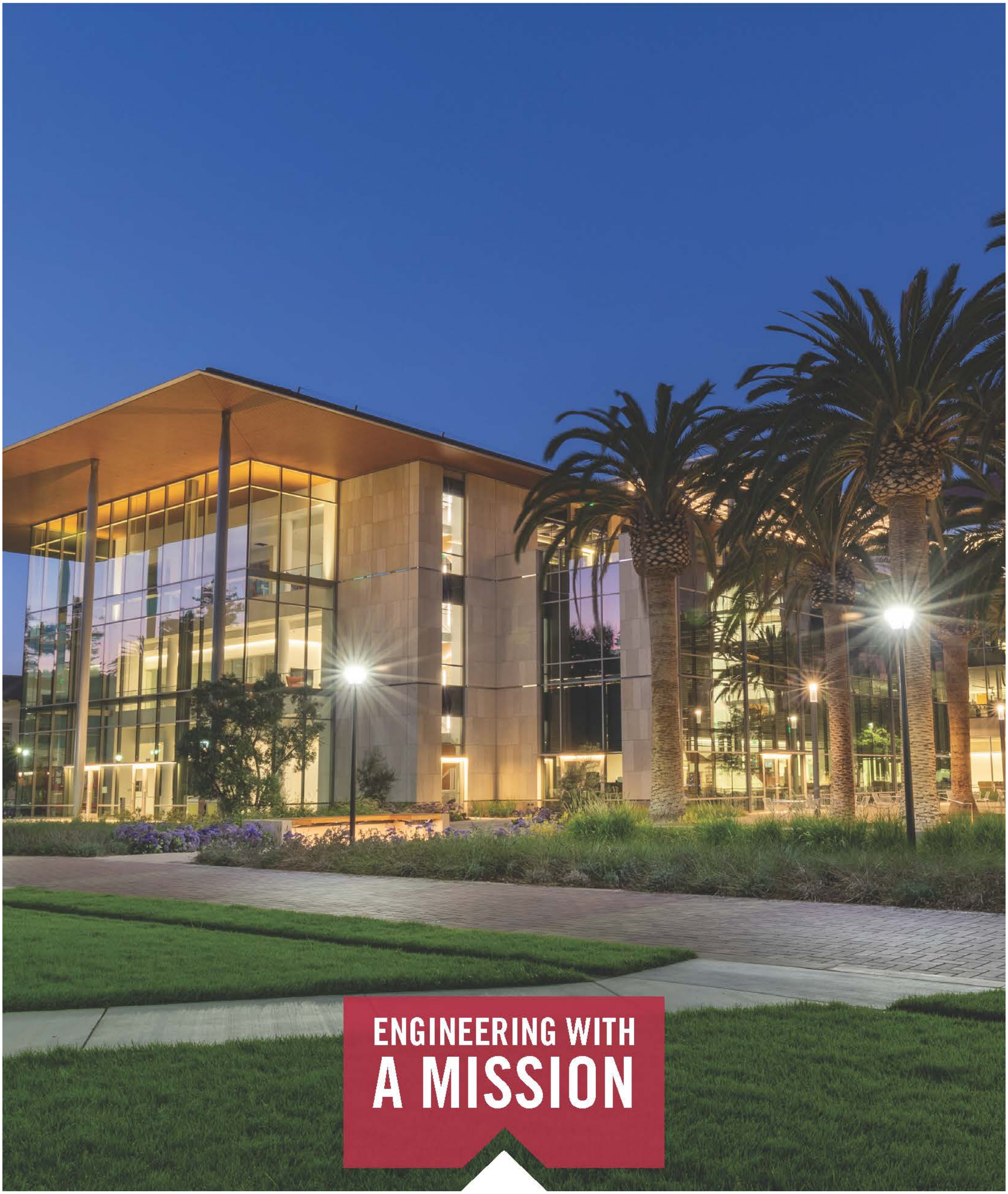
2024-25 Engineering Graduate Bulletin



Santa Clara University

School of Engineering

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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 112th 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 and 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.

2024-2025 Graduate Academic Calendar

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

Chapter 1: Santa Clara University

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 in 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.

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 to be in solidarity and service of others—run deep in all of its curricular and co-curricular programs.

Santa Clara University is perennially ranked among the top comprehensive universities by U.S. News & World Report and has one of the highest graduation rates for undergraduate students among all comprehensive universities. The University has a national reputation for its undergraduate program which features a distinctive core curriculum, an integrated learning environment, and research opportunities for undergraduate students.

The University was established as Santa Clara College on the site of 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 admission 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, erecting eight residence halls, a student union, and an athletic stadium. In 1985, the University adopted "Santa Clara University" as its official name.

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 a 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.). 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. 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 law degrees in intellectual property or U.S. law.

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, licensure, and graduate programs.

The Department of Education prepares teachers and leaders for public, private, and Catholic schools. It offers programs in teacher preparation leading to credentials (e.g., California preliminary multiple-subject and single-subject teaching credentials), bilingual authorization, and the Master of Arts in Teaching (MAT) degree. Its programs in educational leadership prepare public K–12 leaders for credentials (e.g., Preliminary California Administrative Services credential, California Clear Administrative Services credential) with an opportunity to also receive an MA degree in Educational leadership. The Educational leadership program also offers a Doctor of Education (EdD) in Social Justice Leadership degree with specializations in Higher Education Leadership, PreK-12 Leadership, and Social Impact Leadership.

The Department of Counseling Psychology offers three degree programs: M.A. in Counseling Psychology, M.A. in Counseling, and an M.A. in Applied Psychology. The M.A. in Counseling Psychology can lead to state licensure for Marriage and Family Therapists (MFT) or Licensed Professional Clinical Counselors (LPCC). The M.A. in Counseling is for students who wish to pursue work in which they will use counseling skills in non-mental health settings. The M.A. in Applied Psychology is designed for students who wish to pursue a variety of human service fields or as preparation to apply for graduate-level Ph.D. work in any branch of psychology. Emphasis for all three degree programs includes Latino Counseling, LGBTQ Counseling, Health Psychology, and Correctional Psychology.

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

For over 25 years, the Miller Center for Social Entrepreneurship has been a leader in the global social enterprise movement. With an emphasis on climate resilience and women's economic power, we accelerate social entrepreneurship to end poverty and protect the planet, guided by the United Nations' Sustainable Development Goals. Located at Santa Clara University, we fuse the entrepreneurial spirit of Silicon Valley with the university's heritage of social justice, community engagement, and global impact.

As one of the University's Center of Distinction, we offer faculty and students real-world case studies, distinctive curricula, and unique opportunities for research, fellowships, and internships. Last year, we provided over 700 students with meaningful learning experiences in entrepreneurship, poverty eradication, and sustainable development. We also work with almost 400 executive mentors — global business leaders who engage their passion for business to help social entrepreneurs build sustainable and scalable organizations. Miller Center has served more than 1,400 social entrepreneurs based in over 100 countries that are impacting hundreds of millions of lives. 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. Almost half of the alumni live in the San Francisco Bay Area, where many former Broncos 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

Amidst 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 provide 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

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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

Santa Clara has unique Residential Learning Communities (RLCs) housed in eight on-campus residence halls. The RLCs include both suites and traditional double rooms, allowing for both a traditional and communal on-campus experience. The RLCs focus on eight different themes, bringing co-curricular programming and events that inspire all students to thrive in the campus setting. RLCs also instill a sense of belonging because students can create, join, learn, and contribute to the community the moment they arrive on campus. Juniors and seniors may apply for townhouse-style living in the 138-unit University Villas and in several neighborhood, units surrounding campus.

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 Center’s late-night venue, serving beverages and pub-style food.

Another hot spot 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, an adjacent outdoor workout area, sand volleyball and basketball courts, and other facilities to support the recreational and fitness needs of the campus community.

The campus includes many locations for quiet reflection, 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, the 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, eight acres of well-lit and grassy 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

The School of Engineering offers both traditional disciplinary-based programs and cross-disciplinary programs to meet the needs of engineering students and support their future professional trajectories in research or practice.

Master of Science Program

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

- 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.
- 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.
- 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.

The Master of Science degree is designed to extend the technical breadth and depth of an engineer's knowledge. The School of Engineering offers Master's programs 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.

The coursework requirements for the degree are determined by each of the major departments and program directors. Students in the M.S. program must complete a Program of Studies approved by the faculty advisor. The program must include a minimum of 46 quarter units. In order to graduate, students must complete the required coursework for the program to which they are admitted, must have a cumulative GPA of 3.000 in all coursework taken at Santa Clara University, and must meet the residency requirement. In addition to this requirement, Engineering Management and Leadership degree candidates must earn a 3.000 GPA in those courses applied to their technical stem and a 3.000 GPA in their engineering management course stem. Note that the number of engineering management course units 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.

Only classes with assigned grades of C- or higher will count toward 46 units required for the completion of the M.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. The thesis option is not available in the Engineering Management and Leadership Program.

Residence requirements of the University are met by completing 36 quarter units of the graduate program at Santa Clara. MS students must complete their Master's degree requirements within 6 years. At the discretion of the student's advisor, a maximum of 9 quarter units (6 semester units) of graduate-level coursework that have not been applied to any previous degree may be transferred from other accredited institutions.

B.S./M.S. Program

The School of Engineering offers qualified Santa Clara University undergraduates the opportunity to earn both a Bachelor of Science and a Master of Science degree. This is an excellent way to save time, reduce opportunity costs, and open up more career possibilities early on. This degree option is offered in Aerospace Engineering, Applied Mathematics, Bioengineering, Civil Engineering, Computer Science 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 B.S./M.S. program should consult the resources provided by the intended graduate program and include required prerequisite courses in their undergraduate program.

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 major GPA of 3.000. 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. Eligible units are defined as courses not used to fulfill requirements for the undergraduate major and minor degrees.

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

Certificate Programs

Certificate programs are designed to provide an intensive background in a focused area at the graduate level. With sixteen to twenty required units for completion, each certificate is designed to be completed in a much shorter period of time than an advanced degree. Santa Clara Engineering's certificate programs are appropriate for students working in industry who wish to update their skills or for those interested in redirecting 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 units can be transferred to the M.S. program depending on the course applicability). Students who wish to continue for such a degree must submit a separate application to the M.S. program 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 higher.

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, Thermofluids and Energy, and Robotics and Automation.

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

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 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.

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 3.000. 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 quality 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.

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 quarter 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 dissertation based on that research, and a program of advanced studies consisting of 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. 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 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.

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.

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 doctoral advisor and department.

Doctoral Advisor

It is the student's responsibility to obtain consent from a full-time tenure-stream faculty member in the student's major department to serve as their prospective advisor.

It is strongly recommended that Ph.D. students find a doctoral advisor before taking the preliminary examination. After passing the preliminary examination, Ph.D. students must have a doctoral 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 doctoral advisor as soon as possible after being accepted as a Ph.D. student.

The student and the advisor with recommendations from the student's doctoral committee develop a complete program of studies for coursework and research. The complete program of studies (and any subsequent changes) must be approved by the student's doctoral committee and then must be filed with Engineering Graduate Programs.

Doctoral Committee

After passing the Ph.D. preliminary exam, a student requests that the doctoral 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 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 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 committee reviews the student's program of study, conducts an oral comprehensive exam, conducts the dissertation defense, and reviews the dissertation. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, dissertation defense, and dissertation 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 3.000 or better. Of these, 36 quarter units may be earned through coursework, independent study, and directed research, and 36 through the dissertation. Deviation from this distribution must be approved by the student's doctoral committee and must not be more than six units. All Ph.D. dissertation units are graded on a Pass/No Pass basis. A maximum of 18 quarter units (12 semester units) of credit for work beyond a master's level, which have not previously been used for the completion of another degree, may be transferred from any accredited institution at the discretion of the student's advisor.

Please note: Only classes with assigned grades of C- or higher will count toward the completion of the Ph.D. degree.

Comprehensive Examination and Admission to Candidacy

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

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

Dissertation Research and Defense

The period following the comprehensive examination is devoted to research for the dissertation, although such research may begin earlier. After successfully completing the dissertation research, the student must pass an oral defense examination on their research. This exam is conducted by the doctoral committee and whomever they appoint as examiners. The complete dissertation 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 research and the defense. This examination presentation is open to all faculty members and students of Santa Clara University. Following the public presentation, a closed session for further questions includes only the doctoral committee, and only members of the doctoral committee may vote on the successful completion of the defense.

Dissertation and Publication

At least one month before the degree is conferred, the candidate must submit one copy of the final version of the dissertation to the department. The dissertation will not be considered accepted until a copy signed by all committee members has been submitted to the library 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 and suitability should be obtained from the candidate's advisor, the doctoral committee, the department chair, and the graduate program office. This written approval must be kept in the candidate's file. The final version of the dissertation must be filed with the library.

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 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.

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 Associate Dean of Graduate Studies 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, and spring quarters and also for their final graduating quarter. Those who do not wish to enroll must submit a leave of absence or a withdrawal request through 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: Students who miss one or more quarters and fail to submit the appropriate requests will be discontinued automatically and may have to reapply to the Ph.D. program. Readmission is not guaranteed.

The Industrial Track Ph.D.

In addition to our regular Ph.D. program, Graduate Engineering also offers an “industrial track” for working professionals as an option to facilitate the collaboration between academia and industry and allow the sponsoring company to be specifically included in research guidance. 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 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 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 program-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 specific 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 student 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: Graduate Admissions

Program (See Program Details Below)	Application Requirements (See Application Requirement Details Below)
B.S./M.S. Program (Current SCU Undergraduate Students)	• Online Application • Unofficial SCU Transcripts • Application Fee Waived • GRE Scores Waived
Open University	• Application Fee $95 (Nonrefundable) • Statement of Purpose • Official Transcripts • TOEFL/IELTS/DUOLINGO (If Applicable)
Certificate	• Application Fee $95 (Nonrefundable) • Statement of Purpose • Official Transcripts • TOEFL/IELTS/DUOLINGO (If Applicable)
Master's Degree	• Application Fee $95 (Nonrefundable) • Statement of Purpose • Official Transcripts • 2 Letters of Recommendation • GRE Waived (Except for the MS in CSE) • TOEFL/IELTS/DUOLINGO (If Applicable)
Engineer's Degree	• Application Fee $95 (Nonrefundable) • Statement of Purpose • Official Transcripts • 3 Letters of Recommendation • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)
Ph.D. Degree	• Application Fee $95 (Nonrefundable) • Statement of Purpose • Official Transcripts • 3 Letters of Recommendation • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)

Application Requirement Details

1. Online Application
Submit your online application, using the Slate application system

https://slate.scu.edu/apply/. Complete an application using your personal email address as the username and create a password. Application status and official decisions are made available through the Slate portal.

