Transfer Laboratory (MSHTL)* develops state-of-the-art experimentation in processes such as micro-boiling, spray cooling, and laser-induced fluorescence thermometry. Today, trends indicate that these processes are finding interesting applications in drop-on-demand delivery systems, ink-jet technology, and fast transient systems (such as combustion or microseconds scale boiling).

The **CAM and Prototyping Laboratory** consists of two machine shops and a prototyping area. One machine shop is dedicated to student use for University-directed design and research projects. The second is a teaching lab used for undergraduate and graduate instruction. Both are equipped with modern machine tools, such as lathes and milling machines. The milling machines all have two-axis computer numerically controlled (CNC) capability. The teaching lab also houses two three-axis CNCvertical milling centers (VMC) and a CNC lathe. Commercial CAM software is available to aid programming of the computer-controlled equipment. The prototyping area is equipped with a rapid prototyping system that utilizes fused deposition modeling (FDM) to create plastic prototypes from CAD-generated models. Also featured in this area is an Epilog Laser cutter/engraver system for nonmetallic materials.

The **Fluid Dynamics/Thermal Science Laboratory** contains equipment to illustrate the principles of fluid flow and heat transfer and to familiarize students with hydraulic machines, refrigeration cycles, and their instrumentation. The lab also contains a subsonic wind tunnel equipped with an axial flow fan with adjustable pitch blades to study aerodynamics. Research tools include modern, non-intrusive flow measurement systems.

The **Heat Transfer Laboratory** contains equipment to describe three modes of heat transfer. The temperature measurement of the extended surface system allows students to learn steady state conduction, and the pyrometer enables measurement of emitted power by radiation. The training systems for heat exchanger and refrigeration system are also placed in the lab.

The **Instrumentation Laboratory** contains seven computer stations equipped with state-of-the-art, PC-based data acquisition hardware and software systems. A variety of transducers and test experiments for making mechanical, thermal, and fluid measurements are part of this lab.

The **Materials Laboratory** contains equipment for metallography and optical examination of the microstructure of materials as well as instruments for mechanical properties characterization including tension, compression, hardness, and impact testing. The Materials Laboratory also has a tube furnace for heat treating and a specialized bell-jar furnace for pour casting and suction casting of metallic glasses and novel alloy compositions.

The **Vibrations Laboratory** is equipped with configurable torsional, rectilinear, and inverted pendulum test apparatuses (ECP Systems) allowing for exploration of both single and multiple degree-of-freedom forced and free vibration. In addition, the lab contains a portable laser doppler vibrometer (Polytec) to allow for non-contact measurement of vibration in continuous systems.

The **Control Systems Laboratory** is equipped with the Rotary Motion Platform, QUBE-Servo 2, Rotary Flexible Link, Ball and Beam, and Rotary Inverted Pendulum which are designed and manufactured by Quanser Company. All equipment works with the MATLAB/SIMULINK® environment and can be used to evaluate linear and nonlinear control algorithms.

Undergraduate Course Descriptions

Lower-Division Undergraduate Courses

MECH 10L. Engineering Graphics and Computer-Aided Design I
An introduction to engineering graphics and computer-aided design (CAD) using a 3D solid modeling software package. Topics include geometric construction, sketching, orthographic projection, isometric, and sectional views. Drawing and CAD laboratory classes will consist of lectures and exercises, demonstrations, and student work sessions. (1 unit)

MECH 11. Materials and Manufacturing Processes
The principles of manufacturing processes as related to materials properties, design, and production. A review of structures, properties, and manufacturing processes for main groups of engineering materials including metals and metallic alloys, polymers, and ceramics. Prerequisite: MECH 15. (4 units)

MECH 12L. Engineering Graphics and Computer Aided Design II

Continuation of MECH 10L. An introduction to engineering graphics and computer-aided design (CAD) using a 3D solid modeling software package. Topics include dimensioning and tolerancing, descriptive geometry and auxiliary views, and assemblies. Drawing and CAD laboratory classes will consist of lectures and exercises, demonstrations, and student work sessions. Light machining will be introduced, as well. Prerequisite: MECH 10L, MECH students only. (1 unit)

MECH 13L. Engineering Graphics and CAD III

An introduction to advanced computer-aided design (CAD) using an advanced 3D parametric surface and solid modeling commercial tool. Topics include Advanced surface modeling, sheet metal design, meldment structures, topology optimization tools, FEA tools, etc. Prerequisite: MECH 10L or similar, ENGR students only. (1 unit)

MECH 15. Introduction to Materials Science

Physical basis of the electrical, mechanical, optical, and thermal behavior of solids. Relations between atomic structure and physical properties. Prerequisite: CHEM 11. Corequisite: MECH 15L. (4 units)

MECH 15L. Introduction to Materials Science Laboratory

Laboratory for MECH 15. Corequisite: MECH 15. (1 unit)

MECH 25. Tools for Collegiate-centric Student Competitions

Design and development of new student-centric projects that may follow a "concept design-to-build-and-test" type routine. Weekly student-faculty meetings, design reviews, research and prototype development presentations, industry tours, presentations from keynote speakers, etc. Prerequisites: MECH 12L or equivalent. (2 units)

MECH 45. Applied Programming in MATLAB

Computer programming in MATLAB, including: use of the development environment, m-files, and debugging; data structures; flow control, including loops, vectorization, and conditional statements; functions and variable scope; file input and output; plotting and visualization; selected topics in object-oriented programming. Applications to engineering problems including linear algebra and differential equations. Prerequisite: C- or better in MATH 13. Co-requisite: MECH 45L. (4 units)

MECH 45L. Applied Programming in MATLAB Lab

Laboratory for MECH 45. Co-requisite: MECH 45. (1 unit)

Upper-Division Undergraduate Courses

MECH 101L. Machining Laboratory

Practical experience with machine tools such as mills, lathes, band saws, etc. Basic training in safe and proper use of the equipment associated with simple mechanical projects. Laboratory. P/NP grading. Prerequisites: MECH 12L and senior standing. Corequisite: MECH 194. (1 unit)

MECH 103. Mathematical Methods in Mechanical Engineering

Review of ordinary differential equations and Laplace transform, Fourier series, partial differential equations with applications to problems in vibration and heat conduction, and selected topics from linear algebra. Prerequisite: AMTH 106. Corequisite: MECH 103R. (4 units)

MECH 103R. Mathematical Methods in Mechanical Engineering Recitation

Recitation for MECH 103. Corequisite: MECH 103. (1 unit)

MECH 114. Machine Design I

Analysis and design of mechanical systems for safe operation. Stress and deflection analysis. Failure theories for static loading and fatigue failure criteria. Team design projects begun. Formal conceptual design reports required. Prerequisites: MECH 12L, 15 and CENG 43. (4 units)

MECH 115. Machine Design II
Continuation of MECH 114. Treatment of basic machine elements (e.g., bolts, springs, gears, bearings). Design and analysis of machine elements for static and fatigue loading. Team design projects completed. Design prototypes and formal final report required. Prerequisite: MECH 114. (4 units)

MECH 121. Thermodynamics I
Definitions of work, heat, and energy. First and second laws of thermodynamics. Properties of pure substances. Application to fixed mass systems and control volumes. Irreversibility and availability. Prerequisite: C- or better in PHYS 32. (4 units)

MECH 121R. Thermodynamics I Recitation
Recitation for MECH 121. Required for all mech students. Corequisite: MECH 121. (1 unit)

MECH 122. Fluid Mechanics
Fluid properties and definitions. Fluid statics, forces on submerged surfaces, manometry. Streamlines and conservation flow fields. Euler's and Bernoulli's equations. Mass, momentum, and energy analysis. Laminar and turbulent flows. Losses in pipes and ducts. Dimensional analysis and similitude. External flows. Corequisite: MECH 121, MECH 122L and MECH 140. (4 units)

MECH 122L. Fluid Mechanics Laboratory
Laboratory for MECH 122. Corequisite: MECH 122. (1 unit)

MECH 123. Heat Transfer
Introduction to the concepts of conduction, convection, and radiation heat transfer. Application of these concepts to engineering problems. Prerequisites: MECH 121 and MECH 122. Corequisite: MECH 123L. (4 units)

MECH 123L. Heat Transfer Laboratory
Laboratory work to understand the concept of heat transfer. Practical experience with temperature and heat flux measurement. Corequisite: MECH 123. (1 unit)

MECH 125. Thermal Systems Design
Analysis, design, and simulation of fluids and thermal engineering systems. Application of optimization techniques, life cycle, and sustainability concepts in these systems. Prerequisite: MECH 123. (4 units)

MECH 131. Thermodynamics II
Thermodynamic potential and availability, advanced power and refrigeration cycles, chemical equilibrium, advanced power and refrigeration cycles with non-reacting or reacting air/vapor mixture. Prerequisites: MECH 121. (4 units)

MECH 132. Aerodynamics
Fundamentals of aerodynamics. Governing equations (mass, momentum, energy). Inviscid, incompressible flow applied to subsonic air flow: Laplace's equations and flow superposition, Kutta-Joukowski theorem and generation of lift. Incompressible flow over airfoils: Kutta condition, Kelvin circulation theorem. Lifting flow over arbitrary bodies. Incompressible flow over finite wings: downwash and induced drag. Introduction to fundamental principles of viscous flow and discussion of drag components. Prerequisites: MECH 121, MECH 122 and MECH 122L. (4 units)

MECH 140. Dynamics
Kinematics of particles in rectilinear and curvilinear motion. Kinetics of particles, Newton's second law, energy and momentum methods. Systems of particles. Kinematics and kinetics of plane motion of rigid bodies, energy and momentum methods. Introduction to three-dimensional dynamics of rigid bodies. Prerequisite: CENG 41. Corequisite: AMTH 106. (4 units)

MECH 141. Mechanical Vibrations
Fundamentals of vibration, free and forced vibration of (undamped/damped) single degree and two-degree of freedom systems. Vibration under general forcing conditions. Determination of natural frequencies and mode shapes. Prerequisites: MECH 140. Corequisite: MECH 141L and AMTH 118. (4 units)

MECH 141L. Mechanical Vibrations Laboratory
Laboratory for MECH 141. Corequisite: MECH 141. (1 unit)

MECH 142. Feedback Control Systems
Introduction to system theory, transfer functions, and state space modeling of physical systems. Course topics include stability, analysis and design of PID, Lead/Lag, other forms of controllers in time and frequency domains, root locus, Bode diagrams, state space pole placement, and gain and phase margins. Prerequisite: MECH 141. Corequisite: MECH 142L. (4 units)

MECH 142L. Feedback Control Systems Laboratory
Laboratory for MECH 142. Corequisite: MECH 142. (1 unit)

MECH 143. Mechatronics
Introduction to behavior, design, and integration of electromechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and integration of transducers, microcontrollers, and actuators. Also listed as ELEN 123 and COEN 123. Prerequisite: MECH 45 and ELEN 50. Corequisite: MECH 143L. (4 units)

MECH 143L. Mechatronics Laboratory
Laboratory for MECH 143. Also listed as COEN 123L and ELEN 123L. Corequisite: MECH 143. (1 unit)

MECH 144. Smart Product Design
Design of innovative smart electromechanical devices and products. Topics include a review of the basics of mechanical, electrical, and software design and prototyping, and will emphasize the synthesis of functional systems that solve a customer need, that are developed in a team-based environment, and which are informed by the use of methodologies from the fields of systems engineering, concurrent design, and project/business management. Designs will be developed in the context of a cost-constrained business environment, and principles of accounting, marketing, and supply chain are addressed. Societal impacts of technical products and services are reviewed. Enrollment is controlled in order to have a class with students from diverse majors. Also listed as ENGR 144. Prerequisites: Core Foundation-level natural science and mathematics, or equivalent; instructor permission required. Corequisite: MECH 144L. (4 units)

MECH 144L. Smart Product Design Laboratory
Laboratory for MECH 144. Also listed as ENGR 144L. Corequisite: MECH 144. (1 unit)

MECH 145. Introduction to Aerospace Engineering
Basic design and analysis of atmospheric flight vehicles. Principles of aerodynamics, propulsion, structures and materials, flight dynamics, stability and control, mission analysis, and performance estimation. Introduction to orbital dynamics. Prerequisites: MECH 122 and MECH 122L. (4 units)

MECH 146. Mechanism Design
Kinematic analysis and synthesis of planar mechanisms. Graphical synthesis of linkages and cams. Graphical and analytical techniques for the displacement, velocity, and acceleration analysis of mechanisms. Computer-aided design of mechanisms. Three or four individual mechanism design projects. Prerequisite: MECH 114. (4 units)

MECH 151. Finite Element Theory and Applications
Introduction to finite elements; direct and variational basis for the governing equations; method of weighted residuals; elements and interpolating functions. Applications to general field problems: elasticity, fluid mechanics, and heat transfer. Extensive use of software packages. Prerequisites: CENG 43 and MECH 45 or equivalent and AMTH 106. (3 units)

MECH 152. Composite Materials
Analysis of composite materials and structures. Calculation of properties and failure of composite laminates. Manufacturing considerations and design of simple composite structures. Knowledge of MATLAB or equivalent programming environment is required. Also listed as MECH 350. Prerequisites: MECH 15, CENG 43, and MECH 45. (4 units)

MECH 153. Aerospace Structures
This introductory course presents the application of fundamental theories of elasticity and stress analysis to aerospace structures. Course topics include fundamentals of elasticity, virtual work and matrix methods, bending and buckling of thin plates, component load analysis, and airframe loads, torsion shear, and bending of thin-walled sections. Prerequisites: CENG 43 and CENG 43L. (4 units)

MECH 155. Astrodynamics
This course provides the foundations of basic gravitation and orbital theory. Topics include Review of particle dynamics, classical orbital elements, basic transformation matrices, ground tracks, Hohmann transfer, coplanar rendezvous, combined change maneuver, and interplanetary flight. Prerequisite: MECH 45 or equivalent, and MECH 140. (4 units)

MECH 156. Introduction to Nanotechnology
Introduction to the field of nanoscience and nanotechnology. Properties of nanomaterials and devices. Nanoelectronics: from silicon and beyond. Measurements of nanosystems. Applications and implications. Laboratory experience is an integral part of the course. Also listed as ECEN(ELEN) 156. Prerequisites: PHYS 33 and either PHYS 34 or MECH 15. Corequisite: MECH 156L. (4 units)

MECH 156L. Introduction to Nanotechnology Laboratory
Optional laboratory for MECH 156. (1 unit)

MECH 157. Engineering Simulations and Modeling
Simulation and modeling of solids and fluids using modern computational methods. Application of finite element modeling techniques to analyze mechanical systems subjected to various types of loading. Heat conduction and fluid interaction effects with solids. Transient problems including vibrations. Practical experience gained in using commercial simulation packages and interacting with CAD systems. Review of basic finite element theory with particular attention to modeling loads, constraints and materials. Prerequisites: CENG 43, MECH 122, MECH 123 (can be taken concurrently) or equivalent knowledge. (4 units)

MECH 158. Aerospace Propulsion Systems
Fundamentals of air breathing and rocket jet propulsion. Gas dynamics fundamentals, review of thermodynamic relation. Basic theory of aircraft gas turbine engines, propulsive efficiency, and application of Brayton cycle to gas turbine engine analysis. Rocket engine nozzle configuration and design. Thrust Equation. Chemical rocket engine fundamentals. Solid versus liquid propellant rockets. Prerequisites: MECH 121, MECH 122 and MECH 122L. (4 units)

MECH 160. Modern Instrumentation for Engineers
Introduction to engineering instrumentation, sensors, electric circuits, computer data acquisition, hardware and software, sampling theory, statistics, and error analysis. Theory of pressure, temperature, acceleration, and strain measurement. Prerequisites: MECH 123 or MECH 142. Corequisite: MECH 160L. (4 units)

MECH 160L. Modern Instrumentation for Engineers Laboratory
Laboratory work spans the disciplines of mechanical engineering: dynamics, controls, fluids, heat transfer, and thermodynamics, with emphasis on report writing. Students will design their own experiment and learn how to set up instrumentation using computer data acquisition hardware and software. Corequisite: MECH 160. (1 unit)

MECH 163. Materials Selection and Design
Design considerations in the use of materials; materials selection for optimizing multiple properties; materials failure modes and failure mechanism; materials selection to prevent failure; case studies and discussions on process economics, life-cycle thinking, and eco-design. Ansys Granta EduPack will be introduced as a materials and processes database and a tool for students to compare, analyze, and select materials and processes. Prerequisites: MECH 11 and CENG 43. (4 units)

MECH 171. Special Topics in Material, Mechanics, Manufacturing, and Design
Technical Elective in the area of material, mechanics, manufacturing, and design. A new topic in the area will be introduced. Topics vary every time it is offered. (4 units)

MECH 172. Special Topics in Thermofluids and Energy

Technical Elective in the area of thermofluids and energy. A new topic in the area will be introduced. Topics vary every time it is offered. (4 units)

MECH 173. Special Topics in Dynamics, Controls, and Robotics

Technical Elective in the area of dynamics, controls, and robotics. A new topic in the area will be introduced. Topics vary every time it is offered. (4 units)

MECH 177. Continuum Mechanics

General introduction to the mechanics of continuous media. Topics include the kinematics of deformation, the concept of stress, and the balance laws for mass, momentum, and energy. This is followed by an introduction to constitutive theory with applications to established models for viscous fluids and elastic solids. Concepts are illustrated through the solution of tractable initial-boundary-value problems. Prerequisites: MECH 122, CENG 43, and AMTH 106. (4 units)

MECH 179. Satellite Operations Laboratory

This laboratory course reviews the physical principles and control techniques appropriate to communicating with, commanding, and monitoring spacecraft. Students learn to operate real satellite tracking, commanding, and telemetry systems, and to perform spacecraft-specific operations using approved procedures. Given the operational status of the system, students may conduct these operations on orbiting NASA spacecraft and interact with NASA scientists and engineers as part of operations processes. Instructor permission required. (1 unit)

MECH 188. Co-op Education

Practical experience in a planned program designed to give students practical work experience related to their academic field of study and career objectives. Satisfactory completion of the assignment includes preparation of a summary report on co-op activities. P/NP grading. May be taken for graduate credit. (2 units)

MECH 189. Co-op Technical Report

Credit given for a technical report on a specific activity such as a design or research project after completing the co-op assignment. Approval of the department co-op advisor is required. Letter grades are based on content and presentation quality of report. Prerequisite: MECH 188. (2 units)

MECH 191. Mechanical Engineering Project Manufacturing

Laboratory course that provides supervised evening access to the machine shop and/or light fabrication area for qualified mechanical engineering students to work on their University-directed projects. Students wishing to utilize the machine shop or light fabrication during the evening lab/shop hours are required to enroll. Enrollment in any section allows students to attend any/all evening shop hours on a drop-in basis. Staff or faculty will be present during each scheduled meeting to supervise as well as be available for consultation and manufacturing advising. Prerequisites: Students must be qualified for machine shop use through successful completion of MECH 101L and passing grade on the Mechanical Engineering Lab Safety Test. Qualifications for light fabrication area use: successful completion of the Light Fabrication Training Seminar and a passing grade on the Mechanical Engineering Lab Safety Test. P/NP. (1 unit)

MECH 193. Peer Educator in Mechanical Engineering

Peer Educators in Mechanical Engineering work closely with a faculty member to help students understand course material; think more deeply about course material; benefit from collaborative learning; feel less anxious about testing situations; and/or to help students enjoy learning. Enrollment is by permission of the instructor. P/NP. (1-2 units)

MECH 194. Advanced Design I: Tools

Design tools basic to all aspects of mechanical engineering, including design methodology, computer-design tools, simulation, engineering economics, and decision making. Senior design projects begin. Prerequisite: MECH 115. Corequisite: MECH 101L. (4 units)

MECH 195. Advanced Design II: Implementation

Implementation of design strategy. Detail design and fabrication of senior design projects. Quality control, testing and evaluation, standards and specifications, and human factors. Prerequisite: MECH 194. (2 units)

MECH 196. Advanced Design III: Completion and Evaluation

Design projects completed, assembled, tested, evaluated, and judged with opportunities for detailed re-evaluation by the designers. Formal public presentation of results. Final written report required. Prerequisite: MECH 195. (2 units)

MECH 198. Independent Study

By arrangement with faculty. (1–5 units)

MECH 199. Directed Research/Reading

Investigation of an engineering problem and writing an acceptable report. Weekly meetings with faculty advisor are required. (1-4 units per quarter, for a total of up to 8 units can be considered as technical electives)

Graduate Courses

MECH 200. Advanced Engineering Mathematics I

Method of solution of the first, second, and higher order differential equations (ODEs). Integral transforms including Laplace transforms, Fourier series and Fourier transforms. Cross-listed with AMTH 200. (2 units)

MECH 201. Advanced Engineering Mathematics II

Method of solution of partial differential equations (PDEs) including separation of variables, Fourier series, and Laplace transforms. Introduction to calculus of variations. Selected topics from vector analysis and linear algebra. Cross-listed with AMTH 201. Prerequisite: AMTH/MECH 200. (2 units)

MECH 202. Advanced Engineering Mathematics I and II

Method of solution of the first, second, and higher order ordinary differential equations, Laplace transforms, Fourier series and Fourier transforms, method of solution of partial differential equations including separation of variables, Fourier series, and Laplace transforms. Selected topics from vector analysis, linear algebra, and calculus of variations. Also listed as AMTH 202. (4 units)

MECH 205. Aircraft Flight Dynamics I

Review of basic aerodynamics and propulsion. Aircraft performance, including equations of flight in vertical plane, gliding, level, and climbing flight, range and endurance, turning flight, takeoff and landing. Prerequisite: MECH 140. (2 units)

MECH 206. Aircraft Flight Dynamics II

Developing a nonlinear six-degrees-of-freedom aircraft model, longitudinal and lateral static stability and trim, linearized longitudinal dynamics including short period and phugoid modes. Linearized lateral-directional dynamics including roll, spiral, and Dutch roll modes. Aircraft handling qualities and introduction to flight control systems. Prerequisite: MECH 140 or MECH 205. (2 units)

MECH 207. Advanced Mechatronics I

Theory of operation, analysis, and implementation of fundamental physical and electrical device components: basic circuit elements, transistors, op-amps, sensors, electro-mechanical actuators. Application to the development of simple devices. Also listed as ELEN 460. Prerequisite: MECH 141 or ELEN 100. (3 units)

MECH 208. Advanced Mechatronics II

Theory of operation, analysis, and implementation of fundamental controller implementations: analog computers, digital state machines, microcontrollers. Application to the development of closed-loop control systems. Also listed as ECEN (ELEN) 461. Prerequisites: MECH 207 and 217. (3 units)

MECH 209. Advanced Mechatronics III

Electro-mechanical modeling and system development. Introduction to mechatronic support subsystems: power, communications. Fabrication techniques. Functional implementation of hybrid systems involving dynamic control and command logic. Also listed as ECEN (ELEN) 462. Prerequisite: MECH 208. (2 units)

MECH 210. Advanced Mechatronics IV

Application of mechatronics knowledge and skills to the development of an industry- or laboratory-sponsored mechatronics device/system. Systems engineering, concurrent design, and project management techniques. Performance assessment, verification, and validation. Advanced technical topics appropriate to the project may include robotic teleoperation, human-machine interfaces, multi-robot collaboration, and other advanced applications. Prerequisite: MECH 209. (2 units)

MECH 214. Advanced Dynamics

Partial differentiation of vector functions in a reference frame. Configuration constraints. Generalized speeds. Motion constraints. Partial angular velocities and partial linear velocities. Inertia scalars, vectors, matrices, and dyadics; principal moments of inertia. Generalized active forces. Contributing and non-contributing interaction forces. Generalized inertia forces. Relationship between generalized active forces and potential energy; generalized inertia forces and kinetic energy. Prerequisites: MECH 140 and AMTH 106. (4 units)

MECH 217. Introduction to Control

Laplace transforms, block diagrams, modeling of control system components and kinematics and dynamics of control systems, and compensation. Frequency domain techniques, such as root-locus, gain-phase, Nyquist and Nichols diagrams used to analyze control systems applications. Prerequisite: AMTH 106. (2 units)

MECH 218. Guidance and Control I

Modern and classical concepts for synthesis and analysis of guidance and control systems. Frequency and time domain methods for both continuous-time and sampled data systems. Compensation techniques for continuous-time and discrete-time control systems. Prerequisite: MECH 217, MECH 142, or instructor approval. (2 units)

MECH 219. Guidance and Control II

Continuation of MECH 218. Design and synthesis of digital and continuous-time control systems. Nonlinear control system design using phase plane and describing functions. Relay and modulator controllers. Prerequisite: MECH 218. (2 units)

MECH 220. Orbital Mechanics

This course provides the foundations of basic gravitation and orbital theory. Topics include the two-body problem, three-body problem, Lagrangian points, orbital position as a function of time, orbits in space and classical orbital elements, launch window, and calculating launch velocity. A Rocket dynamics and performance, orbital maneuvers, preliminary orbit determination including Gibbs and Gauss methods, Lambert's problem, relative motion and Clohessy-Wiltshire equations, and interplanetary flight. Prerequisites: MECH 140 or equivalent and AMTH 118 or equivalent. (4 units)

MECH 222. Aircraft and Rotorcraft System Identification

Theory and application of frequency domain system identification, collection of data, numerical Fourier Transform techniques, auto-spectra determination and frequency response identification, effect of noise and cross-control correlation, transfer function modeling, and determination of state space models, model structure selection and theoretical accuracy analysis. Prerequisites: MECH 142 or equivalent. (2 units)

MECH 225. Gas Dynamics

Flow of compressible fluids. One-dimensional isentropic flow, normal shock waves, frictional flow. Prerequisites: MECH 121 and 132. (2 units)

MECH 228. Energy Conversion and Conservation

Principles of thermodynamic laws and their application to energy conversion technologies. Concept of exergy, power generation from cycles, and improvement of modern power plants will be covered. Prerequisite: MECH 121 (4 units)

MECH 230. Statistical Thermodynamics

Kinetic theory of gasses. Maxwell-Boltzmann distributions, thermodynamic properties in terms of partition functions, quantum statistics, and applications. Prerequisites: AMTH 106 and MECH 121. (2 units)

MECH 232. Multibody Dynamics

Kinematics (angular velocity, differentiation in two reference frames, velocity and acceleration of two points fixed on a rigid body and one point moving on a rigid body, generalized coordinates and generalized speeds, basis transformation matrices in terms of Euler angles and quaternions), Newton-Euler equations, kinetic energy, partial angular velocities and partial velocities, Lagrange's equation, generalized active and inertia forces, Kane's equation and its operational superiority in formulating equations of motion for a system of particles and hinge-connected rigid bodies in a topological tree. Linearization of dynamical equations, application to Kane's formulation of the equations of motion of beams and plates undergoing large rotation with small deformation, dynamics of an arbitrary elastic body in large overall motion with small deformation and motion-induced stiffness, computationally efficient, recursive formulation of the equations of motion of a system of hinge-connected flexible bodies, component elastic mode selection, recursive formulation for a system of flexible bodies with structural loops, variable mass flexible rocket dynamics, modeling large elastic deformation with large reference frame motion. Prerequisite: MECH 140 or equivalent. (4 units)

MECH 239. Solid State Power Generation and Energy Harvesting

Introduction to unconventional power generation technologies via solid state energy conversion, such as photovoltaic (solar cells); thermoelectric; piezoelectric; and fuel cells. The course involves a term project as well as in-class lab activities to design an energy harvester by exploring practical issues. (4 units)

MECH 241. Approximation and Design of Heat Transfer System

Introduction to concepts of heat transfer mechanisms. Back-of-the-envelope style approximation for heat transfer system design problems. Prerequisite: MECH 123. (4 units)

MECH 242. Advanced Heat Transfer

Conservation equations to derive governing relations for fundamental heat transfer phenomena. More in-depth approach for Conduction; Convection; and Radiation. Prerequisite: MECH 123 or Undergraduate Heat Transfer. (4 units)

MECH 251. Finite Element Methods I

Introduction to finite elements; direct and variational basis for the governing equations; method of weighted residuals; elements and interpolating functions. Applications to general field problems: elasticity, fluid mechanics, and heat transfer. Extensive use of software packages. Cross-listed with MECH 151. Prerequisites: MECH 45 or equivalent and AMTH 106. (4 units)

MECH 252. Finite Element Methods II

Solution of nonlinear problems using finite element analysis. Methods for solving nonlinear matrix equations. Material, geometrical, boundary condition (contact) and other types of nonlinearities and application to solid mechanics. Transient nonlinear problems in thermal and fluid mechanics. Application of commercial FF codes to nonlinear analysis. Prerequisite: MECH 251. (4 units)

MECH 257. Engineering Simulations and Modeling

Simulation and modeling of solids and fluids using modern computational methods. Application of finite element modeling techniques to analyze mechanical systems subjected to various types of loading. Heat conduction and fluid interaction effects with solids. Transient problems including vibrations. Practical experience gained in using commercial simulation packages and interacting with CAD systems. Review of basic finite element theory with particular attention to modeling loads, constraints and materials. Prerequisites: CENG 43, MECH 122, MECH 123 (can be taken concurrently) or equivalent knowledge. (4 units)

MECH 266. Viscous Flow & Advanced Fluid Mechanics

Mathematical formulation of the conservation laws and theorems applied to flow fields. Potential flow, creeping flow, and physical phenomena. Derivation of the Navier-Stokes equations. The boundary layer approximations for high

Reynolds number flow. Exact and approximate solutions of laminar flows. Prerequisite: MECH 122. (4 units)

MECH 268. Computational Fluid Mechanics I
Introduction to numerical solution of fluid flow. Application to general and simplified forms of the fluid dynamics equations. Discretization methods, numerical grid generation, and numerical algorithms based on finite difference techniques. Prerequisite: MECH 266. (2 units)

MECH 269. Computational Fluid Mechanics II
Continuation of MECH 268. Generalized coordinate systems. Multidimensional compressible flow problems, turbulence modeling. Prerequisite: MECH 268. (2 units)

MECH 271. Turbulent and Convective Flow
Similarity solutions, instability, fundamentals of turbulence, convective heat transfer. Analytical and approximate solution techniques. Prerequisite: MECH 270. (4 units)

MECH 275. Design for Competitiveness
Overview of current design techniques aimed at improving global competitiveness. Design strategies and specific techniques. Group design projects in order to put these design ideas into simulated practice. (2 units)

MECH 276. Design for Manufacturability
Design for manufacturability and its applications within the product design process. Survey of design for manufacturability as it relates to design process, quality, robust design, material and process selection, functionality, and usability. Students will participate in group and individual projects that explore design for manufacturability considerations in consumer products. (2 units)

MECH 281. Elasticity, Fracture, and Fatigue
Fundamentals of the theory of linear elasticity, formulation of boundary value problems, applications to torsion, plane stress & strain, flexure, and bending of plates. Introduction to three-dimensional solutions. Fracture mechanics evaluation of structures containing defects. Theoretical development of stress intensity factors. Fracture toughness testing. Relationships among stress, flaw size, and material toughness. Emphasis on design applications with examples from aerospace, nuclear, and structural components. Prerequisite: Instructor approval. (4 units)

MECH 285. Computer-Aided Design of Mechanisms
Kinematic synthesis of mechanisms. Graphical and analytical mechanism synthesis techniques for motion generation, function generation, and path generation problems. Overview of various computer software packages available for mechanism design. (2 units)

MECH 286. Introduction to Wind Energy Engineering
Introduction to renewable energy, history of wind energy, types and applications of various wind turbines, wind characteristics and resources, introduction to different parts of a wind turbine including the aerodynamics of propellers, mechanical systems, electrical and electronic systems, wind energy system economics, environmental aspects and impacts of wind turbines, and the future of wind energy. Also listed as ECEN (ELEN) 286. (2 units)

MECH 287. Introduction to Alternative Energy Systems
Assessment of current and potential future energy systems; covering resources, extraction, conversion, and end-use. Emphasis on meeting regional and global energy needs in a sustainable manner. Different renewable and conventional energy technologies will be presented and their attributes described to evaluate and analyze energy technology systems. Also listed as ECEN (ELEN) 280. (2 units)

MECH 290. Graduate Research/Project
Research into topics of mechanical engineering; topics and credit to be determined by the instructor, report required, cannot be converted into Master or Ph.D. research. By arrangement. Prerequisites: instructor and department chair approval. (1–6 units)

MECH 291. Special Topics in Aerospace Engineering
Topics vary each quarter. (2-4 units)

MECH 292. Special Topics in Mechatronic Systems Engineering

Topics vary each quarter. (2-4 units)

MECH 293. Special Topics in Mechanics and Materials

Topics vary each quarter. (2-4 units)

MECH 294. Special Topics in Design and Manufacturing

Topics vary each quarter. (2-4 units)

MECH 295. Special Topics in Thermofluids and Energy

Topics vary each quarter. (2-4 units)

MECH 296. Special Topics in Dynamics and Controls

Topics vary each quarter. (2-4 units)

MECH 297. Seminar

Discrete lectures on current problems and progress in fields related to mechanical engineering. P/NP grading. (1 unit)

MECH 298. Independent Study

By arrangement. (1–6 units)

MECH 299. Master's Thesis

By arrangement. May be repeated up to 6 units. (1–4 units)

MECH 305. Advanced Vibrations

Response of single and two-degrees-of-freedom systems to initial, periodic, nonperiodic excitations. Reviewing the elements of analytical dynamics, including the principle of virtual work, Hamilton's principle and Lagrange's equations. Response of multi-degree-of-freedom systems. Modeling and dynamic response of discrete vibrating elastic bodies. Analytical techniques for solving dynamic and vibration problems. Vector-tensor-matrix formulation with practical applications to computer simulation. Dynamic response of continuous elastic systems. Strings, membranes, beams, and plates exposed to various dynamic loading. Applications to aero-elastic systems and mechanical systems. Modal analysis and finite element methods applied to vibrating systems. Prerequisite: MECH 141. (4 units)

MECH 311. Modeling and Control of Telerobotic Systems

Case studies of telerobotic devices and mission control architectures. Analysis and control techniques relevant to the remote operation of devices, vehicles, and facilities. Development of a significant research project involving modeling, simulation, or experimentation, and leading to the publication of results. Prerequisite: Instructor approval. (4 units)

MECH 313. Advanced Aerospace Structures

Advanced aircraft, spacecraft structural design and analysis. Airworthiness requirements and load factors. Stress analysis of aircraft components including wing spars and box beams, fuselage structures, and structural materials. Defection analysis of structural systems. Conventional, stiffened, sandwich, and laminated composite structures. Thermal effects. Prerequisite: MECH 153. (4 units)

MECH 323. Modern Control Systems I

Concept of state-space descriptions of dynamic systems. Relations to frequency domain descriptions. State-space realizations and canonical forms. Stability. Controllability and observability. State feedback and observer design. Also listed as ECEN (ELEN) 236. Prerequisite: MECH 142 or 217. (2 units)

MECH 324. Modern Control Systems II

Shaping the dynamic response, pole placement, reduced-order observers, LQG/LTR, introduction to random process and Kalman filters. Prerequisite: MECH 323. (2 units)

MECH 325. Computational Geometry for Computer-Aided Design and Manufacture

Analytic basis for description of points, curves, and surfaces in three-dimensional space. Generation of surfaces for numerically driven machine tools. Plane coordinate geometry, three-dimensional geometry and vector algebra, coordinate transformations, three-dimensional curve and surface geometry, and curve and surface design. (2 units)

MECH 330. Atomic Bonding, Crystal Structure, and Material Properties

Structure of crystalline materials and the relationship between structure and mechanical, thermal, and electrical properties. For all engineering disciplines. Prerequisites: AMTH 245 or MECH 200 or MECH 202. (4 units)

MECH 331. Equilibrium Thermodynamics and Phase Transformations

Thermodynamics of multi-component systems and phase diagrams. Diffusion and phase transformations. For all engineering disciplines. (4 units)