2. Nonrefundable Application Fee:
All applicants to any School of Engineering program are required to submit a nonrefundable $95 application fee.

3. 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 degree-granting institution. The official transcript must include the degree received and the 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.

4. 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 results to gradengineeradmissions@scu.edu. For information on the GRE, please visit the website: www.ets.org/. Required for all computer science and engineering applicants.

5. 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, 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. program is for current SCU undergraduate students who wish to begin taking courses required for a master’s degree before completing the requirements for a bachelor’s degree.
The B.S./M.S. program is based on a minimum GPA of 3.000 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 3.500 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 engineering professionals 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 requirements for graduate admission to the master's degree will be waived for students who complete a certificate with a GPA of 3.500 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 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 a 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, and 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 for checking 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 abide by all policies and procedures.

Tuition and Fees

Santa Clara reserves the right to change tuition, room and board, fees, or other costs, to modify its services, or to 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, per quarter unit, for all courses…$1,206

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 $TBD **Subject to pending approval from California Dept. 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 certificates 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 online 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 the number of units, will be automatically enrolled into the SCU-sponsored health insurance plan.

Other Fees

- Non-refundable application fee, per application…$95
- Non-refundable Enrollment Deposit (will be credited toward student 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
- 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 4:30 PM only - (per year) ... $200

Please 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 2024 Billing available August 1; payment due August 21
Winter 2025 Billing available December 1; payment due December 21
Spring 2025 Billing available March 1; payment due March 21
Summer 2025 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. Payments made by electronic check will be subjected to a 7-day calendar hold.

Payment by Mail

Payment for student account charges is accepted by mail utilizing the University's cash management service lockbox. 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. Payments made by paper check will be subjected to a 10-day calendar hold.

Payment in Person

Payments for student account charges may be made in person by check only at the OneStop Office located in the Admissions and Enrollment Services Building. Payments made by paper check will be subjected to a 10-day calendar hold. The OneStop Office is not able to initiate any form of electronic payment. However, 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 credit cards as payment 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 by the due date, all charges on a student's account have not been cleared by payment, financial aid, or loan disbursement, a late payment fee will be assessed to the student's account and an account hold will be placed on the student's account. The institution reserves the right to also require students with repeated instances of late payments to prepay for future enrollment. If a student's prior-term payment history shows at least 2 consecutive terms of late payments, a registration hold may be placed on the account that would require prepayment with guaranteed funds for a minimum of three consecutive terms before the pre-payment registration hold is lifted. A hold on a student's account prevents the release of diplomas or certificates, 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.

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. All unpaid balances referred to an outside collection agency will accrue 10 percent interest per annum on the balance remaining from the date of default in accordance with California state law. 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 reasonable 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. Returning students whose balances were previously referred[RS1] to an external collection agency due to a delinquent account will be required to prepay for future enrollment.

Billing Disputes

If a student wishes to dispute any charge on his or her 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 disputed charge appeared.

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. However, all other charges need to be paid by the payment deadlines. If the disputed amount is deemed to be invalid, then an adjustment will be made on the student's account. If the amount in question is found to be valid, 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 10-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 or payment method. 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, and 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 5:00 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 5:00 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 degree-seeking students who completely withdraw from the University or who are administratively withdrawn from the University after the third week of the term due to a qualifying hardship not covered by Dewars Tuition Insurance Protection Plan may be eligible for an allocation from the student hardship fund for 25 percent of the tuition charges for that term. Qualifying hardships include (1) death, disabling injury, medical emergency, or loss of job of the parent or guardian of a dependent student; (2) loss of job by an independent student; (3) medical or other emergency involving a dependent of an independent student; and (4) deployment for active military duty of a student. The vice provost for student life or designee, in consultation with the Financial Aid Office, will determine qualifying hardships and any allocation from the student hardship fund. Students must submit a request for reconsideration of tuition charges or for an allocation from the student hardship fund not later than 90 days from the end of that term.

Tuition Insurance Protection

The University has partnered with A.W.G. Dewar, Inc. to provide a low-cost, tuition insurance protection plan. This plan protects students and their families against financial loss due to an unexpected complete withdrawal from the University, for diagnosed medical or mental health reasons. It is highly recommended that students purchase tuition insurance coverage for all sessions including summer sessions. If you wish to purchase coverage for any session, please contact Dewar directly at trp@dewarinsurance.com or 617-774-1555.

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 California State Approving Agency for Veterans Education (CSAAVE) 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. Instructors 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

For convenience for working professionals, classes are offered in the early morning before 9:00 A.M. and late afternoon after 5:00 P.M., Monday through Friday with some weekend offerings. Two-unit courses meet one day per week, three-unit courses may meet one or two days 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 contribute to the unit total for the Master’s, Engineer’s, or Ph.D. degree or certificates. The student must earn a minimum 3.000 cumulative grade point average (GPA) overall and a minimum 3.000 grade point average (GPA) in their major for all degrees. Only credits, not grade points, may be transferred from other institutions.

Students who have not met the minimum cumulative 3.000 GPA after completing 16 units will be placed on an academic warning. Students who do not meet the minimum cumulative GPA after being on an academic warning will be placed on academic probation. If a student is on academic probation for two consecutive active quarters they are eligible for dismissal. The student’s advisor and Department Chair will be notified about their GPA status. A dismissal decision by 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 may appeal to the Department Chair, and subsequently to the Associate Dean for Graduate Studies.

Although only classes with assigned grades of C- or higher will count toward the units required for certificates, M.S., Engineer, or Ph.D. degrees, the grades of all courses completed during the certificate, M.S., Engineer’s, or Ph.D. program are used to compute the cumulative grade point average (GPA).

Directed Research, Independent Study, and ENGR courses are not included in the student's major GPA. Only major subject courses will be calculated in the student’s major GPA.

Grading System

Grading is based on an A through F scale. 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

Seminar courses (with the exception of CSEN 400 and ECEN 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 circumstances, some essential portion of the coursework remains unfinished after the final examination, or if the thesis has not been completed. An incomplete (I) will automatically convert to a failing grade (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 the summer session. Makeup work must be submitted to 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

The faculty instructor is solely responsible for assigning the grade in a course. 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 graduate 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 and fees 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 can request to audit a course with a reduced tuition fee. Alumni 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. Anyone interested in this option is welcome to contact the graduate program office.

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 to compute overall student performance. The units from a course may be counted only once when fulfilling graduation requirements. A course may only be repeated once.

Withdrawal from Courses

Students may change their course registration as stated in the Academic Calendar. Withdrawal from any course is allowed up to the seventh Friday of the term. Before the end of the fourth week of the quarter, a withdrawal is not recorded on the transcript. After the fourth week of the quarter, a withdrawal will be recorded as W on the transcript. After the seventh Friday of the quarter, a withdrawal is no longer possible. Emergencies that qualify may be handled as an incomplete (I). 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 an academic advisor to complete a Program of Studies (POS) form. It is the student’s responsibility to contact their department or listed advisors. Here are the assigned advisors for the following departments

- Aerospace Engineering- Mohammad Ayoubi (Program Advisor)
- Applied Mathematics- Aaron Melman (Department Chair)
- Bioengineering- Please contact the department for available advisors.
- Civil, Environmental and Sustainable Engineering- Please contact the department for available advisors.
- Computer Science and Engineering- The CSE department will send an email with your academic advisor information by the end of the first week of the quarter. However, you can always 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 Khanbaghi (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. Changes to the approved Program of Studies may be made by submitting at any time 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, courses, and transfer credits, and must be submitted before the end of the student’s final quarter for graduation.

Courses Transferred from Santa Clara University

Students admitted into the B.S./M.S. program may transfer up to 20 units of graduate-level courses that they completed as an undergraduate as long as those courses or units were not used to satisfy their undergraduate degree requirements. Any requested transfer course will need to be approved by the academic advisor and listed on the program of studies under the transfer credit section. Only courses with a grade of B or higher will be transferred to the M.S. degree. The grade and the units will be applied to the Master's degree.

Santa Clara alumni entering the M.S. program at a later date can transfer up to 12 units of eligible graduate-level coursework with the approval of their academic advisor 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 or minor.
- 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 semesters 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 the Graduate Engineering Programs Office.
- In order to transfer units into a degree program, please follow this procedure:
  (1) 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).
  (2) The student's academic advisor must sign the Program of Studies form.
  (3) The Program of Study form with the transfer credit listed must be submitted to the Graduate Engineering Programs Office by the end of the student's first quarter.

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 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 a program completion request to graduate by the deadline listed in the Academic Calendar. The program completion is submitted in the Workday Student Portal. All graduating students must submit a final Program of Study form and enroll in at least one unit during their final quarter.

In order to participate in the June graduate commencement ceremony, all requirements and units must be completed by the end of the preceding spring quarter.

Cooperative Education

The objective of the cooperative education option is to provide students with the opportunity, through the interaction of study and work experience, to enhance their academic knowledge, to further their personal teamwork experience, and to gain a better understanding of the application of their classroom studies. 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. 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.

Students who wish to pursue this option through curricular practical training (CPT) must enroll in ENGR/GREN 289 for the M.S. program or ENGR/GREN 389 for the Ph.D. program. To be eligible to enroll in ENGR/GREN 289 students need to maintain a minimum cumulative GPA of 3.000, complete 3 quarters in the current program, and complete at least one course from the Engineering Core Requirement (refer to Chapter 6). For ENGR/GREN 389, Ph.D students must have passed the comprehensive examination and be admitted to candidacy. Both ENGR/GREN 289 and ENGR/GREN 389 may be repeated for credit up to three times.

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 U.S. Citizenship and Immigration Service (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 a Designated School Official (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 contact the International Student Services Office at 408-554-4318 or refer to website: www.scu.edu/globalengagement/international-students

Non-enrollment Period

Students in the Certificate, Non-Degree, Master's, Engineer's, and Ph.D. programs are expected to have continuous enrollment requiring 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 requests must be submitted by the end of the first week of the quarter. A request to return to the program is not guaranteed if a substantial leave of absence has occurred or the student is not in good academic standing. A denied request for return may be appealed.

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. Ph.D. students are required to complete their degree within eight years from their original admit term date. Both the six-year and eight-year time frames include quarters that the student was on a leave of absence or withdrew. Certificate students are required to complete their certificate within two years from their original admit term date. Students on an F-1 Visa are required to complete their degree per their I-20 document deadline.

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: Graduate Core Requirements and Graduate Engineering

Santa Clara Engineering offers a wide range of general Graduate Engineering courses, of which the majority are designated with the prefix ENGR/GREN. Note that some ENGR/GREN courses are not included as part of the graduate core but are designed to be elective courses that are accessible to and of interest to students from many engineering programs. This includes the Co-op Education Courses ENGR/GREN 289 and ENGR/GREN 389. 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 Graduate 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.

The Graduate Core is required for all M.S. degree-seeking students in all departments and programs in the School of Engineering. The components that are associated with this requirement are designed to broaden the scope of the student's knowledge and develop professional skills essential for operating effectively in a global environment including the ability to communicate clearly, to function on interdisciplinary and diverse teams, and to make ethically and socially responsible decisions.

All core courses must be taken at SCU and transfer credit cannot be approved for core courses. B.S./M.S. students may start to take the core courses while they are undergraduate students.

In order to fulfill the Graduate Core requirement, students must take one course selected from each of the following two areas:

- Engineering and Society
- Professional Development

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

GRADUATE CORE AREAS AND TOPICS

Engineering and Society

- BIOE 210 Ethical Issues in Bioengineering (2 units)
- CSEN 269 Computing for Good: Project Design and Implementation (2 units)
- CSEN 288 Software Ethics (2 units)
- ENGR/GREN 245 Innovation, Entrepreneurship and the Evolution of Silicon Valley (3 units)
- ENGR/GREN 272 Energy Public Policy (2 units)
- ENGR/GREN 303 Gender and Engineering (2 units)
- ENGR/GREN 336 Engineering for the Developing World (2 units)
- ENGR/GREN 337 Social Entrepreneurship- Innovating with Impact (2 units)
- ENGR/GREN 342 3D Print Technology and Society (2 units)
- ENGR/GREN 344 Artificial Intelligence and Ethics (2 units)
- ENGR/GREN 345 Space Ethics (2 units)

Professional Development

- ENGR/GREN 269 Human Resources Development and the Engineering Manager (2 units)
- ENGR/GREN 270 Effective Oral Technical Presentations (2 units)
- ENGR/GREN 271A. Effective Written Technical Communication I (2 units)
- ENGR/GREN 271B. Effective Written Technical Communication II (2 units)
- ENGR/GREN 285 Managing Business Relationships (2 units)
- ENGR/GREN 302 Managing in the Multicultural Environment (2 units)
- ENGR/GREN 304 Building Global Teams (2 units)
- ENGR/GREN 306 Engineering and the Law (2 units)
- ENGR/GREN 330 Law, Technology, and Intellectual Property (2 units)
- ENGR/GREN 332 How Engineers, Businesspeople, and Lawyers Communicate With Each Other (3 units)
- ENGR/GREN 349 Ethical Decision Making for Technology Leaders (2 units)
- ENGR/GREN 358 Global Technology Development (2 units)
- ENGR/GREN 373 Technology Entrepreneurship (2 units)

Course Descriptions

ENGR/GREN 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. (3 units)

ENGR/GREN 256. Introduction to NanoBioengineering

This course is designed to present a broad overview of diverse topics in nanobioengineering, with an 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/GREN 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/GREN 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. Applications of nanoscale materials. (2 units)

ENGR/GREN 261. Nanotechnology and Society

Addresses the fundamental scientific and technological underpinnings of the important 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 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/GREN 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)

ENGR/GREN 270. Effective Oral Technical Presentations

Role of communications in the workplace, persuasive communications, organizing and leading meetings, interviewing skills, and delivering effective technical presentations to large and small groups. (2 units)

ENGR/GREN 271A. 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)

ENGR/GREN 271B. Effective Written Technical Communication II

Intensive writing practicum, overview of writing, mechanics of style, editing techniques, digital communications. (2 units)

ENGR/GREN 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 280/MECH 287. (2 units)

ENGR/GREN 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 the ability to influence across one's network. High class participation using group exercise, combined with practical training methods. (2 units)

ENGR/GREN 289. MS 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. Please note that F-1 student visa requirements for this course include the completion of three full-time academic quarters in the current degree program. Prerequisite: At least one Graduate Core course completed or in progress and a minimum 3.000 cumulative GPA.