MECH 333. Experiments in Materials Science

This course is an introduction into experimental methods in materials science with the focus on the evaluation of structural and physical properties, especially at the nanoscale. A review of the fundamentals of X-ray, SEM, EDS, and TEM microanalysis represents the core of the course. The main AFM imaging modes and their applications are covered. Practical implementation concepts of Optical, Electron and Atomic Force Microscopes are given along with sample preparation techniques, calibration methods, image analysis, and AFM artifacts. (2 units)

MECH 335. Adaptive Control I

Overview of adaptive control, Lyapunov stability theory, direct and indirect model-reference adaptive control, least-squares system identification technique, neural network approximation, and neural-network adaptive control. Prerequisites: MECH 324, ECEN (ELEN) 237, and knowledge of Matlab/Simulink. (2 units)

MECH 336. Adaptive Control II

Stability and robustness of adaptive controller, robust modification, bounded linear stability analysis, metrics-driven adaptive control, constraint-based optimal adaptive control, and advanced topics in adaptive control. Prerequisite: MECH 335 or instructor approval, and ECEN (ELEN) 237. (2 units)

MECH 337. Robotics I

Overview of robotic systems and applications. Components. Homogeneous transforms. Denavit-Hartenberg representation. Forward and inverse kinematics. Manipulator Jacobian. Singular configurations. Also listed as ECEN (ELEN) 337. Prerequisites: AMTH 245 and MECH 217. (2 units)

MECH 338. Robotics II

Newton-Euler Dynamics. Trajectory planning. Linear manipulator control. Nonlinear manipulator control. Joint space control. Cartesian space control. Hybrid force/position control. Obstacle avoidance. Robotic simulation. Also listed as ECEN (ELEN) 338. Prerequisite: MECH 337. (2 units)

MECH 339. Robotics III

Advanced topics: parallel manipulators, redundant manipulators, underactuated manipulators, coupled manipulator/platform dynamics and control, hardware experimentation and control, dextrous manipulation, multi-robot manipulation, current research in robotic manipulation. Also listed as ECEN (ELEN) 339. Prerequisite: MECH 338. (2 units)

MECH 345. Instrumentation and Design of Experiment

Overview of sensors and experimental techniques. Fundamentals of computer-based data acquisition and control, principles of operation of components in a data acquisitions system. Design and analysis of engineering experiments with emphasis on practical applications. Characterization of experimental accuracy, error analysis, and statistical analysis. Experiments involving measurements and control of equipment. (2 units)

MECH 350. Composite Materials

Design, analysis, and manufacturing of composite materials. Characterization of composites at the materials and substructural levels. Hyperselection. Manufacturing technology and its impact on design. Also listed as MECH 152. (4 units)

MECH 371. Space Systems Design and Engineering I

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to orbital

mechanics, power, command and data handling, and attitude determination and control. Also listed as ENGR 371. Note: MECH 371 and MECH 372 may be taken in any order. (4 units)

MECH 372. Space Systems Design and Engineering II
A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to mechanical, thermal, software, and sensing elements. Also listed as ENGR 372. Note: MECH 371 and 372 may be taken in any order. (4 units)

MECH 377. Continuum Mechanics
General introduction to the mechanics of continuous media. Topics include the kinematics of deformation, the concept of stress, and the balance laws for mass, momentum, and energy. This is followed by an introduction to constitutive theory with applications to established models for viscous fluids and elastic solids. Concepts are illustrated through the solution of tractable initial-boundary-value problems. Prerequisites: MECH 122, CENG 43, AMTH 106. (4 units)

MECH 379. Satellite Operations Laboratory
Introduces analysis and control topics relating to the operation of on-orbit spacecraft. Several teaching modules address conceptual topics to include mission and orbit planning, antenna tracking, command and telemetry operations, resource allocation, and anomaly management. Students will become certified to operate real spacecraft and will participate in the operation of both orbiting satellites and ground prototype systems. (1 unit)

MECH 399. Ph.D. Thesis Research
By arrangement. May be repeated up to 40 units. (1–9 units)

MECH 415. Optimization in Mechanical Design
Introduction to optimization: design and performance criteria. Application of optimization techniques in engineering design, including case studies. Functions of single and multiple variables. Optimization with constraints. Prerequisites: AMTH 106 and AMTH 245. (2 units)

MECH 420. Model Predictive Control
Review of state-space model in discrete time, stability, optimal control, prediction, Kalman filter. Measurable and unmeasurable disturbance, finite and receding horizon control, MPC formulation and design. Also listed as ECEN (ELEN) 238. Prerequisite: MECH 323 or ECEN (ELEN) 236. (2 units)

MECH 423. **Nonlinear Systems & Control I** This course is an Introduction to nonlinear systems. Topics include introducing some nonlinear phenomena, phase-plane analysis including phase portraits, singular points, linearization, limit cycles, Poincare-Bendixson criteria, Lyapunov stability theorems, LaSalle's invariance principle, stability analysis of linear system via Lyapunov stability theorem, Lyapunov stability analysis of nonautonomous, and linear time-varying systems. Also listed as ECEN (ELEN) 232. Prerequisite: MECH 323/ ECEN (ELEN) 236 or its equivalent. (2 units)

MECH 424. **Nonlinear Systems & Control II** This course is an Introduction to nonlinear control system design. Topics include Introduction to nonlinear control, stabilization via linearization, Integral control, integral control via linearization, feedback linearization including input-output, input-state, and full state linearization, sliding mode control, back stepping, introduction to adaptive control. Prerequisite: MECH 423/ ECEN (ELEN) 232 or its equivalent. (2 units)

MECH 429. Optimal Control I
Introduction to the principles and methods of the optimal control approach: performance measure criteria including the definition of minimum-time, terminal control, minimum-control effort, tracking, and regulatory problems, calculus of variations applied to optimal control problems including Euler-Lagrange equation, transversality condition constraint, Pontryagin's minimum principle (PMP), linear quadratic regulator (LQR) and tracking control problems. Also listed as ECEN (ELEN) 237. Prerequisite: MECH 323 or an equivalent course in linear system theory. Students are expected to be proficient in MATLAB/Simulink or MECH 142 or equivalent. (2 units)

MECH 430. Optimal Control II

Continuation of Optimal Control I, control with state constraints, minimum-time and minimum-fuel problems, singular arcs, Bellman's principle of optimality, dynamic programming, the Hamilton-Jacobi-Bellman (H-J-B) equation, and introduction to differential game theory including zero-sum game and linear quadratic differential game problem. Prerequisite: MECH 429 or an equivalent course. Students are expected to be proficient in MATLAB/Simulink. (2 units)

MECH 431. Spacecraft Dynamics and Control

Kinematics and Attitude dynamics, gravity-gradient stabilization, single and dual-spin stabilization, control laws with momentum exchange devices, momentum wheels. Time-optimal slew maneuvers, momentum-biased attitude stabilization, reaction thruster attitude control, introduction to dynamics of flexible spacecraft and liquid sloshing problem. Prerequisites: MECH 140 and AMTH 106. (4 units)

Chapter 15: Power Systems and Sustainable Energy Program

Program Advisor: Dr. Maryam Khanbaghi

Overview

Twenty-first century problems demand holistic thinking to effectively address the social, environmental, and economic impact of emerging energy technologies. We offer a graduate certificate in Renewable Energy and a multi-disciplinary master's degree in Power Systems and Sustainable Energy. Both offerings balance deep technical expertise with practical application experience, while also promoting understanding of the economics, public policy, and ethics that shape the industry. A broad and ever-increasing range of courses—power systems, smart grid, energy management, security, and infrastructure, to name a few—are complemented by lectures, workshops, and field trips offered quarterly by our energetic Energy Club. Fuel your passion for energy engineering as you train alongside Silicon Valley professionals to meet the changing demands in energy and fulfill a pressing need in the rapidly growing renewable energy market in our Valley and the world.

Master's Degree Program and Requirements

Students interested in this major must satisfy the standard admissions criteria used by the School of Engineering, which include an undergraduate degree in a field of engineering (physics degrees will also be considered), appropriate GRE scores and (for international students) demonstrated proficiency in English. Both TOEFL and IELTS scores are acceptable for this purpose. All students are expected to maintain a minimum grade point average of 3.0 while enrolled in the program. They must also develop a PS\&SE Program of Studies with the program advisor and file this document with the Graduate Programs Office by the end of their first quarter at SCU.

Required Courses

Foundational Courses

- ECEN (ELEN) 280/MECH 287 Introduction to Alternative Energy Systems (2 units)
- ECEN (ELEN) 281A Power Systems: Generation and Transmission (2 units)
- ECEN (ELEN) 281B Power Systems: Distribution (2 units)
- Or ECEN (ELEN) 281E Power Systems (4 units)
- ECEN (ELEN) 285 Introduction to the Smart Grid (2 units)

Graduate Core Courses

- ENGR 272 Energy Public Policy (2 units)
- ENGR 273 Sustainable Energy and Ethics (2 units) or Engr 344 Artificial Intelligence and Ethics (2 units)
- EMGT 255 Managerial Accounting for Operating Managers (2 units)
- EMGT 380 Introduction to Systems Engineering Management (2 units)

Applied Mathematics Courses

- AMTH 245 Linear Algebra I (2 units)
- AMTH 246 Linear Algebra II (2 units)
- Or AMTH 247 Linear Algebra (4 units)
- 4 units to be selected in consultation with the student's academic advisor

A set of specialized energy-related courses which are appropriate to the area of engineering in which the student is interested. These four areas are:

Mechanical Engineering

- ECEN (ELEN) 231 Power System Stability and Control (4 units)
- ECEN (ELEN) 287/ENGR 339 Energy Storage Systems (2 units)
- MECH 239 Solid State Power Generation and Energy Harvesting (4 units)
- MECH 228 Energy Conversion and Conservation (4 units)

Electrical Engineering

- ECEN (ELEN) 231 Power System Stability and Control (4 units)
- ECEN (ELEN) 287/ENGR 339 Energy Storage Systems (2 units)
- ECEN (ELEN) 288 Energy Management Systems or ECEN (ELEN) 236 Linear Control Systems (2 units)
- ECEN (ELEN) 353 DC to DC Power Conversion (2 units)

Computer Engineering

- CSEN (COEN) 242 Big Data (4 units) or CSEN (COEN) 240 Machine Learning (4 units)
- CSEN (COEN) 243 Internet of Things (4 units)
- CSEN (COEN) 266 Artificial Intelligence (4 units)

Civil Engineering

- CENG 217 Sustainable Infrastructure for Developing Countries (4 units) or\ CENG 288 Engineering Decision and Risk Analysis (4 units)
- CENG 219 Designing for Sustainable Construction (4 units)
- CENG 249 Civil Systems Engineering (4 units)

Additional elective courses to complete the 46-unit requirement must be approved by the academic advisor. These elective courses may include a thesis, up to nine units.

Renewable Energy Certificate Program

The main goal of this certificate is to introduce students to the field of renewable energy. The intent is to help equip professionals in Silicon Valley with the knowledge that will help them advance in their present career or enter the renewable energy field. To enroll in this certificate, an applicant should have a B.S. in Engineering from an accredited school and maintain a grade point average of 3.0. As with most certificates in the Graduate School of Engineering, the requirement is 16 quarter units. Eight of these units are in Power Systems and eight units are in Renewable Energy.

Continuation for A Master's Degree

Santa Clara University graduate courses applied to the completion of a certificate program earn graduate credit that may also be applied toward a graduate degree. Students who wish to continue for such a degree must submit a separate application and satisfy all standard admission requirements. The general GRE test requirement for graduate admission to the master's degree will be waived for students who complete a certificate program with a GPA of 3.5 or better.

Required Courses (16 units total)

Power Systems

- ECEN (ELEN) 280/MECH 287 Introduction to Alternative Energy Systems (2 units)

- ECEN (ELEN) 281A Power Systems: Generation and Transmission (2 units)
- ECEN (ELEN) 281B Power Systems: Distribution (2 units)
- Or ECEN (ELEN) 281E Power Systems (4 units)
- ECEN (ELEN) 285 Introduction to the Smart Grid (2 units)

Renewable Energy

- ECEN (ELEN) 284 Solar Cell Technologies and Simulation Tools (2 units) or ECEN (ELEN) 380 Economics of Energy (2 units)
- ECEN (ELEN) 286/MECH 286 Introduction to Wind Energy Engineering (2 units)
- ECEN (ELEN) 287 Storage Device Systems (2 units)
- ENGR 272 Energy Public Policy (2 units)

Chapter 16: Robotics and Automation Program

Program Advisor: Dr. Christopher Kitts

OVERVIEW

Robotics and the automation sciences relating to intelligent machines and smart systems is a burgeoning field that is fueling the economy, driving employment in Silicon Valley and beyond, and transforming the nature of work in a wide range of applications. We offer a multi-disciplinary master's degree in Robotics and Automation, which balances deep technical expertise with practical application-oriented experience and with insight into the societal impacts, ethical challenges and entrepreneurial opportunities relevant to this field. A technical core ensures competence in the areas of design, controls and perception. Elective-based focus areas within the degree provide opportunities for students to build knowledge and expertise in application areas such as industrial internet-of-things and manufacturing, field robotics, etc. Furthermore, partnerships with local companies and agencies provide highly applicable project experiences, ensure a relevant curriculum, and contribute to a strong student recruitment pipeline. Finally, a novel co-curricular option certifies student competencies in modern skills and tools relevant to the robotics and automation industry.

MASTER'S DEGREE PROGRAM AND REQUIREMENTS

Students interested in this major must satisfy the standard admissions criteria used by the School of Engineering, which include an undergraduate degree in a field of engineering or related area, appropriate GRE scores, and demonstrated proficiency in English. Students must also have an academic background or be able to demonstrate proficiency in computer programming, electrical circuit design, and mechanical design; students deficient in one or more of these areas may be required to take additional courses in these areas at either the graduate or undergraduate level prior to entering or early in their degree program. Students are expected to maintain a minimum grade point average of 3.0 while enrolled in the program. They must also develop a Robotics and Automation Program of Studies with an academic advisor and file this document with the Graduate Services Office by the end of their first quarter at SCU.

The degree requires completion of a minimum of 46 graduate units, to include:

- **Enrichment Experience (minimum 8 units)**
    - Graduate Core: one course each from "Engineering and Business/Entrepreneurship" and "Engineering and Society" (a minimum of 4 units)
    - The additional 4 units can be satisfied by any combination of a) one or more technical electives, b) additional classes from Graduate Core List, c) Cooperative Education courses (ENGR 288/289) and d) combination of a, b and c.

Mathematics (8 units): Students must complete at least one Applied Math 4-unit sequence in either linear algebra or probability. The additional 4 units may be completed by taking another Applied Math course or by completing 4 units of technical elective courses that have significant mathematical components (a list of applicable elective courses is maintained in the program office).

- AMTH 245 Linear Algebra I (2) and AMTH 246 Linear Algebra II (2) [or AMTH 247 Linear Algebra I & II (4)]
- AMTH 210 Probability I (2) and AMTH 211 Probability II (2) [or AMTH 212 Probability I & II (4)]

Technical Core (13 units): Students must complete 13 or more units of core courses covering basic mechatronic device design, mechatronic control systems, robotic kinematics/dynamics/control, and advanced sensing/perception techniques:

- ECEN (ELEN) 460 / MECH 207 Advanced Mechatronics I (3)
- ECEN (ELEN) 461 / MECH 208 Advanced Mechatronics II (3)
- ECEN (ELEN) 337 / MECH 337 Robotics I (2)
- ECEN (ELEN) 338 / MECH 338 Robotics II (2)
- 3 or 4 units of course content in advanced sensing/perception, which may be satisfied by either:
    - CSEN (COEN) 240 Machine Learning (4), or
    - CSEN (COEN) 340 / ECEN (ELEN) 640 Digital Image Processing I (2) and CSEN (COEN) 341 / ECEN (ELEN) 643 Digital Image Processing II (2)
    - Other possible courses as approved by the program advisor

Technical Electives (8 units): Students must complete a minimum of 8 units of technical electives based on the following list or by a course approved by the student's advisor via the Program of Studies prior to enrolling in the course. Students are encouraged to select technical electives to build expertise in one or more application areas; a list of these application areas and their associated electives is maintained in the program office.

- AMTH 377 / CSEN (COEN) 279 Design and Analysis of Algorithms (4)
- BIOE 252 Computational Neuroscience (2)
- BIOE 277 Biosensors (2)
- BIOE 281 Introduction to Pattern Recognition (2)
- CSEN (COEN) 201 / ECEN (ELEN) 233 Digital Signal Processing I (2) & CSEN (COEN) 202 / ECEN (ELEN) 234 Digital Signal Processing II (2) or CSEN (COEN) 201E /ECEN (ELEN) 233E Digital Signal Processing I & II (4)
- CSEN (COEN) 240 Machine Learning (4)
- CSEN (COEN) 242 Big Data (4)
- CSEN (COEN) 243 Internet of Things (4)
- CSEN (COEN) 266 Artificial Intelligence (4)
- CSEN (COEN) 277 User Experience Research & Design (2)
- CSEN (COEN) 281 Pattern Recognition and Data Mining (4)
- CSEN (COEN) 317 Distributed Systems (4)
- CSEN (COEN) 319 Parallel Programming (4)
- CSEN (COEN) 340 /ECEN (ELEN) 640 Digital Image Processing I (2) & CSEN (COEN) 341 /ECEN (ELEN) 643 Digital Image Processing II (2)
- CSEN (COEN) 342 Deep Learning
- CSEN (COEN) 344 /ECEN (ELEN) 644 Computer Vision I (2) & CSEN (COEN) 345 / ECEN (ELEN) 645 Computer Vision II (2)
- CSEN (COEN) 376 Expert Systems (4)
- ECEN (ELEN) 235 Estimation (2)
- ECEN (ELEN 236 Linear Control Systems (2)
- ECEN (ELEN 237 Optimal Control (2)
- ECEN (ELEN) 238 / MECH 420 Model Predictive Control (2)
- ECEN (ELEN) 239 Introduction to Self-Driving Car Technology (4)
- ECEN (ELEN) 271 Microsensors (2)
- ECEN (ELEN) 329 / MECH 329 Introduction to Intelligent Control (2)
- ECEN (ELEN) 331(L) Autonomous Driving Systems (and Lab)
- ECEN (ELEN) 333 Digital Control Systems (2)
- ECEN (ELEN) 335 Estimation II (2)
- ECEN (ELEN) 501 Embedded Systems (2)
- ECEN (ELEN) 501L Embedded Systems Lab (1)
- ECEN (ELEN) 502 Real-Time Systems (2)
- ECEN (ELEN) 503 Hardware-Software Codesign (2)
- ECEN (ELEN) 520 Introduction to Machine Learning (2)
- ECEN (ELEN) 520I Introduction to Machine Learning Laboratory (1)
- MECH 218 Guidance & Control I (2) & MECH 219 Guidance & Control II (2)

- MECH 285 Computer Aided Design of Mechanisms (2)
- MECH 296A Mobile Multirobot Systems (2)
- MECH 311 Modeling and Control of Telerobotic Systems (4)
- MECH 323 Modern Control Systems I (2) and MECH 324 Modern Control Systems II (2)
- MECH 335 Adaptive Control I (2) and MECH 336 Adaptive Control II (2)
- MECH 379 Satellite Operations Laboratory (1)

Students are encouraged to complete collections of these electives to meet technology themes within the field of robotics and automation. These collections may evolve over time given technology trends; the program web site lists current themes with affiliated industry partners and capstone/thesis opportunities. Examples include topics such as advanced manufacturing, field robotics, bio-robotics/mechatronics, aerospace robotics, automation sciences, and so on.