ENGR/GENG 293. Directed Research

Special research directed by a faculty member. By arrangement. Registration requires the faculty member's approval. (1–6 units per quarter)

ENGR/GREN 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/GREN 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/GREN 304. Building Global Teams

Challenges of working virtually and globally. Building global teams. Working across cultures and distances; 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/GREN 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/GREN 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/GREN 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/GREN 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/GREN 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/GREN 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/GREN 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/GREN 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/GREN 344. Artificial Intelligence and Ethics

Will artificial intelligence and machine learning save humanity and create heaven on Earth? Or will it take away what makes us human or even kill us? Or somewhere in between? This course takes a broad perspective on some of the ethical issues related to AI and ML. It will explore ethical reasoning and application to AI and ML technologies. Numerous case studies will make sure the theoretical ethical level of the course always remains connected to the concrete experience of AI and ML as practiced in the world. (2 units)

ENGR/GREN 345. Space Ethics

Space: the final frontier for ethics. As humankind and our machines leave Earth, we open up potential problems that are literally larger than our planet. This class will look at ethical issues including whether we should go to space at all, the effects of space on human health, the dangers of space debris, war in space, asteroid risks, the search for extraterrestrial life and intelligence, responsible exploration, new players in space, long duration spaceflight, settlements in space, and terraforming planets. Every topic will include case studies and practical ethical tools for resolving not only ethical issues in space but much more typical ethical issues to be found on Earth as well, especially involving emerging technologies. (2 units)

ENGR/GREN 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)

ENGR/GREN 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/GREN 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)

ENGR/GREN 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/GREN 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/GREN 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)

ENGR/GREN 389. Ph.D. Co-op Education

Ph.D. students who have passed their comprehensive examination and have the approval of their doctoral 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. Please note that F-1 student visa requirements for this course include the completion of three full-time academic quarters in the current degree program. Prerequisite: Admitted to Ph.D. candidacy by passing the Comprehensive Exam and a minimum 3.000 cumulative GPA. (1 unit)

Chapter 7: Department of Applied Mathematics

Associate Professor: Aaron Melman (Department Chair)
Assistant Professor: Francisco Villarroya Alvarez
Lecturer: Magda Metwally, Robert Kleinhenz

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.

Course Descriptions

Undergraduate Courses

Please see the undergraduate bulletin for undergraduate course descriptions.
https://www.scu.edu/bulletin/undergraduate-bulletin/

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; and 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 are 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 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 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 279. Prerequisite: CSEN 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 379. Prerequisite: AMTH 377/CSEN 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

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

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.

Our faculty offers research projects to bioengineering students that are engaging and involve problem-solving at the interface of engineering, medicine, and biology. The list of the current faculty and their research interests is as follows:

Dr. Hamed Akbari, M.D., Ph.D., integrates medicine and engineering to enhance medical imaging and patient care, with a focus on neuro-oncology. His expertise in medical AI, pattern recognition, and machine learning drives innovative solutions for personalized disease diagnosis and treatment.

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

Dr. Asuri's research interests focus on the design and development of biomaterial-based in vitro platforms to understand complex in vivo phenomena. As the Director of the Healthcare Innovation and Design program, he also partners with industry professionals to address complex challenges in healthcare.

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 simulation, optimization, and statistical validation across multiscale biomaterials-related platforms.

Dr. Scott investigates and designs interventions for brain health using immersive technology and neurotechnology. In this applied form of affective computing, the research program studies how and why these technologies modulate brain function.

Dr. Yan's research centers on bioimaging, image and signal analysis, and AI-assisted diagnostics. In collaboration with a local hospital, she is working on multi-modal deep learning models to offer transparent diagnostic outcomes, with the ultimate goal of translating AI into clinical practice.

Dr. Zhang is currently engaged in interdisciplinary research programs intersecting biomolecular and biodevice engineering, synthetic biology, and drug discovery and development (protein and small molecule), enhanced by the integration of GenAI.

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 3.000 (based on a 4.000 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 the 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 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

- Graduate Core - See descriptions in Chapter 6.
- Applied Mathematics (4 units) Select from AMTH 200 & 201 (or 202), 210 & 211 (or 212), or AMTH 245 & 246
- Focus Areas (10 or 16* units) - Students must take six units from one of the five primary focus areas and four units from other focus areas. An additional six units are required for

Computational Bioengineering (Applied Mathematics courses) or Translational Bioengineering (Capstone).

- Bioengineering Core (9 units) - Students must take three units from biostatistics (BIOE 232 L&L), two quarter research seminar units (BIOE 200, 2 x 1 unit), and 4 units from Applied Mathematics.
- Bioengineering Technical Electives (13* or 19 units)
- Five primary focus areas are:

(1) Biomolecular Engineering
- BIOE 257, 263, 282, 283, 286, 288, 300, 301

(2) Biomaterials and Tissue Engineering
- BIOE 258(L+L), 258(L+L), 269, 273, 378

(3) Microfluidics/Biosensors and Imaging
- BIOE 203, 216, 260, 267, 268, 276, 277, 308

(4) Computational Bioengineering
- BIOE 277A&B, 251, 252, 261, 281, 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

All graduate-level BIOE courses (except BIOE 210) may count as Technical Elective (TE) units. Selected graduate courses from ECEN, MECH, or CSEN may be credited as TEs upon approval by a faculty advisor. A maximum of 3 units of BIOE 297 is allowed if also taking BIOE 397, otherwise, a maximum of 6 units of BIOE 297 is allowed. Submission of a M.S. Thesis is required for BIOE 397 (max. 9 units)

For students in Accelerated B.S./M.S. 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 pursued by those who wish to specialize in a particular area of bioengineering. The work for the degree involves conducting in-depth bioengineering research, preparing a thesis based on the research findings, 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 collaboration between academia and industry. 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 will be in written format and 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 to 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 to the Ph.D. program should take the preliminary examination as soon as possible but not more than two years after beginning the program.

Students are expected to pass an exam in biostatistics as well as one each in two areas from the following list: biodevices and bioimaging, biomolecular and bioprocess engineering, biomaterials and biofabrication, and computational bioengineering. At the thesis advisor's discretion, students may be expected to take and pass an exam in three areas (in addition to biostatistics) from the above list. Students opting to pursue the computational bioengineering focus may choose a different exam topic instead of biostatistics. Only those students who pass the preliminary examination shall be allowed to continue in the doctoral program. The preliminary examination may be retaken once, and any additional retakes are at the discretion of the thesis advisor.

Doctoral 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 doctoral advisor before taking the preliminary examination. After passing the preliminary examination, Ph.D. students must have a doctoral 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 doctoral advisor as soon as possible after being accepted as a Ph.D. student.

The student and the doctoral 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 the courses taken will be acceptable toward the Ph.D. course requirements.

Doctoral Committee

After passing the Ph.D. preliminary exam, a student requests their doctoral 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 doctoral 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 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 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.

Dissertation Research and Defense

The period following the comprehensive examinations is devoted to research for the dissertation, 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 dissertation 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 dissertation 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.

Dissertation and Publication

At least one month before the degree is to be conferred, the candidate must submit one copy of the final version of the dissertation to the department. The dissertation will not be considered as accepted until a copy signed by all committee members has been submitted to the library and one or more refereed articles based on it are accepted for publication in a professional or scientific journal approved by the doctoral committee.

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 systems, 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 the 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

The list of undergraduate courses can be found in the Undergraduate Bulletin.
https://www.scu.edu/bulletin/undergraduate-bulletin/

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 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

This course will introduce students to various tools and processes that will improve their ability to identify and prioritize clinical needs, select the best medical device concepts that address those needs, and create a plan to implement inventions. (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 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 focuses 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 emphasis 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 a 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 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, biomedical imaging, visualization technology and applications, biosignals and analysis methods, bioinstrumentation, and bio-nanotechnology. (2 units)

BIOE 250. Genetic and Therapeutic Bioengineering

This course covers the fundamental principles and practical skills of genetic manipulation and therapeutic medicine, with an emphasis on advanced genome editing technologies and applications of gene and cell therapy, drug delivery, and vaccination. Students will be able to implement biomedical solutions in the following areas: Production of recombinant protein drugs; gene therapy; RNA therapeutics and vaccines; targeted gene editing; knockout animal, and disease modeling. Credit is not allowed for both BIOE 250 and 302 (or 263). Also listed as BIOE 150. (4 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 and BIOE 45 (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/GREN 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 emphasis will be placed on emerging applications namely Microbial Fuel Cell Technology and Photo-bioreactors. Also listed as ENGR/GREN 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 complemented by software-enabled simulation of prototyping and driving forces analysis. 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 preferred. (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, and data analysis will be covered. Prerequisites BIOE 22 or BIOL 1C or equivalent. (2 units)

BIOE 267. Introduction to Medical Imaging

This course will cover the 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. (4 units)

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 with the consent of the instructor). (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. Also listed as BIOE 182 (2 units)

BIOE 280. 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 180. Prerequisites: BIOE 120 (or AMTH 108), or with consent of the instructor. (4 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 on 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 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)

290. 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 have 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. Also listed as BIOE 148. (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 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 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 or 380 or BIOE 232. (2 units)

BIOE 397. Master’s Thesis Research

By arrangement. (1–9 units)

Chapter 9: Department of Civil, Environmental and Sustainable Engineering

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
Assistant Professors: Vito Francioso, Rocio Segura
Teaching Professor: Laura Doyle
Lecturers: Tracy Abbott, Mohaddeseh Peyro
Professor Emeritus: E. John Finnemore, P.E.
Associate Professor Emeritus: Steven C. Chiesa, P.E.

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 the 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 prepares 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 Chapter 3 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, and 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 Chapter 5 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 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

---	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 247 (4) 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)

---	Structural Engineering Track	General Civil Engineering Track	Construction Engineering and Management Track	Water and Environmental Engineering Track
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 247 (4) CENG 293 CENG 295 CENG 297	6 units from: CENG 218 (3) CENG 242 (4) CENG 247 (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/GREN 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)

---	Structural Engineering Track	General Civil Engineering Track	Construction Engineering and Management Track	Water and Environmental Engineering Track
Applied Mathematics	4 units from: AMTH 210 (2) & 211 (2) AMTH 214 (2) & 215 (2) AMTH 220 (2) & 221 (2) AMTH 245 (2) & 246 (2)	4 units from: AMTH 210 (2) & 211 (2) AMTH 214 (2) & 215 (2) AMTH 220 (2) & 221 (2) AMTH 245 (2) & 246 (2)	4 units from: AMTH 210 (2) & 211 (2) AMTH 214 (2) & 215 (2) AMTH 367 (4) AMTH 370 (2) & 371 (2)	4 units from: AMTH 210 (2) & 211 (2) AMTH 214 (2) & 215 (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 330 (2) EMGT 335 (2) ENGR/GREN 271B^ (2)	5 units from: CENG 260 (3) EMGT 255 (2) EMGT 330 (2) EMGT 335 (2) ENGR/GREN 271B^ (2)	6 units from: ENGR/GREN 269 (2) ENGR/GREN 270 (2) ENGR/GREN 285 ENGR/GREN 349 EMGT 322 (2) EMGT 324 (2) ENGR/GREN 271B^ (2)	4 units from: CENG 208 (2) CENG 292 (2) EMGT 330 (2 EMGT 335 (2) ENGR/GREN 271B^ (2) ENGR/GREN 304^ (2) ENGR/GREN 336^ (2)
ENGINEERING CORE	To fulfill this requirement, students must take one course selected from each of the following areas: • Engineering and Society • Professional Development See Chapter 6 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. On 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 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

For undergraduate courses refer to the undergraduate bulletin.
https://www.scu.edu/bulletin/undergraduate-bulletin/

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 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 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 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 the 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, and 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 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 247. Pavement Design

Paving materials. Design of highway pavement systems, subgrades, subbases, soil stabilization, and drainage. Design of flexible (asphalt) and rigid (concrete) pavements. Cost analysis and pavement selection. Pavement evaluation. Layout and design of airport runways. Also listed as CENG 147. Prerequisites: CENG 115 and 121. (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, and 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. The course requires students to get hands-on experience with 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. Also listed as 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
Regis and Dianne McKenna Professor: Silvia Figueira (Department Chair)
Professor: Ruth E. Davis
Associate Professors: Margareta Ackerman, Ahmed Amer, Darren Atkinson, Behnam Dezfouli, Yi Fang, Xiang Li, Ying Liu, Yuhong Liu, Weijia Shang
Assistant Professors: David C. Anastasiu, Younghyun Cho, Sean Choi, I-Han Hsiao, Oana Ignat, Shiva Jahangiri, Krishna Kattiyan, Xiao Li, Kai Lukoff, Yidi Wang
Lecturers: Salem Al-Agtash, Yan Cui, Farokh H. Eskafi, Keyvan Moataghed, Angela Musurlian, Michael Schimpf, Navid Shaghaghi, 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 M.S. in CSE program are expected to have competence in the fundamental subjects listed below, as required from an accredited program for a B.S. in Computer Science, Computer Engineering, and Computer Science and Engineering. An applicant without such background must complete foundation courses below 1 through 3 prior to being admitted into the program. These courses must be taken at an approved accredited institution. Courses 1 through 3 are not eligible for transfer credit. Math courses (4 through 6) may be taken as a graduate-level course in Applied Math in the graduate program at SCU as part of the MS degree within the first year of your admissions.

1. Logic design
2. Data structures
3. Computer organization & assembly language
4. Discrete Math
5. Probability
6. One of the following: Differential Equations, Numerical Analysis, or Linear Algebra

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

Degree Requirements

Engineering Graduate Core

Students must take a minimum 4 units from the Graduate Core, one course from each of the following areas:

- Professional Development
- Engineering and Society

Please refer to Chapter 6 for additional information and the core course list.

MSCSE Core

- CSEN 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 313, 379, and/or 383) or, with their advisor's approval, replace said course(s) with elective(s).

MSCSE Electives

- CSE electives must be approved by the advisor.
- Students must take a minimum of 8 units of CSEN 300-899 courses and may take at most 6 units of CSEN 493/494/499.
- Students must take sufficient elective units to bring the total to at least 46, and at least 36 of these units must come from CSEN courses.