Culminating Experience (6-12 units): Students must complete 6-9 units of either a Capstone Design Project or a 9-12 unit Thesis research project through an existing Capstone or Master's Thesis course in a relevant engineering department.

Additional Units (as necessary): Additional units as required to reach a minimum of 46 units must be completed; these must be approved by the student's advisor via the Program of Studies prior to enrolling in the courses. Typically, any extra units would be completed by enrolling in additional technical elective courses; however, in some cases, it may be of interest to take courses such as the project management or systems engineering course sequences offered by the Engineering Management program. Students may not apply the completion of one course to two different requirement categories, with the exception of the mathematics requirement.

Modern Tools/Skills Competency Badging (Optional): Students may participate in this competency certification system to develop verified capabilities, acknowledged through the awarding of a "badge," in a variety of areas that are in great demand by employers. Some of these badges will be obtained through completion of courses within the program. Others may be incorporated into the required "culminating experience." There may also be opportunities to participate in co-curricular non-credit workshops in some topics. Management of these competency badges are managed through an online design portfolio system available to all students.

Chapter 17: Graduate Minor in Science, Technology and Society (STS)

Program Advisor: Dr. Aleksandar Zecevic

Program Description

The graduate minor in science, technology, and society (STS) is designed to help students gain a deeper understanding of the influence that engineering has on society (and vice versa). Knowledge of this kind has become essential in an increasingly complex and interconnected world, in which purely technical expertise often needs to be supplemented by additional skills. In order to successfully operate in such an environment, engineers must (at the very least) have the ability to communicate clearly, function on interdisciplinary and diverse teams, and make ethically and socially responsible decisions.

The need to develop such skills has been widely recognized in universities around the country, as witnessed by the growing emphasis on interdisciplinary studies in undergraduate engineering curricula. It is unusual, however, to encounter programs of this kind on the graduate level. Most traditional master's programs still focus on specialized technical topics and offer little insight into how practicing engineers might engage global challenges such as climate change, sustainability, or economic disparity (to name just a few).

The primary purpose of the STS minor is to offer graduate students an opportunity to examine some of these key social issues on an advanced level. The scope of the minor is broad and includes topics that range from the social impact of new technologies, to applied ethics, sustainability, and religion. As such, it reflects an educational philosophy that goes well beyond narrow specialization and promotes a global and societal orientation. All the courses in this program have a distinctly interdisciplinary flavor, and are designed to develop creativity, innovation, and leadership.

The minor consists of a Core and a set of electives and entails a minimum of 12 units of coursework. It is open to all students who are pursuing a master's degree in engineering, regardless of the specific program in which they are enrolled.

Program Requirements

The STS minor consists of a Core and a set of electives and entails a minimum of 12 units of coursework. The Core courses cover three distinct thematic areas:

• Social and Philosophical Issues in Science and Engineering

• Engineering, Ethics and Spirituality

• Sustainability and Engineering

Students will be required to take at least one course in each of the three Core areas outlined above (for a minimum of 6 units). The remaining units (up to a total of 12, or more if desired) can be accumulated by taking a combination of electives and additional STS Core courses.

A list of approved STS Core courses and the different thematic areas to which they belong is provided below. Note that courses which appear in multiple areas can be used to satisfy only one Core requirement (in other words, no "double dipping" is allowed).

Social and Philosophical Issues in Science and Engineering

- ENGR 261 Nanotechnology and Society
- ENGR 272 Energy Public Policy
- ENGR 302 Managing in the Multicultural Environment
- ENGR 303 Gender and Engineering
- ENGR 304 Building Global Teams
- ENGR 336 Engineering for the Developing World
- ENGR 337 Social Entrepreneurship
- ENGR 341 Innovation, Design and Spirituality
- ENGR 342 3D Print Technology and Society

Engineering, Ethics and Spirituality

- CSEN (COEN) 288 Software Ethics
- ECEN (ELEN) 217 Chaos Theory, Metamathematics and the Limits of Knowledge: A Scientific Perspective on Religion
- ENGR 273 Sustainable Energy and Ethics
- ENGR 344 Artificial Intelligence and Ethics
- ENGR 341 Innovation, Design and Spirituality

Sustainability and Engineering

- ECEN (ELEN) 280/MECH 287 Introduction to Alternative Energy Systems
- ECEN (ELEN) 288/COEN 282 Energy Management Systems
- ENGR 271 Energy Conservation
- ENGR 272 Energy Public Policy
- ENGR 273 Sustainable Energy and Ethics
- ENGR 349 Topics in Frugal Engineering

Admission Procedures

The STS minor option is open to all master's students in the School of Engineering. Those who wish to pursue this minor must submit an application form to the Graduate Services Office by the end of their third quarter at SCU (at the latest), and must have their program of studies approved by the academic advisor for this program (Dr. Aleksander Zecevic).

Students who complete all the technical requirements set by their department, as well as an approved set of STS classes, will receive a master's degree with a minor in Science, Technology, and Society. The degree will be conferred by the department to which the student was originally accepted. Please note that the grades obtained in STS courses will be included in the overall GPA and will carry the same weight as grades obtained in technical classes.

There are no financial or academic penalties for not completing the minor. Such students will receive the standard master's degree, with no reference to the STS minor.

Financial Aid for the STS Minor

Students who have declared a graduate minor in Science, Technology, and Society (STS) are eligible for a special form of financial aid. The amount of aid is limited to 75% of tuition for up to 12 units (excluding fees). These funds can be applied only to courses taken beyond the 46 units that are required for a master's degree.

In order to become eligible for this benefit, students must check the appropriate box that pertains to financial aid on the application form. In addition, their program of studies must be approved by the academic advisor for the program (Dr. Aleksandar Zecevic). Financial aid comes into effect once a student completes 46 units of course work, at which

point he or she should follow the procedure outlined below:

1. The quarterly tuition must be paid in full, and in the timeframe specified by the Bursar's Office.
2. In the second week of each quarter, students must provide the program academic advisor with a list of courses in which they are currently enrolled (this will require official proof of registration).
3. Once the academic advisor establishes that the courses conform to the approved programs of studies (both in the technical and in the STS area), students will receive financial aid in the amount of 75% of their tuition expenses for that quarter (excluding fees).

Chapter 18: Certificate Programs

General Information

Certificate programs are designed to provide intensive background in a narrow area at the graduate level. At approximately one-third of the units required for a master's degree, the certificate is designed to be completed in a much shorter period of time. These certificate programs are appropriate for students working in industry who wish to update their skills or for those interested in changing their career path.

Interdisciplinary

Certificate in Frugal Innovation

Advisor: Dr. Aleksandar Zecevic

Over the past two decades, global trends have been forcing businesses to adapt to growing consumer bases in Africa, Asia, and Latin America, which are in desperate need of low-cost and high-quality solutions to the challenges that they face. The importance of these new "economic realities" is underscored by the fact that emerging markets are expected to exceed 50% of the world's GDP in 2017 (according to IMF estimates). In order to excel professionally in such an environment, engineers will have to be equipped with the knowledge and skill sets to appropriately define, design, and implement solutions that are not merely a "stripping down" of Western products to meet the rising demand. Industry, particularly in Silicon Valley, is becoming increasingly aware of this fact and has begun to move toward a 'Triple Bottom Line' approach to business, which integrates environmental, societal, and financial considerations. The Certificate in Frugal Innovation is designed to give students the ability and the tools to adapt to this new model, and to expand their understanding of the impact that engineering has on society.

This program is suitable for working professionals in a wide variety of engineering disciplines. To enroll, students must have a B.S in Engineering from an accredited institution, and should maintain a GPA of at least 3.0 in order to receive the certificate.

Program Requirements

The Certificate in Frugal Innovation entails a minimum of 16 units of course work. It consists of an eight-unit Core, and a set of electives that are organized into two groups. Students are required to take four units from Group A and another four from Group B, as described below.

Required Core Classes (8 units)

- ENGR 336 Engineering for the Developing World (2 units)
- ENGR 338 Mobile Applications and Instrumentation for Emerging Markets (2 units)
- ENGR 340 Distributed and Renewable Energy for the Developing World (2 units)
- ENGR 341 Innovation, Design and Spirituality (2 units)

Elective Group A (4 units)

- ENGR 273 Sustainable Energy and Ethics (2 units)
- ENGR 304 Building Global Teams (2 units)
- ENGR 342 3D Print Technology and Society (2 units)
- ENGR 349 Special Topics in Frugal Engineering (2 units)

Elective Group B (4 units)

- CENG 219 Designing for Sustainable Construction (4 units)
- CSEN (COEN) 389 Energy Efficient Computing (2 units)
- ECEN (ELEN) 280/MECH 287 Introduction to Alternative Energy Systems (2 units)
- ECEN (ELEN) 288/COEN 282 Energy Management Systems (2 units)
- ENGR 302 Managing in the Multicultural Environment (2 units)
- ENGR 334 Energy, Climate Change, and Social Justice (2 units)

Renewable Energy Certificate

Advisor: Dr. Maryam Khanbaghi

Renewable energy is the fastest-growing sector in California and brings together principles and practices from engineering, environmental science, and economics. Silicon Valley, the home of the world's largest cluster of renewable energy companies and green investors, offers fertile ground to recruit career changers who wish to move into renewable energy and students who want to take advantage of the tremendous career opportunities.

The main goal of this certificate is to introduce students to the field of renewable energy. The intent is to help equip professionals in Silicon Valley with the knowledge that will help them advance in their present career or enter the renewable energy field. To enroll in this certificate, an applicant should have a B.S. in Engineering from an accredited school and should maintain a grade point average of 3.0. As with most certificates in the Graduate School of Engineering, the requirement is 16 quarter units. Eight of these units are in Power Systems, eight units are in Renewable Energy.

Required Courses (16 units total)

Power Systems (8 units)

- ECEN (ELEN) 280/MECH 287 Renewable Energy (2 units)
- ECEN (ELEN) 281A Power Systems: Generation and Transmission (2 units)
- ECEN (ELEN) 281B Power Systems Distribution (2 units) or ECEN (ELEN) 281E (4 units)
- ECEN (ELEN) 285 Introduction to the Smart Grid (2 units)

Renewable Energy (8 units)

- ECEN (ELEN) 284 Solar Cell Technologies and Simulation Tools (2 units) or ECEN (ELEN) 380 Economics of Energy (2 units)
- ECEN (ELEN)/MECH 286 Introduction to Wind Energy Engineering (2 units)
- ECEN (ELEN) 287 Storage Device Systems (2 units)
- ENGR 272 Energy Public Policy (2 units)

Electrical and Computer Engineering Certificates

Digital System Design

Advisor: Dr. Hoeseok Yang

This certificate program has a triple purpose: (a) to increase design skills in digital system development, (b) to strengthen fundamental knowledge of computer architecture, digital design and embedded systems; and (c) to introduce the digital system designer to state-of-the-art tools and techniques. The program consists of the courses listed below totaling 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (6 units)

- ECEN (ELEN) 501 (Embedded Systems) 2 units
- ECEN (ELEN) 511 Advanced Computer Architecture (2 units)

- ECEN (ELEN) 603 Logic Design Using HDL (2 units)

Elective Courses (10 units)

- ECEN (ELEN) 387 VLSI Design I (2 units)
- ECEN (ELEN) 388 VLSI Design II (2 units)
- ECEN (ELEN) 500 Logic Analysis and Synthesis (2 units)
- ECEN (ELEN) 502 Real Time Systems (2 units)
- ECEN (ELEN) 503 Hardware-Software Co-design (2 units)
- ECEN (ELEN) 512 Advanced Computer Architecture II (2 units)
- ECEN (ELEN) 513 Parallel System Architectures (2 units)
- ECEN (ELEN) 530 Hardware Security and Trust (2 units)
- ECEN (ELEN) 608 Design for Testability (2 units)
- ECEN (ELEN) 613 SoC (System-on-Chip) Verification (2 units)

Integrated Circuit Design and Technology

Advisors: Dr. Shoba Krishnan, Dr. Cary Yang, Dr. Mahmudur Rahman

The study of integrated circuits consists of three interconnected areas: Design, Devices and Process Technology. This certificate provides the necessary fundamentals in these areas and advanced concepts and applications in integrated circuit design, devices, and process technology. The program will also introduce the IC designer to state-of-the-art tools and techniques. The program consists of the courses listed below; students are required to complete a total of 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (8 units)

- ECEN (ELEN) 252 Analog Integrated Circuits I (2 units)
- ECEN (ELEN) 261 Fundamentals of Semiconductor Physics (2 units)
- ECEN (ELEN) 270 Introduction to IC Materials (2 units)
- ECEN (ELEN) 387 VLSI Design I (2 units)

Elective Courses (8 units)

- ECEN (ELEN) 251 Transistor Models for IC Design (2 units)
- ECEN (ELEN) 253 Analog Integrated Circuit Design (2 units)
- ECEN (ELEN) 254 Advanced Analog Integrated Circuit Design
- ECEN (ELEN) 264 Semiconductor Device Theory I (2 units)
- ECEN (ELEN) 265 Semiconductor Device Theory II (2 units)
- ECEN (ELEN) 267 Device Electronics for IC Design (4 units)
- ECEN (ELEN) 271 Microsensors: Components and Systems (2 Units)
- ECEN (ELEN) 274 Integrated Circuit Fabrication Processes I (2 units)
- ECEN (ELEN) 275 Integrated Circuit Fabrication Processes II (2 units)
- ECEN (ELEN) 351 RF Integrated Circuit Design (2 units)
- ECEN (ELEN) 352 Mixed Signal IC Design for Data Communications (2 units)
- ECEN (ELEN) 353 DC to DC Power Conversion (2 units)
- ECEN (ELEN) 361 Nanoelectronics
- ECEN (ELEN) 388 VLSI Design II (2 units)

Digital Signal Processing and Machine Learning

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a basic understanding of digital signal processing theory, machine learning and modern implementation methods as well as advanced knowledge of at least one specific application area. Digital signal processing and machine learning have become important across many areas of engineering, and this certificate prepares students for traditional or novel applications. This certificate can be earned with a combination of in-person and on-line courses.

Required Courses (11 units minimum)

- ECEN (ELEN) 233 Digital Signal Processing I (2 units)
- ECEN (ELEN) 520 and ECEN (ELEN) 520L Introduction to Machine Learning (3 units)
- At least one course from: AMTH 210 Probability I or AMTH 245 Linear Algebra I or AMTH 370 Optimization Techniques (2 units)
- At least one course from: ECEN (ELEN) 223 Digital Signal Processing System Development (4 units) or ECEN (ELEN) 226 Machine Learning and Signal Processing Using FPGAs (2 units) or ECEN(ELEN) 234 Digital Signal Processing II (2 units)
- At least one course from: ECEN (ELEN) 421 Speech Processing I or ECEN (ELEN) 640 Digital Image Processing I (2 units) or both ECEN (ELEN) 521 Deep Learning (2 units) and 521L Deep Learning Laboratory (1 unit) *Note: ECEN (ELEN) 233E Digital Signal Processing I, II (4 units) is equivalent to both ECEN (ELEN) 233 and ECEN (ELEN) 234.*

Elective Courses (Additional courses to make a total of 16 units) selected from the list below or from any courses in the list above that are not used to meet the specified certificate requirements:

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ECEN (ELEN) 243 Digital Communications Systems (2 units)
- ECEN (ELEN) 244 Information Theory (2 units)
- ECEN (ELEN) 334 Introduction to Statistical Signal Processing (2 units)
- ECEN (ELEN) 422 Speech Coding II (2 units)
- ECEN (ELEN) 431 Adaptive Signal Processing I (2 units)
- ECEN (ELEN) 522 Reinforcement Learning (2 units)
- ECEN (ELEN) 523 Natural Language Processing with Deep Learning (2 units)
- ECEN (ELEN) 643 Digital Image Processing II (2 units)
- ECEN (ELEN) 644 Computer Vision I (2 units) or ECEN (ELEN) 645 Computer Vision II (2 units)

Digital Signal Processing Theory

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a firm theoretical grounding in fundamentals of digital signal processing (DSP) technology and its applications. It is appropriate for engineers involved with any application of DSP who want a better working knowledge of DSP theory and its applications. A novel feature of the program is a hands-on DSP hardware/software development laboratory course in which students design and build systems for various applications using contemporary DSP hardware and development software.

Required Courses (8 units)

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ECEN (ELEN) 233E or ECEN (ELEN) 233 and 234 Digital Signal Processing I, II (4 units)
- ECEN (ELEN) 334 Introduction to Statistical Signal Processing (2 units)

Elective Courses (8 units)

- ECEN (ELEN) 223 Digital Signal Processing System Development (4 units)
- ECEN (ELEN) 226 Machine Learning and Signal Processing Using FPGAs (2 units)
- ECEN (ELEN) 235 Estimation I (2 units)

- ECEN (ELEN) 241 Introduction to Communications (2 units)
- ECEN (ELEN) 244 Information Theory (2 units)
- ECEN (ELEN) 336 Detection (2 units)
- ECEN (ELEN 431) Adaptive Signal Processing I (2 units)
- ECEN (ELEN) 640 Digital Image Processing I (2 units)
- ECEN (ELEN) 641 Image and Video Compression (2 units)
- ECEN (ELEN) 643 Digital Image Processing II (2 units

Fundamentals of Electrical and Computer Engineering

Advisor: Dr. Shoba Krishnan

This certificate has been designed for those individuals who have significant work experience in some area of electrical and computer engineering and wish to take graduate-level courses but may lack some prerequisite knowledge because they have not earned a BS degree in electrical and/or computer engineering. This one-year program consists of 16 to 28 units, depending on the background of the individual student, and covers electrical and computer engineering core areas. Units from courses at or above the 200 level may be credited toward the Master of Science Degree in Electrical and Computer Engineering after successful completion of the certificate.

The specific required courses for a certificate are selected with the help of the program advisor according to the student's background.

- ECEN (ELEN) 21 Introduction to Logic Design (5 units)
- ECEN (ELEN) 50 Electric Circuits I (5 units)
- ECEN (ELEN) 100 Electric Circuits II (5 units)
- ECEN (ELEN) 104 Electromagnetics I (5 units)
- ECEN (ELEN) 110 Linear Systems (5 units) or ECEN (ELEN) 210 (2 units)
- ECEN (ELEN) 115 Electronic Circuits I (5 units) or ECEN (ELEN) 250 (2 units)
- ECEN (ELEN) 120 Microprocessor System Design (5 units)

RF and Applied Electromagnetics

Advisor: Dr. Kurt Schab

The purpose of this certificate is to meet the increasing need for the knowledge in microwave, antenna and RF integrated circuits in existing electronic products. This program is offered for students who have a B.S. in Electrical Computer Engineering. Students are expected to have knowledge of multivariate calculus and preferably partial differential equations and they must ensure that they have prerequisites for the courses in their program.

The curriculum consists of 16 units: two required courses (4 units) and 12 units of elective courses listed below:

Required Courses (4 units)

- ECEN (ELEN) 201 Electromagnetic Field Theory I (2 units)
- ECEN (ELEN) 701 Microwave System Architecture (2 units)

Elective Courses (12 units)

- ECEN (ELEN) 202 Computational Electromagnetics (2 units)
- ECEN (ELEN) 203 Bio-Electromagnetics (2 units)
- ELEN 204 Magnetic Circuits for Electric and Autonomous Vehicles (2 units)
- ECEN (ELEN) 351 RF Integrated Circuit Design or ECEN (ELEN) 354 Advanced RFIC Design (2 units each)
- ECEN (ELEN) 624 Signal Integrity in IC and PCB Systems (2 units)
- ECEN (ELEN) 706 Microwave Circuit Analysis and Design (2 units) (Passive Component)
- ECEN (ELEN) 711 Active Microwave Devices I or ECEN (ELEN) 712 Active Microwave Devices II (2 units each)

(Active Components)

- ECEN (ELEN) 715 Antennas I or ECEN (ELEN) 716 Antennas II (2 units each)
- ECEN (ELEN) 726 Microwave Measurements, Theory and Tech (3 units) (Laboratory Oriented)

Substitutions for these courses are only possible with the approval of the certificate advisor and the chair

Mechanical Engineering Certificates

Department Chair: Dr. Hohyun Lee

Design and Manufacturing; Dynamics and Controls; Mechanics and Materials; Mechatronic Systems Engineering; Thermofluids and Energy as well as general mechanical engineering. The certificate program is designed for working professionals, who would like to deepen their understanding in disciplinary subjects and apply the knowledge toward real engineering problems. One can receive a certificate in Mechanical Engineering by taking 16 units of Mechanical Engineering graduate courses with a minimum GPA of 3.0 and grade above of C or better in each course. Candidates for a certificate in a specific concentration area must take at least 8 units of core courses from the concentration area, which is listed under the section "Master of Science in Mechanical Engineering" in Chapter 14: Department of Mechanical Engineering of this Bulletin. Applicants must have completed an accredited bachelor's degree program in Mechanical Engineering or a closely related field of engineering. Up to 16 units earned in a certificate can be transferred toward another advanced degree program at SCU if they are accepted to the M.S. program.

Robotics and Automation Certificate Program

Advisor: Dr. Christopher Kitts

This certificate program provides a graduate level introduction to the theoretical knowledge and the practical skills necessary to excel in the growing, interdisciplinary fields of robotics, autonomous systems, intelligent machines, and smart products. The program is offered to students with an undergraduate degree in a field of engineering or related area. Students should also have an academic background or demonstrate proficiency in computer programming, basic electrical circuit design, basic mechanical design, and system dynamics. The curriculum consists of 16 units: three required courses (7 units) and 9 units of elective courses listed below:

Required Courses (7 units)

- MECH/ECEN (ELEN) 207 Advanced Mechatronics I (3 units)
- MECH/ECEN (ELEN) 337 Robotics I (2 units)
- MECH/ECEN (ELEN) 338 Robotics II (2 units)

Elective Courses (9 units)

- BIOE 277 Biosensors (2 units)
- CSEN (COEN) 240 Machine Learning (4 units)
- CSEN (COEN) 266 Artificial Intelligence (4 units)
- CSEN (COEN) 344 /ECEN (ELEN) 644 Computer Vision I (2 units)
- CSEN (COEN) 345 /ECEN (ELEN) 645 Computer Vision II (2 units)
- ECEN (ELEN) 331(L) Autonomous Driving Systems (2 units w/optional 1-unit Lab)
- ECEN (ELEN) 520(L) Intro to Machine Learning (2 units w/optional 1-unit Lab)
- MECH 208 / ECEN(ELEN) 461 Adv Mechatronics II (3 units)
- MECH 323 Modern Control Systems I (2 units)
- MECH 324 Modern Control Systems II (2 units)
- Up to 2 units of experiential research and design work:
  - MECH 290 Graduate Research Project (1-2 units)
- Up to 4 units of mathematics selected from the following courses:
  - AMTH 245 Linear Algebra I (2 units)

- AMTH 246 Linear Algebra II (2 units)
- AMTH 247 Linear Algebra I & II (4 units)
- AMTH 210 Probability I (2 units)
- AMTH 211 Probability II (2 units)
- AMTH 212 Probability I & II (4 units)
- Up to 2 units of coursework relating to business, societal and/or ethical issues:
  - CSEN (COEN) 288 Software Ethics (2 units)
  - EMGT 292 Managing Capital Assets in the Smart Machine Era (2 units)
  - ENGR 342 3D Print Technology and Society (2 units)
  - ENGR 344 Artificial Intelligence and Ethics (2 units)

Substitutions for these courses are possible with the approval of the certificate advisor.

Chapter 19: Campus Life

Santa Clara students are encouraged to participate in extracurricular activities as part of their total development. The primary educational objective in supporting student activities and organizations is to foster a community that is enriched by men and women of diverse backgrounds, wherein freedom of inquiry and expression enjoys high priority.

The following sections describe various aspects of student life and services.

Campus Ministry

Campus Ministry is composed of people who are committed to spiritual and personal growth. Its mission is to foster the spiritual life of our students and Campus Ministry values Gathering across differences, discerning what is needed, and transforming our hearts & communities.

- In support of the University's mission to the "development of the whole person," Campus Ministry offers a variety of programs as well as pastoral presence to support personal and spiritual development.
- Campus Ministry provides a welcoming environment where faith may be explored, discovered, and developed through worship, retreats, small groups, and conversation.

What does Campus Ministry have to offer?

- **Worship**: Three Sunday liturgies in the Mission Church at 10am, 5pm and 8pm, daily noon Mass in the Mission in the Mission, weekly Misa en español, weekly confession, University celebrations, prayer services, ecumenical (Christian) services, religious celebrations for Muslim, Hindu, Sikh, Buddhist, and Jewish students, and interfaith services throughout the year.
- **Retreats**: Santa Clara students are offered a number of retreat experiences over the course of the academic year. There are two retreats offered that graduate students are invited to attend, a silent Ignatian retreat, and Gift of Peace retreat. Retreats are offered to persons of all faiths.
- **Prayer and reflection groups**: The Spiritual Life Community program places students in small groups for weekly prayer and reflection. In addition, there are Interfaith Dinner Discussions, weekly Breaking Open the Word (reflection on the lectionary readings), RLC small groups, and outreach to student athletes.
- **Leadership opportunities**: Students explore the values of "servant leadership" by serving and leading in all program areas as volunteers, or in one of a number of paid internships.
- **Faith formation**: Campus Ministry offers several opportunities for students to learn, reflect, and grow in regard to their Catholic faith through Scripture reflection, forums, and presentations. This includes preparation for the sacraments of Baptism, first Eucharist, and Confirmation in the Catholic Church.
- **Social justice awareness and action**: Campus Ministry provides students with a variety of opportunities to live out a faith that does justice. Some key focus areas include participation in the annual Ignatian Family Teach-in for Justice, and community service at a local school.
- **Faith-based clubs**: In partnership with the Center for Student Involvement, Campus Ministry aids in the mentoring and support of all faith-based registered student organizations.
- **Sacred spaces**: Throughout campus, there are spaces that can be conducive for prayer, meditation, and reflection, such as the Mission Church, the Multifaith Sanctuary in St. Joseph's Hall, or the Meditation Room in Benson.

Is Campus Ministry for everyone?

Yes! We welcome the participation of anyone interested in personal and spritual growth, regardless of faith tradition. Your experience at Santa Clara is a time for learning about yourself and our world, and we hope we can accompany you in that exploration and deepening of faith and spirituality.

Student Media

KSCU: KSCU FM 103.3 is Santa Clara's own student-operated radio station. KSCU provides hands-on radio broadcasting experience to students and community members. The staff of KSCU operates all aspects of the radio station providing leadership opportunities in a variety of areas including music, budgeting, fundraising, promotions, management, and sports broadcasting. KSCU website

Santa Clara Review: The Santa Clara Review (SCR) is a bi-annual literary magazine. Submissions are drawn nationally from students, staff, and community members. There are opportunities to contribute in the areas of poetry, fiction, non-fiction, art, and management. Students are encouraged to submit their pieces for publication in the Santa Clara Review as well as in the companion magazine titled The Owl. Santa Clara Review website

Student Resources and Services

The Cowell Center is the comprehensive health care provider for the Santa Clara University student community. We are committed to caring for the whole person by providing professional medical and psychological services through compassionate treatment and education.

Counseling and Psychological Services

We are a team of licensed therapists, graduate-level psychological trainees, and mental health professionals dedicated to promoting students' well-being through short-term therapy, crisis support, groups & workshops, and more. At Counseling and Psychological Services (CAPS), we are committed to the values of multiculturalism and social justice, and are dedicated to providing mental health services that are open to and accepting of every student we serve. CAPS 24/7 Mental Health Support (408) 554-5220 CAPS 24/7 website. All CAPS appointments are free of charge. Appointments with the Psychiatric Nurse Practitioner in CAPS are also free, though the student is responsible for any lab and medication expenses. For all one-on-one CAPS appointments, there is a $30 fee for late cancellations (under 24 hours) or no-shows.

Student Health Services

At the Student Health Services (SHS), we promote the physical health of all SCU students by identifying and teating the most common medical illnesses and injuries. We provide a wide range of services including primary care, urgent care, minor procedures, physical exams, health education, immunizations, STI testing, nutrition services, and pharmacy services (limited in-house). For specialist medical care (including X-ray services), we help refer students to off-campus community providers when appropriate. Medical visits to the Cowell Center's Student Health Services range from $10 to $50 per visit for all students. Visit fees are in addition to all other nominal associated fees, such as the cost of medications, lab/blood tests, and supplies. Visits to Cowell Center's Counseling and Psychological Services range in cost from no charge to $100 (subject to change) per visit for all students. For further information, see the Cowell Center website. When SHS is closed, an advice nurse is available by phone for students both on campus (extension 4880) and off campus (408-554-4880). A volunteer student emergency medical group, SCU Emergency Medical Services (EMS), is also available to take care of medical emergencies on campus. The health center is closed from mid-June to mid-August.

Chapter 20: Student Conduct Code

Statement of Responsibilities and Standards of Conduct

All members of the University community have a strong responsibility to protect and maintain an academic climate in which the fundamental freedom to learn can be enjoyed by all and where the rights and well-being of all members of the community are protected. To this end, certain basic regulations and policies have been developed to govern the conduct of all students as members of the University community. The Student Handbook is available online at http://www.scu.edu/osl/policies-and-protocols/

Academic Integrity

The University is committed to academic excellence and integrity. Santa Clara University Students affirm the following commitment to academic integrity:

I am committed to being a person of integrity. I pledge, as a member of the Santa Clara University community, to abide by and uphold the standards of academic integrity contained in the Student Conduct Code.

Students are expected to do their own work and to cite any sources they use. Academic dishonesty may include but is not limited to plagiarism (i.e., representing the work or ideas of others as one's own without giving proper acknowledgment), cheating (e.g., copying the work of another person, falsifying laboratory data, sabotaging the work of others), and other acts generally understood to be dishonest by faculty or students in an academic context.

A student who is guilty of a dishonest act in an examination, paper, or other work required for a course, or who assists others in such an act, may, at the discretion of the instructor, receive a grade of "F" for the course. In addition, a student found guilty of a dishonest act may be subject to sanctions, up to and including dismissal from the University, as a result of the student judicial process as described in the Student Handbook and the Academic Integrity Protocol. A student who violates copyright laws, including those covering the copying of software programs, or who knowingly alters official academic records from this or any other institution is subject to similar disciplinary action.

Academic Integrity Protocol

Allegations within the Context of a Course

These procedures are intended to protect the integrity of the instructional program and of student academic achievement. Any member of the Santa Clara University community with a suspicion or evidence of academic dishonesty of some kind as described in the Student Conduct Code (e.g., plagiarism, falsification of data, misrepresentation of research, or the use of prohibited materials during an examination, and other acts generally understood to be dishonest by faculty or students in an academic context) may initiate an allegation of student academic dishonesty. The following describes procedures for resolution by due process.

If the allegation arises within the context of a course or academic assignment, its resolution begins with the instructor responsible for that course or assignment, who informs the student of the suspicion. If the instructor judges on the basis of available evidence that an academic violation has occurred, the instructor applies an academic sanction and notifies the student of the reason for the academic sanction. The instructor decides on the severity of the academic sanction (e.g., refusal to accept an assignment, "F" on the particular assignment, or "F" for the entire course). The instructor will report in writing to the department chair and the Office of Student Life what violation of academic

integrity has occurred and what academic sanction has been applied. The Office of Student Life will pursue the matter as a violation of the Student Conduct Code through the University judicial process. This process is not intended to limit academic freedom.

Appeal Process for Academic Sanctions

If, after discussion with the instructor concerning the academic sanction applied, the student wants to challenge the instructor's decision, the student will contact the chair of the department in which the course is offered. If the instructor is the department chair, then the appeal is made to the dean of the school or college in which the course is offered or designated, and the dean or designate refers the case to the chair of a closely related department.

The department chair hearing the appeal has the option to convene an ad hoc panel if the complexity of the case warrants doing so. The student suspected of committing academic dishonesty has the right to bring a support person whose only role is to accompany the student to the hearing. The panel will include two full-time faculty members from the department in which the course was offered, one full-time faculty member from a closely related department, and two students who are trained student judicial board members. Staff in the Office of Student Life will arrange for the participation of the student panel members. The charge of the panel is to study all previously considered and newly developed evidence, review statements of all parties concerned, interview all parties concerned, and make a recommendation to the department chair.

The parties involved have the right to file an objection to the appointment of a particular faculty member or student to the ad hoc panel. This objection must be based upon a belief that the named faculty member or student is unable to conduct an impartial evaluation and therefore will not review the case in an impartial manner. The objection is filed with the chair hearing the appeal who will make a ruling on this objection. If necessary, the chair will then appoint a different faculty member or student.

After reviewing all relevant materials and information, including the recommendation of the ad hoc panel when one is convened, the department chair will consider all evidence available, confer with all parties concerned, inform all parties of the recommendation regarding the alleged violation, and report the recommendation to the student and the Office of Student Life. However, final responsibility for assigning grades remains with the instructor of the course.

Decisions may only be appealed to one level above the instructor. All proceedings are intended to be confidential.

If the student wishes to withdraw from the course, the instructor's approval is required for the withdrawal process. The instructor may refuse to approve of the withdrawal and may assign an appropriate grade.

University Judicial Records Policy

When the Office of Student Life receives the report, the assistant dean will meet with the student to discuss the relevance of the violation to the Student Conduct Code. Whether further judicial sanctions are applied or not, the report of academic dishonesty will remain on file in the Office of Student Life for the remainder of the student's enrollment at Santa Clara University. The student involved has the right to include a statement as part of these files.

If it is ruled that the student committed an academic integrity violation, the Office of Student Life will administer a judicial sanction that would range from a letter of warning to expulsion from the University. The severity of the judicial sanction depends on the severity of the circumstances, including the student's judicial history and previous academic integrity violations.

Allegations Outside a Course

If the allegation involves a situation outside the context of a course, resolution begins with the Office of Student Life. The assistant dean will confer with all parties concerned. After hearing all evidence and conducting further investigation as needed, the assistant dean will either hear the case or refer it to a judicial board in accordance with the University Judicial Process. The outcome of the hearing will be communicated to those involved.

Chapter 21: University Policies

Clery Act

Santa Clara University values the safety and well-being of our students, staff, and faculty, and visitors. The University community can only remain safe and secure through the cooperation of community members. By working together, we all can continue to make SCU a safe and welcoming university.

Under the Jeanne Clery Disclosure of Campus Security Policy and Campus Crime Statistics Act, Santa Clara University annually collects information about campus crimes and other reportable incidents as defined by the law. This information is made available to assist current and potential students and employees in making informed decisions regarding their attendance or employment at the University. It is the policy of Santa Clara University that the campus community will be informed on a timely basis of all reports of crime and other information affecting the security of our campus and the personal safety of our students, faculty, staff, and guests.