Please Note: Students wishing to do a thesis (CSEN 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 Chapter 2 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 department 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.

Doctoral Advisor

The student and their 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 Office and approved by the student's doctoral committee. Until this approval is obtained, there is no guarantee that the 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 their doctoral 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 doctoral 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 dissertation 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.

Academic 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 3.000 or better. Of these, 36 quarter units may be earned through coursework, independent study, and directed research, and 36 through the thesis. A maximum of 18 quarter units (12 semester units), not previously used for the completion of another degree, may be transferred from any accredited institution at the discretion of the student's advisor.

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. Extensions will be allowed only if approved by the Associate Dean of Graduate Studies 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, AI/ML/DL/LLM and serverless compute.

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 Databases and Information Systems Laboratory (DBIS Lab) focuses on research in designing, developing, and optimizing data management and information systems. Projects cover areas like database internals (query processing, execution engine, data storage), database architecture (including disaggregated architectures), as well as research in Knowledge Graphs and Semantic Web.

The Global Digital Transformation (GDT) Clinic focuses on helping social enterprises, non-profit organizations, and governmental programs that operate in low-resource areas embrace technology. This is done by designing, developing, and deploying customized web/mobile applications that can help them improve and/or scale their operation to better serve their beneficiaries.

The Human-Computer Interaction Laboratory (HCI Lab) researches, designs, and develops technologies with social impact, with a focus on AR/VR, social computing, generative AI, and digital wellbeing.

The Internet of Things (IoT) Research Laboratory (SIOTLAB) focuses on designing and developing intelligent sensing solutions, efficient and secure communication platforms and protocols, and seamless edge-to-cloud computing infrastructures that harness artificial intelligence to enhance systems' performance, decision-making, and operational efficiency.

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 techniques to solve security-related problems in various real-world complex networks.

The Responsible AI Laboratory aims to foster interdisciplinary research, promote ethical AI education, and cultivate partnerships that ensure AI advances are safe, equitable, transparent, and beneficial to the broader good of society.

The Sustainable Systems Laboratory (SSL) is dedicated to a computing-informed perspective on sustainability, and the complementary beliefs that just computing is sustainable, and sustainable computing is more than just computing. Via an initial focus on data storage technologies, it tackles both resilience and efficiency challenges to computing-related problems, and the application of systems-software concepts to broader societal and ethical questions.

The Systems & Performance Research Lab conducts research on system software (e.g., runtime systems and compilers) and performance tools (e.g., automatic tuning, profiling, and analysis) to improve the performance of software on parallel and high-performance computer systems.

The Trustworthy Computing Laboratory focuses on the security, privacy, and trust challenges and solutions for emerging distributed systems and networks, such as online social media, Internet-of-Things, Blockchain, and Distributed Energy Resource (DER)-based Equitable and Self-sustaining Clean Energy Ecosystem.

The Video and Image Processing Laboratory (VIP Lab) investigates state-of-the-art deep learning and signal processing techniques for image and video processing, visual data compression, visual coding for machine intelligence, and 3D point cloud coding.

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.

The list of undergraduate courses can be found in the Undergraduate Bulletin.
https://www.scu.edu/bulletin/undergraduate-bulletin/

Graduate Courses

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

CSEN 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 500. Prerequisite: CSEN 127C or equivalent. (2 units)

CSEN 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 233. Prerequisite: ECEN 210 or its undergraduate equivalent of ECEN 110. (2 units)

CSEN 201E. Digital Signal Processing I & II

Same description as CSEN 201 and CSEN 202. Credit is not allowed for both CSEN 201/202 and 201E. Also listed as ECEN 233E. (4 units)

CSEN 202. Digital Signal Processing II

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

CSEN 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 387. Prerequisite: CSEN or ECEN 127 or equivalent. (2 units)

CSEN 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 388. Prerequisite: CSEN or ECEN 387 or equivalent, or ECEN 153. (2 units)

CSEN 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 207. Prerequisites: ECEN 500 or CSEN 200 and ECEN 303 or equivalent. (2 units)

CSEN 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 920C and CSEN 921C or equivalent. (4 units)

CSEN 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 210. (2 units)

CSEN 225. Secure Coding in C and C++

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

CSEN 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 20 or equivalent and AMTH 108 or equivalent. (4 units)

CSEN 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 233 or equivalent. (2 units)

CSEN 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 238. Multimedia Information Systems

Overview and applications of multimedia systems. A 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 or CSEN 177, 279 or 283. (2 units)

CSEN 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 233 or equivalent. (4 units)

CSEN 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 179 or 279. (4 units)

CSEN 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 12 and CSEN 146 or 233. (4 units)

CSEN 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 178 or 280. (4 units)

CSEN 243. Internet of Things

Application domains. Architecture. 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 12 or 912C and CSEN 146 or 233. Co-requisite: CSEN 243L. (4 units)

CSEN 243L. Laboratory for CSEN 243

Co-requisite: CSEN 243. (1 unit)

CSEN 250. 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 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 233, CSEN 250 or instructor approval. (4 units)

CSEN 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 20 or 920C or equivalent. Co-requisite: CSEN 252L. (4 units)

CSEN 252L. Laboratory for CSEN 252

Co-requisite: CSEN 252. (1 unit)

CSEN 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 250. (4 units)

CSEN 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 256, 283 or 210. (4 units)

CSEN 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 12 or 912C or equivalent, AMTH 210 and 245 or equivalent. (4 units)

CSEN 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 12 or 912C or equivalent. (4 units)

CSEN 269. Computing for Good: Project Design and Implementation

Project-based course that entails the design and development of a full-fledged application for social impact. Prerequisite: Experience in web and/or mobile development is recommended. (2 units)

CSEN 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 179 or 279. (4 units)

CSEN 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 79. (4 units)

CSEN 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 12 or 912C or equivalent. (4 units)

CSEN 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 60 and 161 or demonstrated proficiency. (4 units)

CSEN 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 912C or equivalent. (4 units)

CSEN 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 12 or 912C or Data Structures class and CSEN 283 or equivalent. (4 units)

CSEN 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, 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 12 or 912C or equivalent. (4 units)

CSEN 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 the utilization of resources and/or power network elements. Reporting tools help track operational costs and energy obligations. Also listed as ECEN 288. (2 units)

CSEN 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 12 or 912C and 20 or 920C or equivalent. (4 units)

CSEN 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 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 285 or equivalent. (2 units)

CSEN 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 285 or equivalent. (2 units)

CSEN 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 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 12 or 912C. (4 units)

CSEN 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 296A. Topics in Computer Science and Engineering

Various subjects of current interest. May be taken more than once if topics differ. (2 units)

CSEN 296B. Topics in Computer Science and Engineering

Various subjects of current interest. May be taken more than once if topics differ. (4 units)

CSEN 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 603. Prerequisite: ECEN or CSEN 127 or equivalent. (2 units).

CSEN 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, and 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 389. Prerequisites: CSEN 204 or ECEN 388 or equivalent. (2 units)

CSEN 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 210. (2 units)

CSEN 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 608. Prerequisite: CSEN 200 or equivalent. (2 units)

CSEN 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 210. (4 units)

CSEN 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 233 or equivalent. (4 units)

CSEN 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, and reliability. Prerequisites: CSEN 233 and 283 or equivalent. (4 units)

CSEN 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 210 and AMTH 247 or instructor approval. (4 units)

CSEN 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 12 or 912C or CSCI 61 or equivalent. (4 units)

CSEN 320. Computer Performance Evaluation

Measurement, simulation, and analytic determination of computer systems performance. Workload characterization. Bottleneck analysis tuning. Prerequisites: CSEN 210 and AMTH 211. (4 units)

CSEN 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 233 or equivalent. (4 units)

CSEN 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 233 or equivalent. (4 units)

CSEN 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 331. (4 units)

CSEN 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 233 or equivalent. (2 units)

CSEN 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, and support for multimedia/real-time communication. Prerequisite: CSEN 233 or equivalent. (4 units)

CSEN 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 641. Prerequisites: AMTH 108, AMTH 245, and basic knowledge of algorithms. (4 units)

CSEN 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. A brief introduction to speech coding and speech coding standards. Machine learning for audio and speech coding. Also listed as ECEN 639. Prerequisites: AMTH 108, AMTH 245, and CSEN 279 or equivalent. (2 units)

CSEN 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 640. Prerequisite: CSEN 201 or equivalent. (2 units)

CSEN 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 244. Prerequisites: ECEN 241 and AMTH 211. (2 units)

CSEN 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 240 or CSEN 281. (4 units)

CSEN 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 643. Prerequisite: CSEN 340. (2 units)

CSEN 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 644. Prerequisites: CSEN 340 and knowledge of linear algebra. (2 units)

CSEN 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 645. Prerequisites: CSEN 340 and knowledge of probability. (2 units)

CSEN 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 240 or CSEN 281. CSEN 342 is optional but recommended. (4 units)

CSEN 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 338 or ECEN 641. (4 units)

CSEN 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 421. Prerequisite: ECEN 233 and/or ECEN 334 or equivalent. (2 units)

CSEN 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 422. Prerequisite: ECEN 421. (2 units)

CSEN 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 253. Co-requisite: CSEN 351L. (3 units)

CSEN 351L. Laboratory for CSEN 351

Co-requisite: CSEN 351. (1 unit)

CSEN 352. 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 250. (2 units)

CSEN 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 the 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 179 or 279. (4 units)

CSEN 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 179 or 279. (4 units)

CSEN 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 275. (4 units)

CSEN 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, the 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 266 and a course including predicate logic and lambda calculus. (4 units)

CSEN 377. Data Visualization

This course covers techniques and algorithms for creating effective visualizations based on principles from graphic design, visual art, perceptual psychology, and cognitive science to enhance the understanding of complex data. Topics include Vision & Color, Social & Interactive Visualization, Principle & Design, Perception & Attention, Maps & Cartography, (Social) Network Visualization, Text Visualization, Time Series Visualization, Visual Analytics & Dashboard. Prerequisites: CSEN 277 or CSEN 278 and CSEN 240 or CSEN 281. (4 units)

CSEN 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 or CSEN 279. (4 units)

CSEN 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 280 or equivalent. (4 units)

CSEN 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 283 or equivalent. (4 units)

CSEN 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 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 385. (2 units)

CSEN 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 233 or equivalent and CSEN 283 or equivalent. (2 units)

CSEN 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 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 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 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 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 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 M.S. and Ph.D. students in computer science and engineering. Must be supervised by a regular CSE full-time faculty member. Prerequisite: Registration requires the faculty member’s and department chair's approval. (1–6 units per quarter, for a total of a maximum of 6 units combining CSEN 493, 494, and 499 for M.S. students)

CSEN 494. Interdisciplinary Research

Special research directed by a faculty member. By arrangement. Research must be directed by a tenure-track faculty member in engineering. Limited to M.S. and Ph.D. students in Computer Science and Engineering. Must be supervised by a regular full-time faculty member. Prerequisite: Registration requires the faculty member's and department chair's approval. (1–6 units per quarter, for a total of a maximum of 6 units combining CSEN 493, 494, and 499 for M.S. students)

CSEN 497. Master's Thesis Research

By arrangement. Research must be directed by a tenure-track faculty member in computer science and engineering. Limited to M.S. students in computer science and engineering. Must be supervised by a regular CSE full-time faculty member. Prerequisite: Registration requires the faculty member's and department chair's approval. (1–8 units per quarter, for a total of at least 8 units)

CSEN 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 member. Prerequisite: Registration requires the faculty member's and department chair's approval. (1–10 units per quarter, for a total of 36 units)

CSEN 499. Independent Study

Special problems. By arrangement. Work must be directed by a full-time faculty member. Limited to computer science and engineering students. Prerequisite: Registration requires the faculty member's and department chair's approval. (1–6 units per quarter, for a total of a maximum of 6 units combining CSEN 493, 494, and 499 for M.S. students)

CSEN 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: a 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 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 921C. Logic Design

Intense coverage of topics related to logic design. Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, and 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 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 (Department Chair)
Professors: Tokunbo Ogunfunmi, Sally L. Wood, Cary Y. Yang, Aleksandar Zecevic
Associate Professors: Maryam Khanbaghi, M. Mahmudur Rahman, Kurt Schab, Hoeseok Yang
Assistant Professors: Anoosheh Heidarzadeh, Maria Kyrarini, 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.

Programs are offered which lead to a Master's Degree, a Ph.D. degree, an Engineer's Degree, or a Certificate. Each is described below.

Master's Degree Program

The master's degree will be granted to degree candidates who complete a program of studies approved by a faculty advisor. The program must consist of no less than 46 units, and a 3.000 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. The program may include a thesis or a research component of smaller scope that does not require a thesis.

The program requires that students select one of these defined focus areas within electrical and computer engineering.

Power Systems and Control

Autonomous cars, space shuttles, robots, IoT and airplanes all have sophisticated control strategies. The electric utility industry is probably the largest and most complex industry in the world. How this network operates, and how it can be controlled, and how to integrate renewable energies into the grid in order to have cleaner and more sustainable energy are major challenges.

Faculty Advisors: Maryam Khanbaghi, Aleksandar Zecevic

IC Design and Technology

The study of integrated circuits (IC) (generally known as semiconductors or chips) consists of three interconnected areas of pedagogy, Circuit Design, Device Physics, and Fabrication Process Technology. One cannot imagine the world now and in the future without chips, which are in your home, in your workplace, in your automobile, and in all your electronic devices. With worldwide chips revenue projected to approach $1 trillion by 2030, the semiconductor industry, not unlike its energy counterpart, supplies the critical goods and services that sustain and advance human civilization.

Faculty Advisors: Shoba Krishnan, Cary Yang, Mahmudur Rahman

RF and Applied Electromagnetics

From 5G and the internet of things to automotive radar, high frequency and wireless systems are pervasive in nearly every aspect of modern technology. To prepare engineers for careers in these contemporary fields, the RF and Applied Electromagnetics program provides the fundamental theoretical and applied knowledge for design, analysis, and implementation of high frequency circuits and systems.

Faculty Advisor: Kurt Schab

Signal Processing and Machine Learning

Signal processing algorithms, architectures, and systems are at the heart of modern technologies that generate, transform, and interpret information across applications as diverse as communications, robotics and autonomous navigation, biotechnology and entertainment. This focus area includes courses in theory, architectures, implementations, and specific applications including computer vision and speech processing.