For more information about campus safety policies, procedures, and statistics concerning campus crime, please see the Annual Security & Fire Safety Report (www.scu.edu/clery).

Child Abuse and Neglect Reporting Act (CANRA)

The University strives to safeguard the well-being of all children and encourages all members of the University community who observe, have actual knowledge of, or reasonably suspect child abuse or neglect at a University facility or perpetrated by University personnel to promptly report the concern to appropriate law enforcement, external officials, and university officials.

The Child Abuse Neglect and Reporting Act (CANRA) requires that employers of mandated reporters promote identification and reporting of child abuse or neglect. Mandated Reporters under CANRA are responsible for reporting the incident themselves. They are not required to investigate any known or suspected cases of abuse.

It is the policy of Santa Clara University that all university employees (as well as volunteers and independent contractors) who, in the course of their business or volunteer activity, have reasonable suspicion of child abuse or neglect are required to make a report. This policy applies to all Santa Clara University locations and all University-sponsored or hosted programs, events, and activities, including study abroad programs. Please note that information learned through any confidential communications made to a clergy member subject to the clergy-penitent privilege is not required to be reported. For more information or questions related to this policy, please contact the Office of Equal Opportunity and Title IX (https://www.scu.edu/title-ix).

Communication by the University to Students

The University will communicate with students through a variety of formats. Information that is sent to students from the University via their campus mailbox, local address, or their Santa Clara email address is considered official communication and should be treated as such. Students are asked to check their campus mailbox and their Santa Clara email account on a daily basis, and are responsible for reading and responding to the information they receive from the University. The University urges students to use their Santa Clara email address as their primary email; students who will not be checking that address regularly should forward their email to their preferred email account.

Consensual Relations Between Employees and Students

In addition to prohibiting sexual harassment under the Policy on Discrimination, Harassment Sexual Misconduct, the University prohibits any consensual dating, romantic, or sexual relationship between an employee and a student over whom that employee has any instructional, supervisory, advising, or evaluative responsibility. Such a relationship is fraught with problems, including the potential for exploitation, favoritism, and conflict of interest. The appearance of impropriety or unfairness may also adversely affect the learning and work environment for other students and employees. This policy applies to faculty, staff, and student employees. Employees who violate this policy are subject to sanctions for misconduct under the policies of the Faculty Handbook, Staff Policy Manual, or Student Employment Handbook, as appropriate to their employment status. Employees or students with questions about this policy should contact the Director of Equal Opportunity and Title IX or the Department of Human Resources.

Drug-free Workplace and School Program

It is the goal of Santa Clara University to maintain a drug-free workplace and campus. The unlawful manufacture, distribution, dispensation, possession, and/or use of controlled substances or the unlawful possession, use, or distribution of alcohol is prohibited on the Santa Clara University campus, in the workplace, or as part of any of the University's activities. This includes the unlawful use of controlled substances or alcohol in the workplace even if it does not result in impaired job performance or in unacceptable conduct.

The unlawful presence of any controlled substance or alcohol in the workplace and campus itself is prohibited. The workplace and campus are presumed to include all Santa Clara premises where the activities of the University are conducted.

Violations will result in disciplinary action up to and including termination of employment for faculty and staff or expulsion of students. A disciplinary action may also include the completion of an appropriate rehabilitation program. Violations may also be referred to the appropriate authorities for prosecution.

The program information is distributed on an annual basis to all faculty, staff, and students. New staff employees are given a copy at New Employee Orientation. New faculty employees are given a copy at New Faculty Orientation. The program is reviewed at least biennially by the Office of Student Life and the Department of Human Resources.

Notice of Student Rights under the Family Educational Rights and Privacy Act

The Family Educational Rights and Privacy Act of 1974 (FERPA) is the federal law that protects the confidentiality of the educational records of students maintained by the University and affords students certain rights with respect to those records. A student is any person who attends or has attended a class at the University, which includes courses taken through videoconference, satellite, internet, or other electronic and telecommunication technologies. Students' rights under FERPA include:

The right to inspect and review educational records

Students have the right to inspect and review their education records. Students should submit a written request to the Office of the Registrar that specifies what records the students would like to inspect and review. Within 45 days of receipt of the request, the Office of the Registrar will make arrangements for access and will notify students of the time and place where the records may be reviewed.

The right to seek amendment to educational records

Students have the right to request the amendment of their educational records to ensure that those records are not inaccurate, misleading, or otherwise in violation of students' privacy or other rights. Students who wish to seek an amendment to a record should write to the University Registrar, clearly identify the part of the record they want changed, and specify why it should be changed. If the University decides not to amend the record as requested, the

University will notify students in writing of the decision and their right to a hearing regarding the request for amendment. Additional information regarding the hearing procedures will be provided to students when notified of the right to a hearing.

The right to consent to disclosure of educational records

Students have the right to consent to the disclosure of personally identifiable information contained in their educational records. In some instances, the University may disclose personally identifiable information from a student's educational record without the student's consent. One such instance is to a school official who has a legitimate educational interest in the record. A school official is a person employed by the University in an administrative, supervisory, academic, research, or support staff position; a person elected to the Board of Trustees; or a person or entity under contract with the University who has been designated a school official by the University and is performing specific duties for the University that require a legitimate educational interest.

A school official has a legitimate educational interest if the official needs to review any educational records in order to fulfill his or her professional responsibility.

The University is authorized under provisions of FERPA to release directory information without the student's prior consent, unless a student explicitly requests in writing that the University not do so and keep directory information confidential.

Directory information is designated as follows:

- Name
- Address: Campus post office box, local, and permanent addresses (residence hall and room numbers are not disclosed)
- Telephone number
- Email address
- Photograph
- Date and place of birth
- Major field of study
- Classification level/academic standing
- Dates of attendance (defined as academic year or quarter)
- Participation in officially recognized activities and sports
- Weight and height of members of athletic teams
- Degrees (including expected or actual degree date), honors and awards received, and dates
- Most recent educational agency or institution attended

Students may submit a Request to Prevent Disclosure of Directory Information form to the Office of the Registrar, which directs the University not to disclose directory information. Once filed, the nondisclosure remains in effect until the beginning of the next academic year or a shorter period if designated by a student. Graduating students must notify the Office of the Registrar in writing to remove the nondisclosure from their record.

Former or current borrowers of funds from any Title IV student loan program should note carefully that nondisclosure will not prevent the University from releasing information pertinent to employment, enrollment status, current address, and loan account status to a school lender, subsequent holder, guarantee agency, the United States Department of Education, or an authorized agent.

The right to file a complaint with the U.S. Department of Education

Students have the right to file a complaint with the United States Department of Education concerning alleged failures by the University to comply with the requirements of FERPA. Written complaints should be directed to the U.S. Department of Education, Student Privacy Policy Office, 400 Maryland Ave., SW, Washington D.C. 20202-8520.

For further information regarding Santa Clara University's FERPA policy, please refer to www.scu.edu/ferpa/scu-ferpa-policy/, or contact the Office of the Registrar.

Equal Opportunity, Nondiscrimination and Sexual Harassment Policies

Gender-Based Discrimination and Sexual Misconduct Policy

Santa Clara University is committed to providing an environment free of gender-based discrimination, including sexual harassment, sexual misconduct, sexual violence and assault, relationship (dating and domestic) violence, and stalking. The University provides resources and reporting options to students, faculty, and staff to address concerns related to gender-based discrimination and sexual misconduct prohibited by Title IX and University policy, and, through training and education, works to prevent its occurrence. The University seeks to provide a consistent, caring, and timely response when sexual and gender-based misconduct occurs within the University community. When the University becomes aware of allegations of sexual misconduct, it will take prompt and effective action. This action may include an initial assessment of safety and well-being, implementing interim remedies at no cost to the complainant for protection and support, discussing how the complainant wishes to proceed, initiating an investigation, and/or identifying appropriate avenues for resolution. The University's response will be overseen by the Director of Equal Opportunity and Title IX.

The University's Gender-Based Discrimination and Sexual Misconduct Policy applies to all students, faculty, and staff, and includes any individual regularly or temporarily employed, studying, living, visiting, or serving in an official capacity at Santa Clara University (including volunteers and contractors). The policy applies to both on-campus and off-campus conduct and to online actions that have a potential or actual adverse impact on any member of the University community, or which substantially interferes with a person's ability to participate in University activities, or which could affect a substantial University interest or its educational mission. For more information about reporting, response, and adjudication, please see the University's Gender-Based Discrimination and Sexual Misconduct Policy or contact the Director of Equal Opportunity and Title IX, www.scu.edu/title-ix.

> NOTE: The Department of Education issued proposed Title IX regulations in 2022. The University will update relevant policies and procedures including the Gender-Based Discrimination and Sexual Misconduct Policy to ensure compliance and will post revisions online at www.scu.edu/title-ix.

What Constitutes Consent

The University adheres to California's definition of affirmative consent for sexual activity. Affirmative consent means affirmative, conscious, and voluntary agreement to engage in sexual activity. Since individuals may experience the same interaction in different ways, it is the responsibility of each party to determine that the other has consented before engaging in the activity.

For consent to be valid, there must be a clear expression in words or actions that the other individual consented to that specific sexual conduct. Reasonable reciprocation can be implied. For example, if someone kisses you, you can kiss them back (if you want to) without the need to explicitly obtain their consent to being kissed back.

Consent can also be withdrawn once given, as long as the withdrawal is reasonably and clearly communicated. If consent is withdrawn, that sexual activity should cease. Consent to some sexual contact (such as kissing or fondling) cannot be presumed to be consent for other sexual activity (such as intercourse). A current or previous intimate relationship is not sufficient to constitute consent.

Consent is based on the totality of the circumstances evaluated from the perspective of a reasonable person in the same or similar circumstances, including the context in which the alleged incident occurred and any similar previous patterns that may be evidenced. The question of whether the responding party should have known of the reporting

party's incapacity is an objective inquiry as to what a reasonable person, exercising sober judgment, would have known, in the same or similar circumstances.

Consent is not voluntary if forced or coerced. Force is the use of physical violence or physical imposition to gain sexual access. Force also includes threats, intimidation (implied threats), and coercion that is intended to overcome resistance or produce consent Coercion is unreasonable pressure for sexual activity. Sexual activity that is forced is, by definition, non-consensual, but non-consensual sexual activity is not necessarily forced. Silence or the absence of resistance alone is not consent. Consent is not demonstrated by the absence of resistance. While resistance is not required or necessary, it is a clear demonstration of non-consent.

A person cannot consent if they are unable to understand what is happening, asleep, or unconscious for any reason. A person violates this policy if they engage in sexual activity with someone they know to be, or should know to be, physically or mentally incapacitated. This policy also covers a person whose incapacity results from a temporary or permanent physical or mental health condition, involuntary physical restraint, or the consumption of incapacitating drugs or alcohol. Incapacitation occurs when someone cannot make rational, reasonable decisions because they lack the capacity to give knowing/informed consent (e.g. to understand the "who, what, when, where, why, or how" of their sexual interaction).

Incapacitation is determined through consideration of all relevant indicators of an individual's state and is not synonymous with (under the) influence, impairment, intoxication, inebriation, blackout, or being drunk. It is not an excuse that the responding party was intoxicated and, therefore, did not realize the incapacity of the reporting party.

Reporting Options

There are confidential and non-confidential reporting options available. Confidential Resources include on and off-campus mental counselors, health service providers, local rape crisis counselors, domestic violence resources, and members of the clergy and chaplains. Confidential on-campus resources include CAPS, Cowell Center, 408-554-4501; Wellness Center, 862 Market Street, 408-554-4409; and members of the clergy or chaplains when acting in their role as clergy (ie. the act of confession). Confidential means that what a reporting party shares will not be communicated with anyone else except in extreme cases of immediacy of threat or abuse of a minor.

Reporting to Law Enforcement

For immediate, emergency assistance or to report a crime of sexual violence, including sexual assault, domestic/dating violence (intimate partner violence), and stalking students, contact the Santa Clara Police Department, dial 911, or contact Campus Safety Services at 408-554-4444.

Reporting to the University

To report an incident to the University, students may:

- Report directly to the Director of Equal Opportunity and Title IX
- Report online at https://www.scu.edu/title-ix/reporting/
- Report anonymously using EthicsPoint at www.scu.edu/title-ix/reporting/anon-reporting

Other campus non-confidential reporting options: Students may report incidents and seek support from other University officials, including:

- The Office of Student Life,
- The Office of Residence Life (including Community Facilitators, Resident Directors, Assistant Resident Directors, Neighborhood Representatives, and Assistant Area Coordinators),
- Spirituality Facilitators,
- The Office of Housing,
- Athletics and Recreation,

- The Center for Student Leadership,
- The Drahmann Center,
- Office of Accessible Education (OAE),
- The Career Center
- Campus Ministry, and
- Faculty

All staff and faculty members, except those within the Confidential Resources section (Wellness Center Staff, CAPS Clinicians, and Clery when acting in that capacity) are mandatory reporters and are required to report incidents to the Director of Equal Opportunity and Title IX, who will contact the impacted person to provide information about supportive measures, resources, and the resolution options. A report to the EO and Title IX Office does not automatically initiate an investigation. At the time a report is made, a complainant does not have to decide whether or not to request supportive measures or participate in an investigation or University resolution process.

Notice of Nondiscrimination

Santa Clara University's fundamental principles of academic excellence through diversity and inclusion are central to the University's Jesuit, Catholic values, and require us to provide a workplace and educational environment free from discrimination. In accordance with federal and state law, Santa Clara University does not discriminate and prohibits discrimination against any individual on the basis of race, ethnicity, nationality, religion, age, gender, gender expression, gender identity, sexual orientation, marital status, registered domestic partner status, veteran or military status, physical or mental disability (including perceived disability), medical condition (including cancer related or genetic characteristics), pregnancy (including childbirth, breastfeeding, and related medical conditions), or other protected classes under the law. This policy, therefore, affects employment policies and actions, as well as the delivery of educational services at all levels and facilities of the University including admissions, scholarships and loan programs, athletics, hiring, promotion, job assignment, retention, and compensation. The University will promptly investigate all complaints of protected class discrimination, sexual harassment, sexual misconduct, and related retaliation in accordance with University's Policy on Discrimination, Harassment and Sexual Misconduct and applicable federal and state laws.

Title IX of the Education Amendments of 1972

Title IX of the Education Amendments of 1972 ("Title IX"), 20 U.S.C. §1681 et seq., is a Federal civil rights law that prohibits discrimination on the basis of sex in education programs and activities. Santa Clara University is committed to providing an environment free from discrimination based on sex and provides a number of resources and services to assist students, faculty, and staff in addressing issues involving sex discrimination. Under Title IX, discrimination on the basis of sex can include sexual harassment or forms of sexual violence, such as rape, sexual assault, domestic violence, dating violence, sexual exploitation, and stalking also prohibited by University Policy.

Inquiries regarding the University's equal opportunity and nondiscrimination policies may be directed to the Director for the Office of Equal Opportunity and Title IX who serves as the University's designated Title IX Coordinator and Affirmative Action Officer.

Aaron Zisser, Director, Office of Equal Opportunity and Title IX Coordinator \ Santa Clara University\ Office of Equal Opportunity and Title IX\ 500 El Camino Real\ Santa Clara, CA 95053\ Office Location: Loyola Hall, Suite 140, 425 El Camino Real, Santa Clara, CA 95053\ Main Office: 408-551-3043 | Direct Line: 408-551-3521\ Email: azisser@scu.edu \ Web: www.scu.edu/title-ix

Sex discrimination claims or other inquiries concerning the application of Title IX of the Education Amendments of 1972 and its implementing regulations may also be directed to the Director of Equal Opportunity and Title IX, the Assistant Secretary, Office for Civil Rights or both, and to the Equal Employment Opportunity Commission (EEOC),

and/or the California Department of Fair Employment and Housing (DFEH).

Americans with Disabilities Act / Section 504 of the Rehabilitation Act of 1973

Santa Clara University, in compliance with state and federal laws and regulations including Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA), and the Americans with Disabilities Act Amendments Act (ADAAA) does not discriminate on the basis of disability in administration of its education-related programs and activities. The University is committed to providing individuals with disabilities including those with learning disabilities, ADHD, chronic health conditions, traumatic brain injuries, hearing impairments, physical disabilities, psychological disorders, visual impairments, and other health impairments equal access to academic courses, programs, activities, services and employment opportunities, and strives in its policies and practices to provide for the full participation of individuals with disabilities in all aspects of University life.

For information concerning policies and procedures for students with disabilities, see the Office of Accessible Education (OAE) website, https://www.scu.edu/oae/. Students with disabilities who are registered with the OAE office may be qualified to receive accommodations, auxiliary aids or services based on supporting documentation. To register with OAE, contact the Director at 408-554-4109 or by email at oae@scu.edu. Faculty and staff should contact Human Resources for information on how to request employee disability-related accommodations, auxiliary aids or services, https://www.scu.edu/hr/.

Students, faculty, and staff who believe they have been subjected to unlawful discrimination on the basis of disability, or have been denied access to services or accommodations required by law, should contact the Director of Equal Opportunity and Title IX, https://www.scu.edu/title-ix/.

Policy for Withdrawal for Health Reasons

Withdrawal for Health Reasons

Students may experience an illness, injury, or psychological condition that significantly impairs their ability to function successfully or safely in their role as students. In these instances, the Policy for Withdrawal for Health Reasons allows time away from the University for treatment and recovery until functioning is restored to a level that will enable the student to return to the University. The purpose of this policy is to set forth the procedures for student withdrawals from the University for reasons of health and/or safety. The University has designated four categories relating to withdrawal. They differ according to who initiates the action, whether it is voluntary or not, and the re-enrollment procedures.

The Vice Provost for Student Life or designee, in consultation with the appropriate mental and medical health professionals and other staff as deemed necessary, is responsible for the implementation of this policy as stated in the Student Handbook.

Academic Accreditations

University Accreditation

Western Association of Schools and Colleges (WASC) Senior College and University Commission 985 Atlantic Avenue, Suite 100 Alameda, CA 94501 510-748-9001

Specialized Academic Accreditations

American Association of Museums

ABET Inc.