Faculty Advisors: Maria Kyrarini, Tokunbo Ogunfunmi, Sally Wood

Digital Systems

Digital systems include the three broad areas of computer architecture, digital design principles, techniques and verification, and embedded systems. Systems that execute software, whether they be general-purpose computers or computing platforms (digital platforms) embedded into a targeted application, fall into the category of digital systems, as do special purpose hardware implementations that might be realized with an FPGA or manufactured as an ASIC.

Faculty Advisors: Hoeseok Yang

Communication Systems and Information Theory

Information systems are vital to modern technology, driving a broad spectrum of applications from wireless networks and internet security to machine learning and AI. Our Communication Systems and Information Theory program prepares engineers for impactful careers in these rapidly evolving fields. The program offers both theoretical foundations and practical applications of storage, networking, and computing systems to meet the dynamic demands of security, privacy, and reliability in today's interconnected world.

Faculty Advisor: Anoosheh Heidarzadeh

Master Degree Requirements

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 Master’s degree program of studies must include the following:

Graduate Core (minimum 4 units): Students must take a minimum of 4 units of the Graduate Core

- One course must be from the “Engineering and Society” area.
- One course must be selected from the “Professional Development” area.
- For additional information please see Chapter 6 which includes lists of courses which can satisfy the area requirements.

Applied Mathematics (4 units)

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:

- Power Systems and Control Either (236 or 281A) and two courses selected from (211, 232, 281B, 333)
- IC Design and Technology Three courses selected from (252, 261, 270, 387)
- RF and Applied Electromagnetics 201 and two courses selected from (202, 203, 204, 624, 701, 706)
- Signal Processing and Machine Learning 233 and two courses selected from (234, 421, 431, 520, 640, 644)
- Digital Systems 501, 511, and 603
- Communications 241 and 243, and one course selected from (244, 444, 446)

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.

Additional graduate courses recommended and approved by the graduate program advisor. This may include up to 6 units of Directed Research (299) and up to 9 units of Master’s Thesis Research (297). More detailed information about the Master’s Thesis can be found below.

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 or ECE core requirements. A student who has earned a Fundamentals of Electrical and Computer Engineering Certificate will have satisfied these background requirements.

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.

Master's Thesis Research

Master's thesis research consists of a minimum of 7 units and a maximum of 15 units, which are included in "Additional Elective Courses" in the Master's Program of Study. The first stage of the research is 6 units of Directed Research, ECEN 299. Students with an average grade of B+ or higher may continue to stage 2, which is advanced research and thesis composition. This stage requires 1 to 9 units of ECEN 297 and the submission of the completed thesis to the University library.

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 proceed to the subsequent Research Aptitude and Comprehensive 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.

Research Aptitude Examination (RAE)

The doctoral research aptitude milestone is the second major milestone in the progression towards a Ph.D. degree. This exam is designed to foster and evaluate the student's breadth of knowledge based on their performance in graduate level coursework and growing knowledge in their specific topic of interest. It also tests the student's suitability for conducting competent research, which includes evaluating their technical writing and presentation skills.

General Requirements

Doctoral 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 doctoral advisor. It is strongly recommended that Ph.D. students find a doctoral advisor before taking the preliminary examination. After passing the preliminary examination, Ph.D. students must have an 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 doctoral advisor as soon as possible after being accepted as a Ph.D. student.

The student and the 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 their 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 doctoral 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, approves the required publication, and reviews the dissertation. Successful completion of the doctoral program requires that the student's program of study, performance on the oral comprehensive examination, dissertation defense, and dissertation 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 doctoral research units. All Ph.D. research 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 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 their research proposal as part of a comprehensive oral examination on the coursework and the subject of their research work. This represents the third major milestone in the Ph.D. program. 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.

Doctoral Research and Dissertation Defense

The period following the comprehensive examinations is devoted to research, 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 dissertation, conducted by the doctoral committee and whomever they appoint as examiners. The dissertation must be made available to all examiners one month prior to the examination. The oral examination shall consist of a presentation of the research results and the defense. This examination is open to the public, but only members of the doctoral committee have a vote.

Dissertation and Publication

At least one month before the degree is to be conferred, the candidate must submit one copy of the final version of the dissertation to the department. The dissertation will not be considered as accepted until a copy signed by all committee members has been submitted to the library 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. The final version of the dissertation must be filed with the 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.

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 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.

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 3.000 or better to earn a certificate.

Continuation for a Master's Degree

All 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 3.500 or higher.

Academic Requirements

Individual certificates are described briefly below. Additional information can be found in Chapter 17.

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.

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.

Digital Signal Processing and Machine Learning
Advisors: Dr. Maria Kyrarini, 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.

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.

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.

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:

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-time, 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

Undergraduate course descriptions may be found in the Undergraduate Bulletin.

Graduate Courses

Some graduate courses may not apply toward certain degree programs. During the first quarter of study, students are urged to discuss the program of study they wish to pursue in detail with their faculty advisor.

ECEN 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. (1 or 2 units)

ECEN 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 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 201. (2 units)

ECEN 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 201 (or equivalent) or BIOE 168/268. (2 units)

ECEN 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 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 110. May not be included in the minimum required units of Electrical and Computer Engineering courses. (2 units)

ECEN 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 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 210 or its undergraduate equivalent of ECEN 110. (4 units)

ECEN 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 160. Prerequisites: AMTH 106 or an equivalent course in differential equations, and a basic familiarity with MATLAB. (4 units)

ECEN 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 162. Prerequisites: AMTH 246 or equivalent, and familiarity with MATLAB. (4 units)

ECEN 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 filters, 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 21, ECEN 100, and ECEN 115. (4 units)

ECEN 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 234 or ECEN 233E and knowledge of “C” programming language. (4 units)

ECEN 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 133, ECEN 233E or ECEN 234) and (ECEN 127 or the equivalent) and C++ programming experience. (2 units)

ECEN 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 130 and ECEN 230. Prerequisite: ECEN 210 or its undergraduate equivalent of ECEN 110. (4 units)

ECEN 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 184. Prerequisite: ECEN 183 or equivalent. (4 units)

ECEN 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 or ECEN 236 or its equivalent. (2 units)

ECEN 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 201. Prerequisite: ECEN 210 or its undergraduate equivalent of ECEN 110. (2 units)

ECEN 233E. Digital Signal Processing I and II

Same description as ECEN 233 and ECEN 234. Credit not allowed for both ECEN 133 and 233E. Also listed as CSEN 201E (4 units)

ECEN 234. Digital Signal Processing II

Continuation of ECEN 233. Digital FIR and IIR filter design and realization techniques. Multirate signal processing. Fast Fourier transform. Quantization effects. Also listed as CSEN 202. Prerequisite: ECEN 233. (2 units)

ECEN 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 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 130 or its undergraduate equivalent. (2 units)

ECEN 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 236. Students are expected to be proficient in MATLAB/Simulink. (2 units)

ECEN 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 237 or MECH 324 or equivalent. (2 units)

ECEN 239. Topics in Systems Theory

Various topics. (2 units)

ECEN 241. Introduction to Communication

Review of signals and systems in both time and frequency domain. Analog modulation and demodulation. The impact of noise on analog systems. Prerequisite: ECEN 210 or equivalent. (2 units)

ECEN 241E. Modern Communications

This course combines the topics found in ECEN 241 and ECEN 243 (both 2 unit courses) into one 4-unit course. Credit not allowed for both ECEN 241/243 and ECEN 241E. Prerequisites: ECEN 210 or equivalent and AMTH 108 or its equivalent. (4 units)

ECEN 243. Digital Communication Systems

Review of probability, random variables, and random processes. Digital modulation/demodulation techniques and their performance in the presence of noise. Prerequisite: ECEN 241 and AMTH 108 or equivalent. (2 units)

ECEN 244. Information Theory

Principles of information theory and error-correcting codes. Information-theoretic measures and their properties. Lossless source coding theorem and algorithms. Noisy channel models and channel coding theorem. Also listed as CSEN 341. Prerequisite: AMTH 211 or equivalent. (2 units)

ECEN 244E. Information Theory and Error-Correcting Codes

This course combines the topics found in ECEN 244 and ECEN 444 (both 2 unit courses) into one 4-unit course. Credit not allowed for both ECEN 244/444 and ECEN 244E. Prerequisite: AMTH 211 or its equivalent. (4 units)

ECEN 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 233 and 243. (2 units)

ECEN 248. Communication Systems Modeling Using Simulink II

Continuation of ECEN 247. Prerequisite: ECEN 247. (2 units)

ECEN 249. Topics in Communication

Various topics. (2 units)

ECEN 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 50 or equivalent. (2 units)

ECEN 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 265 or ECEN 267. (2 units)

ECEN 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 115 or equivalent. (2 units)

ECEN 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 252. (2 units)

ECEN 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 116. Co-requisite: ECEN 117L. (4 units)

ECEN 259. Topics in Circuit Design

Various topics. (2 units)

ECEN 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 264. Semiconductor Device Theory I

Physics of semiconductor materials, junctions, and contacts as a basis for understanding all types of semiconductor devices. Prerequisite: ECEN 261 or ECEN 151 or equivalent. (2 units)

ECEN 265. Semiconductor Device Theory II

Continuation of ECEN 264. MOSFET basics, short-channel and high-field effects, CMOS, bipolar junction transistors. Prerequisite: ECEN 264. (2 units)

ECEN 266. Semiconductor Device Theory I and II

Same description as ECEN 264 and 265. Prerequisite: ECEN 261 or ECEN 151 or equivalent. Credit allowed for either ECEN 264 and 265, or ECEN 266. (4 units)

ECEN 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 151 and ECEN 267. Prerequisite or Co-requisite: ECEN 104 or basic knowledge of electrostatics. (4 units)

ECEN 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 gasses 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 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 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 270. (2 units)

ECEN 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 270. (2 units)

ECEN 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 152. Prerequisite: ECEN 270. (4 units)

ECEN 276L. Integrated Circuit Fabrication Process Technology Laboratory

Laboratory for ECEN 276. Also listed as ECEN 152L. (1 unit)

ECEN 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 201. (2 units)

ECEN 279. Topics in Semiconductor Devices and Processing

Various topics. (2 units)

ECEN 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 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; reliability, availability, and quality of power delivery; efficiency, minimization of power loss; sustainability, and integration of low carbon energy sources. Prerequisite: ECEN 100 or equivalent. (2 units)

ECEN 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 281A. (2 units)

ECEN 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 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 282 or equivalent. (2 units)

ECEN 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 284L. Solar Cell Technologies and Simulation Tools Laboratory

Co-requisite: ECEN 284. (1 unit)

ECEN 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. Prerequisite: ECEN 50 or equivalent. (2 units)

ECEN 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 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. (2 units)

ECEN 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 282. (2 units)

ECEN 289. Topics in Energy Systems

Various topics (2 units)

ECEN 296. Independent Study

Supervised study of specialized and/or advanced topics not covered by current course offerings. By arrangement. (1-6 units)

ECEN 297. Master’s Thesis Research

By arrangement. Limited to department majors only (1–9 units). A grade of “N” is assigned each quarter until the thesis is submitted. Upon thesis submission, all “N” grades are changed to a letter grade, signifying completion of the thesis research. Prerequisite: ECEN 299 (6 units)

ECEN 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 299. Directed Research

Supervised research not requiring a thesis. Limited to department majors only. By arrangement. (1–6 units)

ECEN 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 236. (2 units)

ECEN 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 238 or equivalent. (2 units)

ECEN 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 331L. Autonomous Driving Systems Lab

Lab for Autonomous Driving Systems, ECEN 331. (1 unit)

ECEN 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 230 or 236. (2 units)

ECEN 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 233 or ECEN 233E. (2 units)

ECEN 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 235. (2 units)

ECEN 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 243, or ECEN 335. (2 units)

ECEN 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 337L. Introduction to Robot Operating System (ROS)

Laboratory for Robot Programming using Python and Robot Operating System (ROS). Also listed as ECEN 131L. Prerequisite: Basic Programming (1 unit)

ECEN 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 236 and 337. (2 units)

ECEN 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 338. (2 units)

ECEN 345. Phase-Locked Loops

Basic loop. Components. Describing equations. Stability. Transients. Modulation and demodulation. Prerequisite: ECEN 130. (2 units)

ECEN 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 243. (2 units)

ECEN 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 226 and 247. (2 units)

ECEN 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 252 and 387. (2 units)

ECEN 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 252 and 387. (2 units)

ECEN 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 230 and ECEN 252 or 116. (2 units)

ECEN 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 351. (2 units)

ECEN 359. Advanced Topics in Circuit Design

Various topics. (2 units)

ECEN 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/GREN 260 and ECEN 261. (2 units)

ECEN 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 265 or ECEN 267. (2 units)

ECEN 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 265 or ECEN 267. (2 units)

ECEN 379. Topics in Micro/Nanoelectronics

Various Topics. (2 units)

ECEN 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 183 or ECEN 281A and ECEN 281B. (2 units)

ECEN 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 203. Prerequisite: CSEN/ECEN 127 or equivalent. (2 units)

ECEN 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 CSEN 204. Prerequisite: CSEN 203/ECEN 387 or equivalent, or ECEN 153. (2 units)

ECEN 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 305. Prerequisite: CSEN 204/ECEN 388 or equivalent. (2 units)

ECEN 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 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 274. (2 units)

ECEN 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 348. Prerequisite: ECEN 233 and/or 334 or equivalent. (2 units)

ECEN 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 349. Prerequisite: ECEN 421. (2 units)

ECEN 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 233 or knowledge of basic digital signal processing concepts. (2 units)

ECEN 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 233 and ECEN 334 or AMTH 362 or knowledge of random processes. (2 units)

ECEN 431E. Adaptive Signal Processing I and II

Same description as ECEN 431 and ECEN 432. Prerequisite: ECEN 334 or AMTH 362 or knowledge of random processes. (4 units)

ECEN 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 431. (2 units)

ECEN 439. Topics in Adaptive Signal Processing

Various topics. (2 units)

ECEN 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 243 or equivalent. (2 units)

ECEN 444. Error-Correcting Codes

Fundamentals of linear codes, block coding principles, convolutional codes, and modern coding techniques such as turbo codes and LDPC codes. Prerequisite: AMTH 211 or equivalent. (2 units)

ECEN 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 241 or its equivalent. (2 units)

ECEN 446E Wireless Communications and Networking

This course combines the topics found in ECEN 446 and ECEN 447 into one 4-unit course. (4 units)

ECEN 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 446 or equivalent. (2 units)

ECEN 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 100. (3 units)

ECEN 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 460 or MECH 207, and MECH 217. (3 units)

ECEN 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 461. (2 units)

ECEN 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 200. Prerequisite: ECEN 127C or equivalent. (2 units)

ECEN 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 501L. (2 units)

ECEN 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 501. (1 unit)

ECEN 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 501 or equivalent. (2 units)

ECEN 503. Hardware-Software Codesign

The design, analysis, and verification of mixed hardware-software systems focusing on model of computations, the design of hardware-software interfaces, hardware/software partitioning, hardware-software co-simulation, and transaction level modeling. Practical design examples such as optimizing hardware-software partitioning through integer linear programming (ILP) or genetic algorithms (GA), and platform-based design are covered. Prerequisite: A grade of C- or better in ECEN 502 or equivalent. (2 units)

ECEN 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 or ECEN 21, or equivalent. (2 units)

ECEN 511. Advanced Computer Architecture

Advanced architectural concepts built upon fundamentals. Superscalar and out-of-order execution for instruction-level parallelism and advanced branch prediction techniques. Vector architecture and Single Instruction Multiple Data (SIMD) extensions for data-level parallelism. Prerequisite: ECEN 122 or CSEN 122 or ECEN 510 or equivalent. (2 units)

ECEN 512. Advanced Computer Architecture II

Continuation of advanced architectural concepts. Memory system implementation concepts. Multiprocessing, including multi-core and multithreaded architectures. Shared memory and cache coherence. More on cache coherence protocols. Multi-level cache hierarchies. Memory consistency and synchronization. GPU architectures and Domain-Specific Architectures such as TPU. Prerequisite: ECEN 511 or equivalent. (2 units)

ECEN 513. Parallel System Architectures

Exploration of alternative computing architectures and their uses. SIMD computing. GPUs. Deep Learning accelerators. Warehouse-scale computing. Prerequisite: ECEN 511 or equivalent. (2 units)

ECEN 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 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 520L. (2 units)

ECEN 520L. Introduction to Machine Learning Laboratory

Laboratory component of ECEN 520. Co-requisite: ECEN 520. (1 unit)

ECEN 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 520. Co-requisite: ECEN 521L. (2 units)

ECEN 521L. Deep Learning Laboratory

Laboratory component of ECEN 521. Co-requisite: ECEN 521. (1 unit)

ECEN 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 521. (3 units)

ECEN 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 521. (2 units)

ECEN 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 127 OR ECEN 603 with a grade of C- or better. (2 units)

ECEN 532. Design of Assistive Technologies

Accessible and Interactive Design. Design of Assistive Technologies. Prototype Development. Data Gathering. Data Analysis, Interpretation, and Representation. Project-based course. Also listed as ECEN 132. (2 units)

ECEN 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 387. (2 units)

ECEN 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 500. (2 units)

ECEN 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. Switch-level modeling. Multiple model cross-validation. Simulation and synthesis of systems. Prior HDL experience is expected. Also listed as CSEN 303. Prerequisite: ECEN 127 or equivalent. (2 units)

ECEN 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 308. Prerequisite: ECEN 500 or equivalent. (2 units)

ECEN 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 500 or CSEN 200 and ECEN 387 or CSEN 203. (2 units)

ECEN 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 CSEN 207. Prerequisites: ECEN 500 or CSEN 200 and ECEN 603 or equivalent. (2 units)

ECEN 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 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 501, ECEN 511, ECEN 603. (1-6 units)

ECEN 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 201. (2 units)

ECEN 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 339. Prerequisites: AMTH 245 and CSEN 279 or equivalent. (2 units)

ECEN 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 340. Prerequisite: ECEN 233 or equivalent. (2 units)

ECEN 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 338. Prerequisites: AMTH 108, AMTH 245, basic knowledge of algorithms. (4 units)

ECEN 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 233 or AMTH 358 or equivalent. (2 units)

ECEN 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 343. Prerequisite: CSEN 340. (2 units)

ECEN 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 344. Prerequisites: ECEN 640 and knowledge of linear algebra. (2 units)

ECEN 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 345. Prerequisites: ECEN 640 and knowledge of probability. (2 units)

ECEN 649. Topics in Image Processing and Analysis

Various topics. (2 units)

ECEN 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 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 201. (4 units)

ECEN 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 706. (2 units)

ECEN 712. Active Microwave Devices II

Continuation of ECEN 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 711. (2 units)

ECEN 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 201. (2 units)

ECEN 715E. Antenna Theory and Design

This course combines the topics found in ECEN (715 and ECEN 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. (4 units)

ECEN 716. Antennas II

Continuation of ECEN 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 715. (2 units)

ECEN 717. Antennas III

Continuation of ECEN 716. Reflector, and lens antennas. Large antenna design. High-frequency techniques. Geometrical optics. Physical optics. Diffraction. Antenna synthesis. Offered in alternate years. Prerequisite: ECEN 716. (2 units)

ECEN 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 201 or equivalent. (4 units)

ECEN 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 711. (3 units)

ECEN 729. Topics in Electromagnetics and Optics

Selected advanced topics in electromagnetic field theory. Prerequisite: As specified in class schedule. (2 units)

ECEN 809. Special Topics in Human-Machine Interaction

Selected advanced topics in Human-Machine Interaction. Prerequisite: As specified in class schedule. (2-4 units)

ECEN 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 921C. (2 units)

Chapter 12: Department of Engineering Management and Leadership

Dean's Executive Professor: Paul Semenza (Department Chair)
Quarterly Lecturers: Michele Ellie Ahi, Octave Baker, Marlene Cole, Ray Combs, Theresa Conefrey, Don Danielson, John Giddings, Pravin Jain, 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
- Project, Program, and Product Management (at least 4 units): select from EMGT 284, 288, 296, 307, 308, 333, 335, 338, 339, 345, or 378
- Operations/Innovation Management (at least 4 units): select from EMGT 249, 253, 254, 287, 289, 292, 311, 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

Graduate Core (minimum 4 units) - One course each from the following areas:

- Engineering and Society

- Professional Development

Technical STEM Courses

Engineering Management and Leadership students are required to create a focused, coherent program of studies within the field of engineering. The following lists 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: Design and Manufacturing; Dynamics and Controls; Mechanics and Materials; Mechatronic Systems Engineering; Thermofluids and Energy
- 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: ELEN 235)

- Mathematical Finance option: substitute AMTH 367 for 2 of the above
- Network option: substitute ELEN 211 and/or 330 for 1 or 2 of the above

- Machine Learning: AMTH 245, 246, 370, 371; 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/GREN 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 that overlap 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 200; CSEN 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 269, 287,288; ELEN 217; all ENGR/GREN 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, for example, special topics courses. 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 for domestic students, international students with an F-1 Visa must complete their degree by the date listed on their I-20. In addition to the overall 3.000 GPA graduation requirement, engineering management, and leadership degree candidates must earn a 3.000 GPA in those courses applied to their technical stem and a 3.000 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 the 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 B.S./M.S 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. 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, and 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, and computer-integrated manufacturing. TQM, statistical process control, Lean, Just-in-Time, simulation, and supply-chain and inventory management. (2 units)

EMGT 254. Usability Engineering

This course introduces the principles and practices of usability engineering, focusing on designing, evaluating, and implementing user interfaces and systems to be efficient, effective, and satisfying. Emphasis is placed on the integration of usability principles in technology and AI-driven systems. Topics include human factors and ergonomics, usability metrics and testing, user research techniques, heuristic evaluation, designing for accessibility, interaction design for AI systems, prototyping, and iterative design. (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 284. Product Management

This course provides a structured overview of Product Strategy and Go-to-Market principles, functions, and techniques enabling students to understand and work as Product Management leaders now and throughout their careers. Topics cover Business-to-Business, Business-to-Consumer, hardware, software, and service environments. During the course, students will define a product using real-world methods to create a product strategy proposal. (2 units)

EMGT 287. Applications of Artificial Intelligence in Manufacturing Systems

This course explores the application of artificial intelligence in the manufacturing ecosystem, focusing on optimizing production processes through AI technologies. Participants will learn how to predict production rates, analyze machinery performance, and plan preventive maintenance using data-driven AI methods. The syllabus covers essential AI tools and frameworks, including Python, TensorFlow, and Keras, along with foundational topics like machine learning concepts, neural networks, and deep learning techniques. Also listed as ENGR 187. Prerequisite: AMTH 108 or equivalent; familiarity with Python programming and machine learning using Python. (4 units)

EMGT 288. Risk and Reliability Engineering

This course introduces and explores the practical concepts and techniques used in reliability and risk studies and the discussion of their use. We will focus on building probabilistic risk assessment models to evaluate and quantify risk engineering and management systems. We will examine different models to help quantify risks and explore how to solve these models both analytically and through simulation.

Because many risk problems involve societal and human behavioral issues, the course will also explore how humans naturally perceive risk, communicating risk issues to a non-technical public, and accounting for intelligent adversaries. Also listed as ENGR 182. Prerequisite: AMTH 108 or equivalent. (2 units)

EMGT 289. Fundamentals of Statistical Quality Engineering

This course focuses on the definition and applications of Six-Sigma quality systems for design production, engineering applications, and business processes. The main topics include statistical methods in quality control and assurance, implementation strategies, practical engineering applications for achieving continuous quality improvement, defect reduction, and quality-related project planning and management methods to achieve universal participation in process improvement. Also listed as ENGR 183. Prerequisite: AMTH 108 or equivalent. (4 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, and 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 are 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; microservices 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 311. Data Science in Systems Management

This course will focus on applications of data science in systems management through descriptive, predictive, and prescriptive analyses used for pattern recognition, system improvement, and optimization. Data mining techniques, decision tree modeling, regression and classification analysis, and big data management for informed decision-making in industrial and business systems management will be discussed. A variety of case studies in selected research, industries, and business settings will be modeled and analyzed using Python. Also listed as ENGR 184. Prerequisite: AMTH 108 or equivalent; familiarity with Python programming. (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

Building on EMGT 338, this course covers 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 startup. Prerequisite: EMGT 338. (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 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 the 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. Also listed as BIOE 357 (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 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, definitions 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 13: Department of Mechanical Engineering

Professor Emeritus: Terry E. Shoup
Associate Professor Emeritus: Timothy K. Hight
Professors: Christopher Kitts, M. Godfrey Mungal
Associate Professors: Mohammad Ayoubi, Drazen Fabris, On Shun Pak, Panthea Sepehrband, Michael Taylor (Department Chair)
Assistant Professors: Michael Abbott, Jun Wang, Xiaoou Yang
Lecturers: Sina Heydari, Robert Marks, Sthanu Mahadev, Michael Neumann, 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's, engineer, and doctorate levels, as well as certificates.

Master of Science Programs

An M.S. degree requires a minimum of 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: Please refer to Chapter 6 for the core list. Students must take one course (2 units) from each of these two areas:

- Engineering and Society
- Professional Development

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. Michael Abbott, Dr. Sthanu Mahadev, Dr. Panthea Sepehrband, Dr. Jun Wang, Dr. Peter Woytowitz, Dr. Xiaoou Yang

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 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. 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. Michael Abbott, 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 Management (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. 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 239 Solid State Power Generation and Energy Harvesting (4 units)
- MECH 241 Approximation and Design of Heat Transfer System (4 units)
- MECH 266 Viscous Flow & Advanced Fluid Mechanics (4 units)
- MECH 377 Continuum Mechanics (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

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/ECEN 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 Chapters 2 and 3 for details on admission and general degree requirements. The following departmental information augments the general School requirements.

Doctoral 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 Chapter 2. 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 of 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 3.000 and a grade 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 microstructural 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 goal of the various projects in the lab is to reduce our reliance on fossil fuels for a sustainable future. The Lab is also interested in making an impact on people in emerging markets, by providing sustainable and economically viable energy/water solutions: portable refrigerators 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 in 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 the measurement of emitted power by radiation. The training systems for heat exchangers and refrigeration systems 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.

Courses Descriptions

An up-to-date listing of undergraduate courses offered by the Department may be found in the Undergraduate Bulletin.

Graduate Courses

MECH 200. Advanced Engineering Mathematics I

Method of solution of the first, second, and higher order differential equations (ODEs). Integral transforms include Laplace transforms, Fourier series and Fourier transforms. Also listed as 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. Also listed as 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, and electro-mechanical actuators. Application to the development of simple devices. Also listed as ECEN 460. Prerequisite: MECH 141 or ECEN 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 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 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. 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, 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, and 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. Concepts 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. Also listed as MECH151. 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 the 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 123 or MECH 266. (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 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 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. May be repeated up to 6 units. (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. (1–6 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 are 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 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 the 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 to experimental methods in materials science with a 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 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 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 337. Prerequisites: Undergraduate in linear algebra or strong familiarity with matrix mathematics or Instructor Permission. (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 338. Prerequisite: MECH 337 and an Undergraduate course in linear control systems or Instructor Permission. (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, and current research in robotic manipulation. Also listed as ELEN 339. Prerequisite: MECH 338. (2 units)

MECH 345. Instrumentation and Design of Experiments

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. (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/GREN 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/GREN 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 238. Prerequisite: MECH 323 or ECEN 236. (2 units)

MECH 423. Nonlinear Control Systems I

Introduction to nonlinear phenomena, planar or second-order systems: qualitative behavior of linear systems, linearization, Lyapunov stability theory, LaSalle’s invariance principle, small gain theorem, and input-to-state stability. Prerequisite: MECH 323 or equivalent. (2 units)

MECH 424. Nonlinear Control Systems II

Continuation of MECH 423. 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, controllability and observability of nonlinear systems, model reference and self-tuning adaptive control. (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 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, and 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 14: 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 3.000 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 Studies Office by the end of their first quarter at SCU.

Required Courses

Foundational Courses

- ECEN 280/MECH 287 Introduction to Alternative Energy Systems (2 units)
- ECEN 281A Power Systems: Generation and Transmission (2 units)
- ECEN 281B Power Systems: Distribution (2 units)
- ECEN 281E Power Systems (4 units)
- ECEN 285 Introduction to the Smart Grid (2 units)

Graduate Core Courses

- ENGR/GREN 272 Energy Public Policy (2 units)
- ENGR/GREN 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 231 Power System Stability and Control (4 units)
- ECEN 287 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 231 Power System Stability and Control (4 units)
- ECEN 287 Energy Storage Systems (2 units)
- ECEN 288 Energy Management Systems or ECEN 236 Linear Control Systems (2 units)
- ECEN 353 DC to DC Power Conversion (2 units)

Computer Engineering

- CSEN 281- Pattern Recognition and Data Mining or CSEN 240 Machine Learning (4 units)
- CSEN 243 Internet of Things (4 units)
- CSEN 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, and 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 careers 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 3.000. 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

All 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 3.500 or better.