American Bar Association

American Chemical Society

Association of American Law Schools

Association of Theological Schools

Association to Advance Collegiate Schools of Business–Accounting

Association to Advance Collegiate Schools of Business

California Board of Behavioral Sciences Accredited Marriage and Family Therapists

California State Commission on Teacher Credentialing

State Bar of California

Engineering Advisory Board

Renee Niemi, Chair

Sam Bertram
CEO and Co-Founder
OnePointOne

Ivo Bolsens
Senior Vice President, Head Corporate Research and Advanced Development
AMD

Bill Carter
Retired Xilinx Fellow
SCU Board of Trustees

Kathryn (Kathy) Chou
Senior Vice President, SAAS Engineering
Nutanix

Lynda Coffman
Senior Operations Executive

Ross Dakin
Co-Founder and CTO
Criticality Sciences

Mir Imran
Chairman and CEO Modulus, Inc.
Managing Director, InCube Ventures LP

Waguih Ishak, Ph.D.
Division Vice President, Science and Technology
Corning West Technology Center

Jack Jia
Chief Executive Officer
Trusper, Incorporated

Kevin Kelly
CEO and Founder
Axias Technology Group

James Lyons, Ex-Officio Member
Vice President for University Relations
Santa Clara University

John Maydonovitch
President and Chief Executive Officer
MCE, Incorporated

Renee Niemi-Chair
Board Director and Business Consultant
Limited Partner, Mighty Capital

Engineering Faculty

TRACY ABBOTT (2012)

Lecturer in Civil, Environmental and Sustainable Engineering

B.S. 1996, University of California, Berkeley

M.S. 1997, University of California, San Diego

Registered Professional Engineer in Civil Engineering and Structural Engineering

MARGARETA ACKERMAN (2017)

Associate Professor of Computer Science and Engineering

B. Math 2006, M. Math 2007, Ph.D. 2012, University of Waterloo, Canada

MICHELE ELLIE AHI (2008)

Lecturer in Engineering Management and Leadership and Graduate Engineering

B.S. 1983, San Jose State University

M.S. 2007, Santa Clara University

HAMED AKBARI (2023)

Lecturer in Bioengineering

M.D. 2000, Tehran University of Medical Science

M. Sc. 2004, Azad University

Ph.D. 2008, Tokyo Institute of Technology

SALEM AL-AGTASH (2018)

Renewable Term Lecturer in Computer Science and Engineering

B. Sc. 1988, Bogazici University, Turkey

M. Sc. 1995, University of Colorado at Denver

Ph.D. 1998, University of Colorado at Boulder

AHMED AMER (2009)

Associate Professor of Computer Science and Engineering

B.S. 1994, M.S. 1997, American University in Cairo

Ph.D. 2002, University of California, Santa Cruz

ARIA AMIRBAHMAN (2020)

Professor Civil, Environmental and Sustainable Engineering

Sukhmander Singh Professor

Chair, Department of Civil, Environmental and Sustainable Engineering

B.S. 1984, M.S. 1989, San José State University

Ph.D. 1994, University of California, Irvine

Registered Professional Engineer in Civil Engineering

MOE AMOUZGAR (2014)

Lecturer in Computer Science and Engineering

B.E. 1989, McGill University, Canada

M.S. 2000, Southern Methodist University

Ph.D. 2013, Concordia University, Canada

DAVID ANASTASIU (2019)

Assistant Professor of Computer Science and Engineering

B.A. 2001, Moody Bible Institute

M.S. 2011, Texas State University

Ph.D. 2016, University of Minnesota-Twin Cities

ISMAIL EMRE ARACI (2015)

Assistant Professor of Bioengineering

B.S. 1999, M.Sc. 2002, Ege University

Ph.D. 2010, University of Arizona

SHAHAB ARDALAN (2020)

Lecturer in Electrical and Computer Engineering

B.Sc. 1999, Amirkabir University of Technology, Tehran, Iran

M.A.Sc. 2003, Reyerson University, Toronto, Canada

Ph.D. 2007 University of Waterloo, Waterloo, Canada

PRASHANTH ASURI (2011)

Chair, Department of Bioengineering

Associate Professor of Bioengineering

B.E. 2003, National Institute of Technology

Ph.D. 2007, Rensselaer Polytechnic Institute

DARREN ATKINSON (1999)

Associate Professor of Computer Science and Engineering

B.S. 1991, M.S. 1994, Ph.D. 1999, University of California, San Diego

MOHAMMAD AYOUBI (2008)

Associate Professor of Mechanical Engineering

B.S. 1991, Amirkabir University

M.S. 1998, Sharif University of Technology

Ph.D. 2007, Purdue University

BONITA BANDUCCI (2000)

Lecturer in Graduate Engineering

B.A. 1969, University of California, Santa Cruz

NIRDOSH BHATNAGAR (2002)

Lecturer in Applied Mathematics and Computer Science and Engineering

M.S., Ph.D., Stanford University

RAFAE BHATTI (2010)

Lecturer in Computer Science and Engineering

B.S. 1999, GIK Institute, Pakistan

M.S. 2003, Ph.D. 2006, Purdue University

ROBERT JAMES BRUCE (2023)

Lecturer in Computer Science and Engineering

B.S. 1994, Sonoma State University, Rohnert Park, CA

Master of Library Science (MLIS). 2006, San Jose State University, San Jose, CA

LEO CASEY (2017)

Lecturer in Electrical and Computer Engineering

B.Sc. 1980, University of Auckland, New Zealand

M.Sc. 1984, Ph.D. 1988, Massachusetts Institute of Technology

YEN-KUANG CHEN (2023)

Lecturer in Computer Science and Engineering

B.S. 1992, National Taiwan University, Taipei

M.A. 1995, Ph.D. 1998, Princeton University

STEVEN C. CHIESA (1987)

Associate Professor Emeritus of Civil, Environmental and Sustainable Engineering

B.S. 1975, Santa Clara University

M.S. 1976, Stanford University

Ph.D. 1982, University of Notre Dame

Registered Professional Engineer in Civil Engineering

SEAN CHOI (2021)

Assistant Professor of Computer Science and Engineering

B.S. 2011, California Institute of Technology

M.S. 2013, Ph.D. 2019, Stanford University

ALEXANDER CLEMM (2008)

Lecturer in Computer Science and Engineering

M.S. 1990, Stanford University

Ph.D. 1994, University of Munich

CLAUDIONOR COELHO (2019)

Lecturer in Electrical and Computer Engineering

B.S.E.E. (summa cum laude), UFMG, Brazil

M.B.A. IBMEC Business School

Ph.D., Stanford University

MARLENE COLE (2019)

Lecturer in Engineering Management and Leadership

B.A. 1970, Ed.M. 1974, BSME 1982, State University of New York, Buffalo

THERESA CONEFREY (2001)

Lecturer in Engineering Management and Leadership

B.A. 1994, University of East Anglia, United Kingdom

M.A. 1991, Ph.D. 1997, University of Illinois

YAN CUI (2022)

Lecturer in Computer Science and Engineering

B.S. 2009, University of Science and Technology Beijing, China

Ph.D. 2019, University of Massachusetts Lowell, MA

ROBBIE CULKIN (2020)

Lecturer in Computer Science in Engineering

B.S. 2019, M.S. 2020, Santa Clara University

VIN D'AGOSTINO (2020)

Lecturer in Electrical and Computer Engineering

B.E.E.E., Stevens Institute of Technology

M.S.C.S., Polytechnic Institute of Technology

Certified Scrum Master from Big Visible

Lean Six Sigma Black Belt form Villanova University

DON DANIELSON (2004)

Lecturer in Engineering Management and Leadership

B.S. 1977, California Polytechnic University, Pomona

M.S. 2008, Santa Clara University

RONALD L. DANIELSON (1976)

Professor Emeritus of Computer Science and Engineering

B.S. 1967, University of Minnesota

M.S. 1968, Northwestern University

Ph.D. 1975, University of Illinois, Urbana

RUTH E. DAVIS (1979)

Professor of Computer Science and Engineering

Associate Dean, Undergraduate Studies

B.S. 1973, Santa Clara University

M.S. 1976, San Jose State University

Ph.D. 1979, University of California, Santa Cruz

BEHNAM DEZFOULI (2016)

Associate Professor of Computer Science and Engineering

B.S. 2006, M.S. 2009, University of Najafabad

Ph.D. 2014, Universiti Teknologi Malaysia

ALBERTO DIAZ-TOSTADO (2017)

Lecturer in Computer Science and Engineering

B.S. 2016, M.S. 2017, Santa Clara University

LAURA DOYLE (2012)

Lecturer in Civil, Environmental and Sustainable Engineering

B.S. 2003, Loyola Marymount University

M.S. 2007, Ph.D. 2011, University of California, Davis

SANTANU DUTTA (2001)

Lecturer in Electrical and Computer Engineering

B. Tech. 1987, Indian Institute of Technology

M.S. 1990, University of Texas, Austin

M.A. 1994, Ph.D. 1996, Princeton University

ARMAN ELAHI (2020)

Lecturer in Computer Science and Engineering

B.S. 2016, M.S. 2017, Santa Clara University

AMR ELKADY (2014)

Lecturer in Computer Science and Engineering

B.S. 1994, American University in Cairo

M.S. 2005, Carleton University

FAROKH H. ESKAFI (2017)

Renewable Term Lecturer in Computer Science and Engineering

B.S. 1991, M.S. 1992, Ph.D. 1996, University of California, Berkeley

AHMED K. EZZAT (1988)

Lecturer in Computer Science and Engineering

B.S. 1971, M.S. 1976, Cairo University

Ph.D. 1982, University of New Hampshire

DRAZEN FABRIS (1999)

Associate Professor of Mechanical Engineering

B.S. 1990, California Institute of Technology

M.S. 1993, Ph.D. 1996, University of California, Berkeley

YI FANG (2012)

Associate Professor of Computer Science and Engineering

B.E. 2002, M.S. 2005, Wuhan University of Technology

M.S. 2006, University of Tennessee
Ph.D. 2012, Purdue University

SILVIA M. B. FIGUEIRA (1998)
Chair, Department of Computer Science and Engineering
Professor of Computer Science and Engineering
Dianne McKenna Professor
B.S. 1988, M.S. 1991, Federal University of Rio de Janeiro
Ph.D. 1996, University of California, San Diego

E. JOHN FINNEMORE (1979)
Professor Emeritus of Civil, Environmental and Sustainable Engineering
B.Sc. 1960, University of London
M.S. 1966, Ph.D. 1970, Stanford University
Registered Professional Engineer in Civil Engineering

CARL FUSSELL (1977)
Lecturer in Computer Science and Engineering
B.S. 1971, Santa Clara University
M.S. 1973, Loyola University

AMIN GHAFOORIPOUR (2018)
Fixed-Term Lecturer in Civil, Environmental and Sustainable Engineering
B.S. 1991, Toosi University of Technology
M.S. 1994, Tabriz University
Ph.D. 2002, Azad University
Registered Professional Engineer in Civil Engineering

INDRADEEP GHOSH (2014)
Lecturer in Electrical and Computer Engineering
B.Tech. 1993, Indian Institute of Technology, Kharagpur
M.A. 1995, Ph.D. 1998, Princeton University

JOHN GIDDINGS (2011)
Lecturer in Engineering Management and Leadership
M.S.E.E. 1991, M.B.A. 1997, Santa Clara University

CHRIS GOELTNER (2014)
Lecturer in Electrical and Computer Engineering
Dipl. Ing. degree from Germany, 1985
Ph.D. 1989, Massachusetts Institute of Technology

RONALD J. G. GOOSSENS (2022)
Lecturer in Electrical and Computer Engineering
B.S. 1976, M.S. 1980, Ph.D. 1984, Utrecht University

BRIAN GREEN (2011)
Lecturer in Graduate Engineering
B.S. 2000, University of California, Davis
M.A. 2006, Ph.D. 2013, Graduate Theological Union, Berkeley

BRUCE S. GREENE (2003)
Lecturer in Electrical and Computer Engineering
B.S. 1987, Boston University
M.S. 1989, University of Illinois
Ph.D. 2003, Santa Clara University

RADHIKA S. GROVER (2004)
Lecturer Electrical and Computer Engineering
B.S. 1991, Indian Institute of Technology-Roorkee, India
M.S. 1992, Birla Institute of Technology, India
Ph.D. 2003, Santa Clara University

ABHISHEK GUPTA (2016)
Lecturer in Computer Science and Engineering
B.Tech. 2008, Indian Institute of Technology at Roorkee, India
M.S. 2011, Ph.D. 2014, University of Illinois, Urbana-Champaign

RACHEL HE (2003)
Associate Professor of Civil, Environmental and Sustainable Engineering
B.E. 1993, M.E. 1996, Chongqing University, People's Republic of China
Ph.D. 2000, University of Wisconsin, Madison

TIMOTHY J. HEALY (1966)
Professor Emeritus of Electrical and Computer Engineering
B.S.E.E. 1958, Seattle University
M.S.E.E. 1959, Stanford University
Ph.D. 1966, University of Colorado, Boulder

ANOOSHEH HEIDARZADEH (2022)
Assistant Professor of Electrical and Computer Engineering
B.S. 2005, Shiraz University, Iran
M.S. 2007, University of Tehran, Iran
Ph.D. 2013, Carleton University, Canada

TIMOTHY K. HIGHT (1984)
Associate Professor Emeritus of Mechanical Engineering
B.S. 1972, California Institute of Technology
M.S. 1973, Ph.D. 1977, Stanford University
Registered Professional Engineer in Mechanical Engineering

SRIKANTH HOSAKOTE (2023)
Lecturer in Computer Science and Engineering
B.S. 1989, Bangalore University, India
M.S. 1993, University of Missouri, Kansas City, MO
M.B.A. 2000, University of Phoenix

PARSA HOSSEINI (2008)
Lecturer in Bioengineering
B.Sc. 2006, Shahid Beheshti University
M.Sc. 2008, University of Tehran, Iran
M.Sc. 2014, Wayne State University
Ph.D. 2018, Rutgers University

I-HAN HSIAO (2021)
Assistant Professor in Computer Science and Engineering
B.A. 2003, National Central University, Taiwan
M.S. 2004, Royal Holloway, University of London, United Kingdom
Ph.D. 2012, University of Pittsburgh

STEPHEN HUDGENS (2009)

Lecturer in Electrical and Computer Engineering and Graduate Engineering

Ph.D. 1976, University of Chicago

CLIFFORD HWANG (1999)

Lecturer in Electrical and Computer Engineering

B.S. 1992, University of California, San Diego

M.S. 1994, Engineer's Degree 1999, Ph.D. 1999, University of California, Los Angeles

MARIA JOSEPH ISRAEL (2022)

Lecturer in Computer Science and Engineering

B. Com. 1996, University of Calcutta, St. Xavier's College, Kolkata, India

B.A. in Philosophy 1999, Jnanan-Deepa Vidyapeeth, Pontifical Athenaeum, Pune, India

B.A. in Theology 2006, Vidyajyoti College of Theology, Delhi, India

M.C.A. 2002, University of Madras, Loyola College, Chennai, India

M.A. 2016, University of San Francisco

Ph.D. 2022, Santa Clara University

AMIRTHARAJ IMMANUEL (2022)

Lecturer in Computer Science and Engineering

B.S. 2017, M.S. 2018, Santa Clara University

SHIVA JAHANGIRI (2022)

Assistant Professor in Computer Science and Engineering

B.S. 2012, Shahrood University of Technology, Iran

M.S. 2016, University of Southern California

Ph.D. 2022, University of California, Irvine

PRAVIN JAIN (2011)

Lecturer in Engineering Management and Leadership and Graduate Engineering

B.S. 1974, University of Poona, India

M.S. 1976, Oregon State University

M.B.A. 1980, University of Portland

ALKA JARVIS (1993)

Lecturer in Computer Science and Engineering

M.B.A. 1996, British Tutorial University

MARYAM KHANBAGHI (2013)

Program Advisor, Powers Systems and Sustainable Energy

Associate Professor of Electrical and Computer Engineering

B.S. 1990 Universite De Nice-Sophia Antipolis

M.S. 1993, Ph. D. 1998, Ecole Polytechnique

UNYOUNG (ASHLEY) KIM (2009)

Associate Professor of Bioengineering

Chair, Department of Bioengineering

B.S. 1999, M.S. 2001, Korea Advanced Institute of Science and Technology (KAIST)

Ph.D. 2009, University of California, Santa Barbara

CHRISTOPHER A. KITTS (1999)

Program Advisor, Robotics and Automation Program

Professor of Mechanical Engineering

B.S.E. 1987, Princeton University

M.P.A. 1996, University of Colorado

M.S. 1992, Ph.D. 2006, Stanford University

ROBERT J. KLEINHENZ (2009)

Lecturer in Applied Mathematics

B.S. 1971, University of Santa Clara

M.A. 1973, Ph.D. 1977, University of Illinois

WALTER KOZACKY (2013)

Lecturer in Electrical and Computer Engineering

B.S. 1977, University of Illinois

M.S. 2004, Ph.D. 2012, Santa Clara University

MAX KREMINSKI (2022)

Assistant Professor in Computer Science and Engineering

B.A. 2017, University of Southern California

M.S. 2020, Ph.D. 2022, University of California, Santa Cruz

SHOBA KRISHNAN (1999)

Professor of Electrical and Computer Engineering

Chair, Department of Electrical and Computer Engineering

B.TECH 1987, Jawaharlal Nehru Technological University

M.S. 1990, Ph.D. 1993, Michigan State University

ZOLTAN KURCZVEIL (2011)

Lecturer in Computer Science and Engineering

B.A. 1998, U. C. Berkeley

M.S. 2004, Santa Clara University

M.B.A. 2008, University of California, Berkeley Haas School of Business

MARIA KYRARINI (2021)

Assistant Professor of Electrical and Computer Engineering and David Packard Jr. Faculty Fellow

B.Eng. & M.Eng. 2012, National Technical University of Athens, Greece

M.Sc. 2014, National Technical University of Athens, Greece

Ph.D. 2019, University of Bremen, Germany

SHUNKGAI LAM (2022)

Lecturer in Computer Science and Engineering

B.S. 1985, University of Alberta

M.S. 1988, Louisiana Tech University

Ph.D. 1992, University of Illinois at Chicago

BENJAMIN LAMPE (2022)