Required Courses (16 units total)

Power Systems

- ECEN 280/MECH 287 Introduction to Alternative Energy Systems (2 units)
- ECEN 281A Power Systems: Generation and Transmission (2 units)
- ECEN 281B Power Systems: Distribution (2 units)
- ECEN 281E Power Systems (4 units)
- ECEN 285 Introduction to the Smart Grid (2 units)

Renewable Energy

- ECEN 284 Solar Cell Technologies and Simulation Tools (2 units) or
- ECEN 380 Economics of Energy (2 units)
- ECEN 286/MECH 286 Introduction to Wind Energy Engineering (2 units)
- ECEN 287 Storage Device Systems (2 units)
- ENGR/GREN 272 Energy Public Policy (2 units)

Chapter 15: 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 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:

Graduate Core (Refer to Chapter 6)

Graduate Core: one course each from Engineering and Society and one course from Professional Development minimum of 4 units)

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 460 / MECH 207 Advanced Mechatronics I (3)
- ECEN 461 / MECH 208 Advanced Mechatronics II (3)
- ECEN 337 / MECH 337 Robotics I (2)
- ECEN (338 / MECH 338 Robotics II (2)
- 3 or 4 units of course content in advanced sensing/perception, which may be satisfied by either:
  (1} CSEN 240 Machine Learning (4), or
  (2) CSEN 340 / ECEN 640 Digital Image Processing I (2) and CSEN 341 / ECEN 643 Digital Image Processing II (2)
  (3) 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 279 Design and Analysis of Algorithms (4)
- BIOE 252 Computational Neuroscience (2)
- BIOE 277 Biosensors (2)
- BIOE 281 Introduction to Pattern Recognition (2)
- CSEN 201/ECEN 233 Digital Signal Processing I (2) & CSEN 202/ECEN 234 Digital Signal Processing II (2) [or CSEN 201E /ECEN 233E Digital Signal Processing I & II (4)]
- CSEN 240 Machine Learning (4)
- CSEN 242 Big Data (4)
- CSEN 243 Internet of Things (4)
- CSEN 266 Artificial Intelligence (4)
- CSEN 277 User Experience Research & Design (2)
- CSEN 281 Pattern Recognition and Data Mining (4)
- CSEN 317 Distributed Systems (4)
- CSEN 319 Parallel Programming (4)
- CSEN 340/ECEN 640 Digital Image Processing I (2) & CSEN 341/ECEN 643 Digital Image Processing II (2)
- CSEN 342 Deep Learning
- CSEN 344 /ECEN 644 Computer Vision I (2) & CSEN 345 / ECEN 645 Computer Vision II (2)
- CSEN 376 Expert Systems (4)
- ECEN 235 Estimation (2)
- ECEN 236 Linear Control Systems (2)
- ECEN 237 Optimal Control (2)
- ECEN 238 / MECH 420 Model Predictive Control (2)
- ECEN 239 Introduction to Self-Driving Car Technology (4)
- ECEN 271 Microsensors (2)
- ECEN 329 / MECH 329 Introduction to Intelligent Control (2)
- ECEN 331(L) Autonomous Driving Systems (and Lab)
- ECEN 333 Digital Control Systems (2)
- ECEN 335 Estimation II (2)
- ECEN 501 Embedded Systems (2)
- ECEN 501L Embedded Systems Lab (1)
- ECEN 502 Real-Time Systems (2)
- ECEN (503 Hardware-Software Codesign (2)
- ECEN 520 Introduction to Machine Learning (2)
- ECEN 520L 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 website 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 on some topics. Management of these competency badges is managed through an online design portfolio system available to all students.

Chapter 16: Graduate Minor in Science, Technology and Society (STS)

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 at 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 that 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/GREN 261 Nanotechnology and Society
- ENGR/GREN 272 Energy Public Policy
- ENGR/GREN 302 Managing in the Multicultural Environment
- ENGR/GREN 303 Gender and Engineering
- ENGR/GREN 304 Building Global Teams
- ENGR/GREN 336 Engineering for the Developing World
- ENGR/GREN 337 Social Entrepreneurship
- ENGR/GREN 342 3D Print Technology and Society

Engineering, Ethics and Spirituality

- CSEN 288 Software Ethics
- ECEN 217 Chaos Theory, Metamathematics and the Limits of Knowledge: A Scientific Perspective on Religion
- ENGR/GREN 344 Artificial Intelligence and Ethics

Sustainability and Engineering

- ECEN 280/MECH 287 Introduction to Alternative Energy Systems
- ECEN 288/CSEN 282 Energy Management Systems
- ENGR/GREN 272 Energy Public Policy

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 Studies 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.

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. Financial aid comes into effect once a student completes 46 units of coursework, 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 17: Certificate Programs

General Information

Certificate programs are designed to provide an 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 3.000 in order to receive the certificate.

Program Requirements

The Certificate in Frugal Innovation entails a minimum of 16 units of coursework. 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/GREN 336 Engineering for the Developing World (2 units)
- ENGR/GREN 338 Mobile Applications and Instrumentation for Emerging Markets (2 units)
- ENGR/GREN 340 Distributed and Renewable Energy for the Developing World (2 units)
- ENGR/GREN 341 Innovation, Design and Spirituality

Elective Group A (4 units)

- ENGR/GREN 304 Building Global Teams (2 units)
- ENGR/GREN 342 3D Print Technology and Society (2 units)
- ENGR 349 Ethical Decision Making for Technology Leaders (2 units)

Elective Group B (4 units)

- CENG 219 Designing for Sustainable Construction (4 units)
- CSEN 389 Energy Efficient Computing (2 units)
- ECEN 280/MECH 287 Introduction to Alternative Energy Systems (2 units)
- ECEN 288/CSEN 282 Energy Management Systems (2 units)
- ENGR/GREN 302 Managing in the Multicultural Environment (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 careers 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 3.000. 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 280/MECH 287 Renewable Energy (2 units)
- ECEN 281A Power Systems: Generation and Transmission (2 units)
- ECEN 281B Power Systems Distribution (2 units) or ECEN 281E (4 units)
- ECEN 285 Introduction to the Smart Grid (2 units)

Renewable Energy (8 units)

- ECEN 284 Solar Cell Technologies and Simulation Tools (2 units) or ECEN 380 Economics of Energy (2 units)
- ECEN/MECH 286 Introduction to Wind Energy Engineering (2 units)
- ECEN 287 Storage Device Systems (2 units)
- ENGR/GREN 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 (7 units)

- ECEN 501/501L (Embedded Systems) 3 units
- ECEN 511 Advanced Computer Architecture (2 units)
- ECEN 603 Logic Design Using HDL (2 units)

Elective Courses (9 units)

- ECEN 387 VLSI Design I (2 units)
- ECEN 388 VLSI Design II (2 units)
- ECEN 500 Logic Analysis and Synthesis (2 units)
- ECEN 502 Real Time Systems (2 units)
- ECEN 503 Hardware-Software Co-design (2 units)
- ECEN 512 Advanced Computer Architecture II (2 units)
- ECEN 513 Parallel System Architectures (2 units)
- ECEN 530 Hardware Security and Trust (2 units)
- ECEN 601 Low Power Designs of VLSI Circuits and Systems (2 units)
- ECEN 608 Design for Testability (2 units)
- ECEN 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 252 Analog Integrated Circuits I (2 units)
- ECEN 261 Fundamentals of Semiconductor Physics (2 units)
- ECEN 270 Introduction to IC Materials (2 units)
- ECEN 387 VLSI Design I (2 units)

Elective Courses (8 units)

- ECEN 251 Transistor Models for IC Design (2 units)
- ECEN 253 Analog Integrated Circuit Design (2 units)
- ECEN 254 Advanced Analog Integrated Circuit Design
- ECEN 264 Semiconductor Device Theory I (2 units)
- ECEN 265 Semiconductor Device Theory II (2 units)
- ECEN 267 Device Electronics for IC Design (4 units)
- ECEN 271 Microsensors: Components and Systems (2 Units)
- ECEN 274 Integrated Circuit Fabrication Processes I (2 units)
- ECEN 275 Integrated Circuit Fabrication Processes II (2 units)
- ECEN 351 RF Integrated Circuit Design (2 units)
- ECEN 352 Mixed Signal IC Design for Data Communications (2 units)
- ECEN 353 DC to DC Power Conversion (2 units)
- ECEN 361 Nanoelectronics
- ECEN 388 VLSI Design II (2 units)

Digital Signal Processing and Machine Learning

Advisors: Dr. Maria Kyrarini, 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 online courses.

Required Courses (11 units minimum)

- ECEN 233 Digital Signal Processing I (2 units)
- ECEN 520 and ECEN 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 223 Digital Signal Processing System Development (4 units) or ECEN 226 Machine Learning and Signal Processing Using FPGAs (2 units) or ECEN 234 Digital Signal Processing II (2 units)
- At least one course from: ECEN 421 Speech Processing I or ECEN 640 Digital Image Processing I (2 units) or both ECEN 521 Deep Learning (2 units) and 521L Deep Learning Laboratory (1 unit)
- Note: ECEN 233E Digital Signal Processing I, II (4 units) is equivalent to both ECEN 233 and ECEN 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:

- ECEN 243 Digital Communications Systems (2 units)
- ECEN 244 Information Theory (2 units)
- ECEN 334 Introduction to Statistical Signal Processing (2 units)
- ECEN 422 Speech Coding II (2 units)
- ECEN 431 Adaptive Signal Processing I (2 units)
- ECEN 522 Reinforcement Learning (2 units)
- ECEN 523 Natural Language Processing with Deep Learning (2 units)
- ECEN 643 Digital Image Processing II (2 units)
- ECEN 644 Computer Vision I (2 units) or ECEN 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 the 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 233E or ECEN 233 and 234 Digital Signal Processing I, II (4 units)
- ECEN 334 Introduction to Statistical Signal Processing (2 units)

Elective Courses (8 units)

- ECEN 223 Digital Signal Processing System Development (4 units)
- ECEN 226 Machine Learning and Signal Processing Using FPGAs (2 units)
- ECEN 235 Estimation I (2 units)
- ECEN 241 Introduction to Communications (2 units)
- ECEN 244 Information Theory (2 units)
- ECEN 336 Detection (2 units)
- ECEN 431 Adaptive Signal Processing I (2 units)
- ECEN 640 Digital Image Processing I (2 units)
- ECEN 641 Image and Video Compression (2 units)
- ECEN 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 21 Introduction to Logic Design (4 units)
- ECEN 50 Electric Circuits I (4 units)
- ECEN 100 Electric Circuits II (4 units)
- ECEN 104 Electromagnetics I (4 units)
- ECEN 110 Linear Systems (4 units) or ECEN 210 (2 units)
- ECEN 115 Electronic Circuits I (4 units) or ECEN 250 (2 units)
- ECEN 120 Microprocessor System Design (4 units)

RF and Applied Electromagnetics

Advisor: Dr. Kurt Schab

The purpose of this certificate is to meet the increasing need for knowledge in microwave, antenna, and RF integrated circuits in existing electronic products. This program is offered to 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 201 Electromagnetic Field Theory I (2 units)
- ECEN 701 Microwave System Architecture (2 units)

Elective Courses (12 units)

- ECEN 202 Computational Electromagnetics (2 units)
- ECEN 203 Bio-Electromagnetics (2 units)
- ECEN 204 Magnetic Circuits for Electric and Autonomous Vehicles (2 units)
- ECEN 351 RF Integrated Circuit Design or ECEN 354 Advanced RFIC Design (2 units each)
- ECEN 624 Signal Integrity in IC and PCB Systems (2 units)
- ECEN 706 Microwave Circuit Analysis and Design (2 units) (Passive Component)
- ECEN 711 Active Microwave Devices I or ECEN 712 Active Microwave Devices II (2 units each) (Active Components)
- ECEN 715 Antennas I or ECEN 716 Antennas II (2 units each)
- ECEN 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. Michael Taylor

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 to 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 3.00 and a grade 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 207 Advanced Mechatronics I (3 units)
- MECH/ECEN 337 Robotics I (2 units)
- MECH/ECEN 338 Robotics II (2 units)

Elective Courses (9 units)

- BIOE 277 Biosensors (2 units)
- CSEN 240 Machine Learning (4 units)
- CSEN 266 Artificial Intelligence (4 units)

- CSEN 344 /ECEN 644 Computer Vision I (2 units)
- CSEN 345 /ECEN 645 Computer Vision II (2 units)
- ECEN 331(L) Autonomous Driving Systems (2 units w/optional 1-unit Lab)
- ECEN 520(L) Intro to Machine Learning (2 units w/optional 1-unit Lab)
- MECH 208 / ECEN 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:
  (1) AMTH 245 Linear Algebra I (2 units)
  (2) AMTH 246 Linear Algebra II (2 units)
  (3) AMTH 247 Linear Algebra I & II (4 units)
  (4) AMTH 210 Probability I (2 units)
  (5) AMTH 211 Probability II (2 units)
  (6) AMTH 212 Probability I & II (4 units)
- Up to 2 units of coursework relating to business, societal and/or ethical issues:
  (1) CSEN 288 Software Ethics (2 units)
  (2) EMGT 292 Managing Capital Assets in the Smart Machine Era (2 units)
  (3) ENGR/GREN 342 3D Print Technology and Society (2 units)
  (4) ENGR /GREN 344 Artificial Intelligence and Ethics (2 units)

Substitutions for these courses are possible with the approval of the certificate advisor.