Lecturer in Electrical and Computer Engineering

B.S. 2018, M.S. 2021, Santa Clara University

HOHYUN LEE (2009)

Professor of Mechanical Engineering

Chair, Department of Mechanical Engineering

B.S. 2003, Seoul National University

S.M. 2005, Ph.D. 2009, Massachusetts Institute of Technology

BROOKS LEMAN (2004)

Lecturer in Electrical and Computer Engineering

B.S. 1979, M.S. 1985, Santa Clara University

DANIEL W. LEWIS (1975)
Professor Emeritus of Computer Science and Engineering
B.S.E.E. 1968, Georgia Institute of Technology
M.S.E.E. 1972, E.E. 1975, Ph.D. 1975, Syracuse University

XIANG LI (2018)
Assistant Professor of Computer Science and Engineering
B.S. 2009, Heilongjiang University, China
M.S. 2012, Chinese Academy of Sciences, China
M.S. 2014, Ph.D. 2018, University of Florida, Gainesville

NIGEL H. LIN (2016)
Lecturer in Computer Science and Engineering
B. Eng. 2000, M. Eng. 2002, Ph.D. 2005, Tamkang University, Taiwan

NAM LING (1989)
Professor of Computer Science and Engineering
Wilmot J. Nicholson Family Professor
B.Eng. 1981, National University of Singapore
M.S. 1985, Ph.D. 1989, University of Louisiana at Lafayette

YING LIU (2018)
Assistant Professor of Computer Science and Engineering
B.S. 2006, Beijing University of Posts and Telecommunications, China
M.S. 2008, Ph.D. 2012, State University of New York, Buffalo

YUHONG LIU (2015)
Associate Professor of Computer Science and Engineering
B.S. 2004, M.S. 2007, Beijing University of Posts and Telecommunications, China
Ph.D. 2012, University of Rhode Island

BIAO LU (2015)
Associate Professor of Bioengineering
M.D. 1988, M.Sc. 1991 Shanghai Medical University, China
BSC, 2001, Ph.D. 2004, University of Manitoba, Canada

CRIST LU (2019)
Lecturer in Electrical and Computer Engineering
B.S. 1992, University of California, Los Angeles
M.S. 1994, University of California, Berkeley

WEN-PAI LU (2020)
Lecturer in Computer Science and Engineering
B.S. 1978, M.S. 1981, University of Tennessee
Ph.D. 1986, University of Arizona

KAI LUKOFF (2022)
Assistant Professor in Computer Science and Engineering
B.A. 2008, Stanford University
M.S. 2016, University of Michigan, Ann Arbor
Ph.D. 2022, University of Washington, Seattle

STHANU MAHADEV (2022)
Lecturer in Mechanical Engineering
B.S. 2008, Anna University, India
M.S. 2011, Ph.D. 2015, University of Texas, Arlington

ROBERT MARKS (2011)

Lecturer in Mechanical Engineering

B.S. 1996, M.S. 2000, Ph.D. 2003, University of California, Berkeley

MANISH MARWAH (2015)

Lecturer in Computer Science and Engineering

B.S. 1993, Indian Institute of Technology at Delhi

M.S. 1996, Ph.D. 2007, University of Colorado at Boulder

EDWIN MAURER (2003)

Professor of Civil, Environmental and Sustainable Engineering

Robert W. Peters Professor

B.S. 1985, University of Rhode Island

M.S. 1989, University of California, Berkeley

Ph.D. 2002, University of Washington

Registered Professional Engineer in Civil Engineering

MICHAEL McELFRESH (2011)

Lecturer in Electrical and Computer Engineering

B.S. 1979, University of California, Davis

M.A. 1981, Washington University

Ph.D. 1988, University of California, San Diego

PADDU MELANAHALLI (2022)

Lecturer in Computer Science and Engineering

B.S. 1987, University of Mysore, India

M.S. 1992, Mangalore University, India

AARON MELMAN (2005)

Renewable Term Lecturer in Applied Mathematics

Department Chair of Applied Mathematics

B.Sc. 1983, University of Louvain;

M.Sc. 1986, Technion - Israel Institute of Technology

Ph.D. 1992, California Institute of Technology

MAGDA METWALLY (1986)

Lecturer in Applied Mathematics

B.S. 1967, Ain-Shams University Egypt

M.S. 1972, University of British Columbia

Ph.D. 1982, Santa Clara University

RANI MIKKILINENI (1996)

Lecturer in Computer Science and Engineering

B.S. 1971, Maris Stella College

M.S. 1973, Andhra University

M.S. 1989, University of Denver

Ph.D. 1998, Santa Clara University

KEYVAN MOATAGHED (2003)

Lecturer in Computer Science and Engineering

B.S. 1975, M.S. 1979, Ph.D. 1982, Technical University of Graz, Austria

RAMIN MOAZENI (2014)

Lecturer in Computer Science and Engineering

B.S. 1999, Isfahan University of Technology, Iran

M.S. 2003, California State University, East Bay

M.S. 2008, University of Southern California

MARYAM MOBED-MIREMADI (2013)

Lecturer in Bioengineering

B.S. 1988, M.S. 1991, Ph.D. 1996, McGill University

BRADEN MOLHOEK (2018)

Lecturer in Computer Science and Engineering and Bioengineering

B.A. 2003, Ohio Wesleyan University

M.T.S. 2005, Boston University

Ph.D. 2016, Graduate Theological Union, Berkeley

RALPH E. MORGANSTERN (1992)

Lecturer in Applied Mathematics

B.S. 1962, Rensselaer Polytechnic Institute

M.A. 1965, Ph.D. 1968, State University of New York, Stony Brook

M. GODFREY MUNGAL (2007)

Professor of Mechanical Engineering

B.A.Sc. 1975, University of Toronto

M.Sc. 1977, Ph.D. 1983, California Institute of Technology

MOHAMMAD MUSA (2019)

Lecturer in Engineering Management and Leadership

B.S. 2003, M.S. 2006, Santa Clara University

ANGELA MUSURLIAN (2014)

Renewable Term Lecturer in Computer Science and Engineering

B.S. 1989, Rio de Janeiro State University, Brazil

M.S. 1993, Madrid Polytechnic University, Madrid, Spain

AYHAN MUTLU (2004)

Lecturer in Electrical and Computer Engineering

B.S. 1996, Middle East Technical University

Ph.D. 2004, Santa Clara University

FRANKIE B. MYERS (2023)

Lecturer in Bioengineering

B.S. 2006, NC State University

Ph.D. 2012, UC Berkeley

MADIHALLY J. (SIM) NARASIMHA (2002)

Lecturer in Electrical and Computer Engineering

B.E. 1971, Bangalore University

M.S. 1976, Ph.D. 1976, Stanford University

SIDDHARTHA NATH (2022)

Lecturer in Computer Science and Engineering

B.S. 2003, Birla of Technology & Science, Pilani, India

Ph.D. 2016, University of California, San Diego

PAUL NAULEAU (2023)

Lecturer in Bioengineering

B.S. 2018, M.S. 2019, Santa Clara University

MICHAEL NEUMANN (2018)
Professor of Practice
B.S. 2003, M.S. 2004, Ph.D. 2017, Santa Clara University

TONYA NILSSON (2010)
Senior Lecturer in Civil, Environmental and Sustainable Engineering
Vice Chair, Department of Civil, Environmental and Sustainable Engineering
B.S. 1991, California Polytechnic State University, San Luis Obispo
M.S. 1993, Stanford University
Ph.D. 2002, University of California, Davis
Registered Professional Engineer in Civil Engineering

TOKUNBO OGUNFUNMI (1990)
Professor of Electrical and Computer Engineering
B.S. 1980, University of Ife, Nigeria
M.S. 1984, Ph.D. 1990, Stanford University

HOSSEIN OMIDIAN (2022)
B.S. 2007, Isfahan University of Technology
M.S. 2011, Islamic Azad University
Ph.D. 2018, University of British Columbia

KOUROSH PAHLAVAN (2021)
Lecturer in Computer Science and Engineering
M.S. 1989, Ph.D. 1994, Royal Institute of Technology, Sweden

ON SHUN PAK (2014)
Associate Professor of Mechanical Engineering
B.Eng. 2008, University of Hong Kong
M.S. 2010, Ph.D. 2013, University of California, San Diego

USHA NITU PARIMI (2012)
Lecturer in Engineering Management and Leadership
B. Tech. 1994, Pune Institute of Computer Technology, India
M.S. 2012, Santa Clara University

VLADIMIR PATRYSHEV (2014)
Lecturer in Computer Science and Engineering
M.S. 1973, St. Petersburg State University, Russia

ERICA PAUL (2019)
Fixed-Term Lecturer in Civil, Environmental and Sustainable Engineering
B.S. 1995, J.D. 2019, Santa Clara University

KERN PENG (2001)
Lecturer in Engineering Management and Leadership
B.S. 1992, San Jose State University
M.B.A. 1996, Ph.D. 2000, San Francisco State University

NICHOLAS PERA (2006)
Fixed-Term Lecturer in Civil, Environmental and Sustainable Engineering
B.S. 1995, Santa Clara University

KISHORE PUSUKURI (2017)
Lecturer in Computer Science and Engineering
B. Tech. 2002, Kakatiya University of India

Ph.D. 2012, University of California, Riverside

XIAOSHU QIAN (2003)

Lecturer in Electrical and Computer Engineering

B.S. 1982, Zhejiang University (China)

M.S. 1990, 1994, Ph.D. 1996, University of Rhode Island

MAHMUD RAHMAN (1986)

Associate Professor of Electrical and Computer Engineering

B.S.E.E. 1969, University of Engineering and Technology, Dhaka, Bangladesh

M.Eng. 1981, Dr. Eng. 1984, Tokyo Institute of Technology

SAMAR SAHA (2003)

Lecturer in Electrical and Computer Engineering

B.S. 1971, Cotton College, India

M.Sc. 1973, Ph.D. 1981, Gauhati University, India

M.S. 1992, Stanford University

HISHAM SAID (2011)

Associate Professor in Civil, Environmental and Sustainable Engineering

B.S. 2003, M.S. 2006, Cairo University, Egypt

Ph.D. 2010, University of Illinois

KURT SCHAB (2018)

Assistant Professor of Electrical and Computer Engineering

B.S. 2011, Portland State University

M.S. 2013, Ph.D. 2016, University of Illinois at Urbana-Champaign

DENNIS SEGERS (2016)

Lecturer in Engineering Management and Leadership

B.S. 1975, Texas A &M University

AEA Stanford Executive Institute 1995

ROCIO L. SEGURA (2022)

Assistant Professor in Civil, Environmental and Sustainable Engineering

B.E. 2013, Del Comahue National University, Neuquén, Argentina

Ph.D. 2019, Université de Sherbrooke, Canada

PAUL SEMENZA (2016)

Dean's Executive Professor

Chair, Department of Engineering Management and Leadership

B.S. 1985, M.S. 1990, Tufts University

Master in Public Policy 1994, Harvard University

GIOVANNI SENI (2003)

Lecturer in Computer Science and Engineering

B.S. 1988, Los Andes University, Bogotá, Colombia

M.S. 1992, Ph.D. 1995, State University of New York, Buffalo

PANTHEA SEPEHRBAND (2012)

Associate Professor of Mechanical Engineering

B.Sc. 2000, University of Tehran, Iran

M.Sc. 2004, Sharif University of Technology

Ph.D. 2010, University of Waterloo

REYNAUD L. SERRETTE (1991)

Professor of Civil, Environmental and Sustainable Engineering

B.Sc. 1987, M.Sc. 1988, University of Manitoba

Ph.D. 1992, Cornell University

WEIJIA SHANG (1994)

Associate Professor of Computer Science and Engineering

B.S. 1982, Changsha Institute of Technology, China

M.S. 1984, Ph.D. 1990, Purdue University

TERRY E. SHOUP (1989)

Professor Emeritus of Mechanical Engineering

BME 1966, M.S. 1967, Ph.D. 1969, Ohio State University

Registered Professional Engineer in Mechanical Engineering

DRAGOSLAV D. SILJAK (1964)

Professor Emeritus of Electrical and Computer Engineering

B.S.E.E. 1958, MSEE 1961, Dr. Sci. 1963, University of Belgrade

SUKHMANDER SINGH (1986)

Professor of Civil, Environmental and Sustainable Engineering

B.S. 1964, Punjabi University

M.S. 1966, Indian Institute of Technology, Delhi

Ph.D. 1979, University of California, Berkeley

Registered Professional Engineer in Civil Engineering and Geotechnical Engineering

JAMES SOWERS (2005)

Lecturer in Electrical and Computer Engineering

B.S. 1978, Cornell University

M.S. 1982, Stanford University

ALEX SUMARSONO (2017)

Lecturer in Computer Science and Engineering

B.S. 1982, M.S. 1985, Iowa State University

Ph.D. 2015, Mississippi State University

KWANG-PILL SUNG (2022)

Lecturer in Computer Science and Engineering

M.S. 1977, Seoul National University

M.S. 1980, University of Michigan

JAMES TAGUCHI (2016)

Lecturer in Computer Science and Engineering

B.S. 2011, Santa Clara University

M.S. 2013, Naval Postgraduate School

STEPHEN TARANTINO (2011)

Fixed-Term Lecturer in Civil, Environmental and Sustainable Engineering

B.S. 1970, Santa Clara University

Registered Professional Engineer in Civil Engineering

MICHAEL TAYLOR (2015)

Associate Professor of Mechanical Engineering

B.S. 2003, Johns Hopkins University

M.S. 2005, Ph.D. 2008, University of California, Berkeley

DAT TRAN, S. J. (2020)
Assistant Professor of Electrical and Computer Engineering
B.S. 1994, M.S. 1996, Portland State University
M. Div. 2009, Jesuit School of Theology at Santa Clara University
Ph.D. 2019, Portland State University

NICHOLAS TRAN (2007)
Lecturer in Computer Science and Engineering
B.S. 1987, University of Minnesota
Ph.D. 1992, University of California, Santa Barbara

CALVIN TSZENG (2013)
Lecturer in Mechanical Engineering
B.S. 1979, M.S. 1981, National Tsinghua University
Ph.D. 1987, University of California, Berkeley

FRANCISCO VILLARROYA ALVAREZ (2022)
Lecturer in Applied Mathematics
Ph.D. 2003, University of Valencia, Spain

LANNY VINCENT (2017)
Lecturer in Graduate Engineering
B.A. 1975, Davidson College
M.Div. 1978, Yale Divinity School

HIEN VU (2013)
Lecturer in Computer Science and Engineering
B.S. 1997, M.S. 2005, Santa Clara University
M.S. 2008, San Jose State University

JUN WANG (2022)
Assistant Professor Mechanical Engineering
B.S. 2012, Xian Jiaotong University
M.S. 2015, Ph.D. 2019, University at Buffalo-SUNY

MING-HWA WANG (1996)
Lecturer in Computer Science and Engineering
B.Ed. 1977, National Taiwan Normal University
M.S. 1982, Rochester Institute of Technology
Ph.D. 1991, Illinois Institute of Technology

YUAN WANG (2014)
Lecturer in Computer Science and Engineering
B.Eng. 1987, M. Eng. 1990, Beijing University of Technology (Beijing Polytechnic University), China
Ph.D. 1995, University of Western Ontario, Canada

GLENN A. WILLIAMS (2009)
Lecturer in Applied Mathematics
B.S. 1984, Northwestern University
M.S. 1992, Ph.D. 1998, University of North Carolina

SARAH KATE WILSON (2006)
Associate Professor of Electrical and Computer Engineering
B.A. 1979, Bryn Mawr College
M.S. 1987, Ph.D. 1994, Stanford University

ANDREW WOLFE (2013)

Academic Year Lecturer in Electrical and Computer Engineering

B.S.E.E 1985, Johns Hopkins

M.S. 1987, Ph.D., 1992 Carnegie Mellon

SALLY L. WOOD (1985)

Professor of Electrical and Computer Engineering

Associate Dean for Graduate Programs

B.S. 1969, Columbia University

M.S. 1975, Ph.D. 1978, Stanford University

PETER J. WOYTOWITZ (1994)

Lecturer in Mechanical Engineering

B.S. 1976, University of Maryland

M.S. 1980, Ph.D. 1993, Santa Clara University

ENGR 1985, Stanford University

Registered Professional Engineer in Mechanical Engineering

SIYUAN XIN (2018)

Lecturer in Electrical and Computer Engineering

B.S. 2011, Shanghai Jiaotong University

B.S. 2011, University of Michigan, Ann Arbor

Ph.D. 2015, University of California, Berkeley

YULING YAN (2008)

Professor of Bioengineering

Department of Bioengineering David Packard Fellow

Phil and Bobbie Sanfilippo Professor

B.S. 1983, M.S. 1986, Nanjing Institute of Technology

Ph.D. 1991, Keio University

CARY Y. YANG (1983)

Professor of Electrical and Computer Engineering

Director, Center for Nanostructures

B.S.E.E. 1970, M.S.E.E. 1971, Ph.D. 1975, University of Pennsylvania

HOESEOK YANG (2022)

Associate Professor of Electrical and Computer Engineering

B.S. 2003, Ph.D. 2010, Seoul National University

ERHAN YENILMEZ (2020)

Lecturer in Bioengineering

B.S. 1999, Bilkent University

Ph.D. 2006 Stanford University

AMR ZAKY (1998)

Lecturer in Computer Science and Engineering

M.S. 1982, Alexandria University

Ph.D. 1989, Ohio State University

SERGIO ZARANTONELLO (1990)

Lecturer in Applied Mathematics

B.S. 1968, M.S. 1968, Ph.D. 1972. University of Wisconsin, Madison

ALEKSANDAR ZECEVIC (1993)

Professor of Electrical and Computer Engineering

B.S. 1984, University of Belgrade, Belgrade, Yugoslavia

M.S. 1990, Ph.D. 1993, Santa Clara University

ZHIWEN (JONATHAN) ZHANG (2011)

Associate Professor of Bioengineering

B.S. 1989, Nanjing University

M.S. 1995, University of Toronto

Ph.D. 2001, University of Texas at Austin