Online Graduate Certificate in Robotics and Automation

Advisor: Dr. Christopher Kitts

This certificate program provides a graduate-level introduction to the theoretical knowledge and 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. This is an online version of the Certificate in Robotics and Automation, intended to support the needs of remote and international students. The Certificate is ideal for professionals wishing to enhance their knowledge of this emerging engineering area as well as for remote students interested in completing the Certificate prior to enrolling in the in-person M.S. Degree in Robotics and Automation. The curriculum consists of 16 units: three required courses (7 units) and 9 units of elective courses listed below. These courses may be taken online or in person. For students who are completely remote, 4 units of coursework will generally be available during each quarter of the academic year, and only a subset of the elective courses listed below may be available:

Required Courses (7 units):

- MECH/ECEN 207 Advanced Mechatronics I (3 units)
- MECH/ECEN 337 Robotics I (2 units)
- MECH/ECEN 338 Robotics II (2 units)

Elective Courses (9 units):

- BIOE 277 Biosensors (2 units)
- CSEN 240 Machine Learning (4 units)
- CSEN 266 Artificial Intelligence (4 units)

- CSEN 344/ECEN 644 Computer Vision I (2 units)
- CSEN 345/ ECEN 645 Computer Vision II (2 units)
- ECEN 331(L) Autonomous Driving Systems (2 units w/optional 1 unit Lab)
- ECEN 520(L) Intro to Machine Learning (2 units w/optional 1 unit Lab)
- MECH 217 Introduction to Control Systems (2 units)
- MECH 208 / Elen 461 Adv Mechatronics II (3 units)
- MECH 323 Modern Control Systems I (2 units)
- MECH 324 Modern Control Systems II (2 units)
- MECH 379 Satellite Operations (1 unit)
- 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:
  (1) AMTH 245 Linear Algebra I (2 units)
  (2) AMTH 246 Linear Algebra II (2 units)
  (3) AMTH 247 Linear Algebra I & II (4 units)
  (4) AMTH 210 Probability I (2 units)
  (5) AMTH 211 Probability II (2 units)
  (6) AMTH 212 Probability I & II (4 units)
- Up to 2 units of coursework relating to business, societal and/or ethical issues:
  (1) CSEN 288 Software Ethics (2 units)
  (2) ENGR/GREN 342 3D Print Technology and Society (2 units)
  (3) ENGR 344/GREN Artificial Intelligence and Ethics (2 units)
  (4) EMGT 292 Managing Capital Assets in the Smart Machine Era (2 units)

Substitutions for these courses are possible with the approval of the certificate advisor.

Chapter 18: 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

The Office of Campus Ministry supports the faith and spirituality of all students at Santa Clara University. Because the University is grounded in the Catholic and Jesuit traditions, we welcome people of all faiths - those seeking a deeper relationship with God through their own faiths, as well as people seeking meaning and connection in their lives. The professional ministry staff members are committed to building a campus community and supporting the full humanity of all people by fostering spirituality, wellness, and belonging. In addition to six full-time campus ministers, the office includes student ministry interns, spirituality facilitators in the residence halls, and desk assistants who foster hospitality. Our stance in Campus Ministry reflects our shared Jesuit that our faith comes alive when we work for justice in the world.

What does Campus Ministry have to offer?

- Worship: During the academic year, we sponsor three Sunday liturgies in the Mission Church, daily noon Mass, and annual Masses celebrating the University's Catholic and Jesuit traditions. Throughout the year, the campus community is invited to participate in Misas en Español, the sacrament of reconciliation, and prayer services across campus to mark holidays both religious and secular across all faith denominations.
- Intercultural Ministry: Campus Ministry staff support a wide variety of cultural identity and faith-based student-led organizations. We also have intercultural celebrations in observance of events such as Día de los Muertos, Simbang Gabi, Las Posadas, la Virgen de Guadalupe, and Lunar New Year, as well as intercultural liturgies for heritage months. In addition, Campus Ministry facilitates and participates in Mosaic events, which are multicultural and multifaith gatherings of students. Mosaic gatherings include monthly dinners, wellness events, campus-wide socials, and sacred space tours.
- Retreats: Santa Clara students are offered a number of retreat experiences over the course of the academic year.
- Spirituality and reflection groups: Campus Ministry organizes Ignatian Life Communities are opportunities for students to explore spiritual practice and identity in small groups of their peers. Other opportunities include Mosaic Dinner Discussions, weekly Breaking Open the Word (reflection on the lectionary readings), and a multifaith meditation group. Individuals and groups seeking support to form reflection groups are encouraged to come to Campus Ministry for assistance.
- LGBTQ+ Ministry: The Office of Campus Ministry models respect and support for students of all identities and orientations through its programming and its hospitality. Specific support includes sponsoring an annual delegation of students to attend IgnatianQ, a conference for LGBTQ+ students from Jesuit universities to "create community, develop spirituality, and build humanity." This conference has inspired the Ignatian Life Community Spiritual Queeries, a small group for queer students who are curious about the mysteries of the universe.

- 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, including, for example, the Muslim Student Association, Students for Life, the Jewish Student Union, College Catholics, and the Sikh Student Association.
- Sacred spaces: Throughout campus, there are spaces for prayer, meditation, and reflection, such as the Mission Church, the Multifaith Sanctuary in St. Joseph's Hall, and the Meditation Room in Benson. All are welcome to find a place of rest in these sacred spaces.

Is Campus Ministry for everyone?

Yes! Student years are a particularly rich time for learning about ourselves and our world and practicing what it means to live our commitments of faith and value more justly in the world. Campus Ministry welcomes all SCU community members to deepen their spiritual practice, faith, and identity, regardless of their tradition or personal stance.

"The real measure of a Jesuit education is who our students become. Tomorrow's 'whole person' cannot be whole without well-educated solidarity…the whole person in solidarity for the real world." - Peter-Hans Kolvenbach, Superior of the Society of Jesuits, speaking at Santa Clara University, October 2000.

Our only focus is to support SCU community members to explore the connection between their commitments and their actions - to practice living faith and values more authentically 'to build a more humane, just, and sustainable world.'

Student Resources and Services

The Cowell Center promotes a holistic approach to students' physical, emotional, psychological, and interpersonal well-being. The Center's counseling and medical staff are available when students believe that their well-being is being compromised in any way. Through Counseling and Psychological Services (CAPS), Student Health Services (SHS), Santa Clara University Emergency Medical Services (SCU EMS), and Student Health Insurance, the Cowell Center has a wealth of health and wellness resources to support students as they navigate the academic rigors at Santa Clara University.

Counseling and Psychological Services

Counseling and Psychological Services (CAPS) is staffed with a diverse 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. The multidisciplinary team is committed to the values of multiculturalism and social justice and is dedicated to providing mental health services that are open to and accepting of every student we serve.

CAPS providers strive to promote, enhance, and support students' emotional and interpersonal well-being through a range of mental health services offered within a safe and confidential environment. In counseling, students work on a wide range of psychosocial and developmental issues such as depression, anxiety, interpersonal problems, disturbed sleep, eating behaviors, identity development, acculturation, academic motivation, homesickness, family concerns, intimacy, and sexuality. CAPS appointments are free of charge. Psychological services are also available 24/7/365. Services include a support line, therapy, and more. Students can call 408-554-5220 at any time to get support.

Student Health Services

Student Health Services (SHS) is staffed with a physicians, nurse practitioners, registered nurses, and medical assistants. A registered dietitian is available on a part-time basis. SHS provides high-quality on-site medical care including diagnosis and treatment of illness and injuries, a limited in-house medication dispensary, and medical referrals to specialists when needed. 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. For further information, see the Cowell Center website. When SHS is closed during the academic year, an advice nurse is available by phone for students at 408-554-4880. A volunteer student emergency medical group, SCU Emergency Medical Services (EMS) is also available after hours for medical emergencies on campus during the academic year. SHS is closed from mid-June to mid-August.

SCU Emergency Medical Services

SCU Emergency Medical Services (EMS) is a student-run organization that is based out of the Cowell Center. These students are known as Emergency Medical Technicians (EMTs) and offer emergency medical services to SCU students from 5 p.m. to 8 a.m. during fall, winter, and spring quarters.

Student Health Insurance

All students are required to maintain health insurance coverage while enrolled at the University. Students will be charged for University health insurance unless they complete an online waiver verifying their own comparable insurance each academic year. Additional information can be found at scu.edu/cowell/insurance.

Chapter 19: Student Conduct Codes

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/

Student Responsibility

Students are personally responsible for knowing all academic and administrative policies and regulations affecting their program of study and for abiding by all such policies and regulations during their period of enrollment at the University. Students are also personally responsible for reading all related messages (email, and other) received from the University and its administrators. Continued enrollment is subject to compliance with the academic and administrative policies and regulations as described herein and otherwise published by the University. Failure to understand the policies and regulations does not relieve a student of the responsibility for adhering to the policies and regulations

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 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, the 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 the withdrawal and may assign an appropriate grade.

University Conduct Process

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 conduct sanction that would range from a letter of warning to expulsion from the University. The severity of the conduct 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 Conduct I Process. The outcome of the hearing will be communicated to those involved.

Patent and Copyright Policies

For information on the University’s Patent and Copyright Policies, see the Intellectual Property website.

Chapter 20: University Policies

Clery Act

Santa Clara University values the safety and well-being of our students, staff, 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 the 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) by emailing titleixadmin@scu.edu or by calling 408-551-3043

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 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 the 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 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.

Notice of Nondiscrimination

Santa Clara University's fundamental principles of academic excellence through diversity and inclusion are central to our Jesuit, Catholic values. These principles and values require us to provide a workplace and educational environment free from discrimination, harassment, and sexual misconduct. In its admission, educational, and employment practices, programs, and activities, the University does not discriminate and prohibits discrimination against any individual based on 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 any other basis prohibited under applicable federal, state, or local laws.

The Director of Equal Opportunity serves as the University's designated Title IX Coordinator and Affirmative Action Officer. The Director coordinates and oversees the prompt response, impartial and thorough investigation, and equitable and timely resolution to all instances of discrimination and harassment, sexual harassment, and other forms of sexual misconduct involving students, faculty, and staff. The Director also tracks incidents and trends involving sexual misconduct involving students, faculty, and staff. The Director also tracks incidents and trends involving sexual misconduct and serves as the principal contact for government and external inquiries regarding civil rights compliance and Title IX.

For more detailed information regarding policies and procedures related to equal opportunity and nondiscrimination, please review the information included in the Santa Clara University Student Handbook (https://www.scu.edu/osl/policies-and-protocols) and on the Office of Equal Opportunity and Title IX website (https://www.scu.edu/title-ix). Inquiries regarding the University's equal opportunity and nondiscrimination policies should contact:

Santa Clara University | Office of Equal Opportunity and Title IX
500 El Camino Real | Santa Clara, CA 95053
Office Location: Loyola Hall (North), Suite 140, 425 El Camino Real, Santa Clara, CA 95053
Main Office: 408-551-3043
Email: titleixadmin@scu.edu
Web: www.scu.edu/title-ix

Claims of discrimination or other inquiries concerning the application of Title IX of the Education Amendments of 1972 and its implementing regulations may also be directed externally to the Office of the Assistant Secretary of Education within the Office for Civil Rights (OCR) (https://www.hhs.gov/ocr/index.html). Inquiries regarding civil rights compliance and employment discrimination may also be made to the Equal Employment Opportunity Commission (EEOC) (https://www.eeoc.gov) and/or the California Department of Fair Employment and Housing (DFEH) (https://www.dfeh.ca.gov)

Title IX of the Education Amendments of 1972

The University does not discriminate in its admissions practices except as permitted by law, in its employment practices, or in its educational programs or activities on the basis of sex or gender.

As a recipient of federal financial assistance for education activities, the University is required by Title IX of the Education Amendments of 1972 to ensure that all of its education programs and activities do not discriminate on the basis of sex or gender. Sex includes sex, sex stereotypes, gender identity, gender expression, sexual orientation, and pregnancy or parenting status. Sexual harassment, sexual assault, dating and domestic violence, and stalking are forms of sex discrimination, which are prohibited under Title IX and by University policy. The University also prohibits retaliation against any person opposing discrimination or participating in any discrimination investigation or complaint process internal or external to the institution.

To review the University's complete policy, as well as more detailed information regarding Title IX-related procedures, please see the Office of Equal Opportunity and Title IX website (https://www.scu.edu/title-ix).

Americans with Disabilities Act / Section 504 of the Rehabilitation Act of 1973

In both practice and policy, Santa Clara University adheres to the requirements of the Americans with Disabilities Act of 1990, as amended 2008 (ADAAA); Sections 504 and 508 of the Rehabilitation Act of 1973, as amended; and all other federal and state laws and regulations prohibiting discrimination on the basis of disability.

The University is committed to providing disabled individuals, including (but not limited to) those with medical, physical, psychological, attention deficit, and learning disabilities, equal access to the academic courses, programs, activities, services, and employment opportunities, and strives in its policies and practices to provide for the full participation of disabled individuals 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). Disabled students who are registered with the OAE office may be qualified to receive accommodations based on supporting documentation. To register with OAE, students should contact the office at 408-554-4109 or by email at oae@scu.edu.

The University's ADA Coordinator facilitates compliance with the Americans with Disabilities Act (ADA) Title II regulations and Section 504 of the Rehabilitation Act of 1973. To contact the ADA Coordinator, please email oae@scu.edu.

Faculty and staff should contact Human Resources to request employee disability-related accommodations, auxiliary aids, and/or services. For more information, please see the Human Resources website (https://www.scu.edu/hr/).

Students, faculty, and staff who have questions or concerns about (1) disagreements or denials regarding requested services, accommodations, or modifications to University practices or requirements; (2) alleged inaccessibility of a University program or activity; (3) alleged harassment or discrimination on the basis of a disability, and (4) any other alleged disability discrimination should contact the Director of Equal Opportunity and Title IX at 408-551-3043 or by email at titleixadmin@scu.edu. For more information related to these policies and procedures on discrimination and harassment, see the Office of Equal Opportunity and Title IX website (https://www.scu.edu/title-ix).

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

Kathryn (Kathy) Chou, Chair

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

Alan Louie
Founder and Angel Investor

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 Emerita
Board Director and Business Consultant
Limited Partner, Mighty Capital

Richard L. Reginato
Chair, Strategic Advisory Board
Momentus

Fariborz (Frankie) Roohparvar
Executive Chairman

Batteroo Corporation

Paul Russell
Chief Executive Officer
Stellant Systems

Alexander S. Shubat
Chief Executive Officer
Espresa

Gordon Stitt
Network Technology Leader,
Former CEO Nebula

Hermant Thapar
Founder and CEO
OmniTier Inc.

Marc van den Berg, Chairman Emeritus
Managing Director
Venture Capital OGCI Climate Investments

Jose Ysaguirre
Senior Manager, Electrical Engineering
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Engineering Faculty

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