2021-22 Graduate Bulletin

Santa Clara University

School of Engineering

Graduate Programs

Engineering with a Mission

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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. Others might be seeking to change the trajectory of your engineering career. Still others might be boldly changing the very field in which you seek to contribute your talents.

We here at Santa Clara University 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 advance not only your technical knowledge and skills, but will also lead you to becoming 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. Silicon Valley pioneers were driven to explore, to innovate, and to improve society through advances in engineering. That 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.

For over 100 years, the School of Engineering at Santa Clara University has helped students turn their dreams to reality. We stand ready in our second 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 and these 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 Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering. In addition, the School of Engineering offers a variety of certificate programs, as well as an Open University program.

SCHOOL OF ENGINEERING MISSION STATEMENT

The mission of Santa Clara University's School of Engineering 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.

2021-2022 Graduate Academic Calendar

FALL QUARTER 2021

Jul 12-16	M-F	Fall 2021 registration period
Jul 19	M	Open enrollment period begins
Aug 21	**Sa**	**Payment deadline for Fall 2021**
Sep 6	M	Labor Day; administrative holiday
Sep 13	**M**	**Late registration; $100 fee if no previous enrollment and Drop/Swap $50 fee begins**
Sep 16	**Th**	**New student orientation (subject to change)**
Sep 20	**M**	**Fall Classes begin**
Sept 24	F	Last day to petition for graduate degrees to be conferred in December (Fall Quarter) 2021
Sep 26	**Su**	**Last day to change registration or withdraw from classes with a 100% tuition refund (less fees) (Clear registration holds by Friday, 9/24 by 4 p.m.)**
Sep 29	W	Mass of the Holy Spirit, 12 p.m. at the Mission Church. Classes will not meet from 11:45-1:15 p.m. Classes scheduled to begin at 1 p.m. will begin instead at 1:15 p.m. **(some classes may meet, consult instructor)**
Oct 3	**Su**	**Last day to withdraw from classes with a 50% tuition refund (less fees)**
Oct 8	F	Last day to submit incomplete Spring 2021 and Summer Session 2021 work to faculty
Oct 10	**Su**	**Last day to withdraw from classes with a 25% tuition refund (less fees)** **No tuition refund after this date**
Oct 15	**F**	**Last day to drop classes without a W**
Oct 15	F	Last day for faculty to remove Spring 2021 and Summer Session 2021 incompletes
Nov 1-5	M-F	Winter 2022 registration period
Nov 5	**F**	**Last day to drop classes with a W**
Nov 8	M	Winter 2022 Open enrollment period begins
Nov 25-	Th-F	Thanksgiving recess; administrative holiday

26	F	
Dec 3	**F**	**Classes end**
Dec 6-10	M-F	Fall final examinations
Dec 15	W	Fall quarter grades due
Dec 21	**T**	**Payment deadline for Winter 2022**
Dec 23-24	Th-F	Christmas recess; administrative holiday
Dec 30-31	Th-F	New Year's recess; administrative holiday

WINTER QUARTER 2022

Nov 1-5	M-F	Winter 2022 registration period
Nov 8	M	Open enrollment period begins
Dec 21	**T**	**Payment deadline for Winter 2022**
Dec 27	**M**	**Late registration; $100 fee if no previous enrollment and Drop/Swap $50 fee begins**
Jan 3	**M**	**Winter Classes begin**
Jan 5	W	New Student Orientation** (subject to change)
Jan 9	**Su**	**Last day to change registration or withdraw from classes with a 100% tuition refund (less fees) (Clear registration holds by Friday 1/7 by 4 p.m.)**
Jan 14	F	Last day to petition for graduate degrees to be conferred in March (Winter quarter) 2022
Jan 16	**Su**	**Last day to withdraw from classes with a 50% tuition refund (less fees)**
Jan 17	M	Martin Luther King Day; administrative holiday **(Consult instructor)**
Jan 21	F	Last day to submit incomplete Fall 2021 work to faculty
Jan 23	**Su**	**Last day to withdraw from classes with a 25% tuition refund (less fees) No tuition refund after this date**
Jan 28	F	Last day for faculty to remove Fall 2021 incompletes
Jan 28	**F**	**Last day to drop classes without a W**
Feb 7-11	M-F	Spring 2022 registration period
Feb 14	M	Spring 2022 Open enrollment appointment begins
Feb 18	**F**	**Last day to drop classes with a W**

Feb 18	F	Last day to petition for graduate degrees to be conferred in June (Spring quarter) 2022
Feb 21	M	Presidents' Day; administrative holiday **(Consult instructor)**
Mar 11	**F**	**Classes end**
Mar 14-18	M-F	Winter final examinations
Mar 21	**M**	**Payment deadline for Spring 2022**
Mar 23	W	Winter quarter grades due

SPRING QUARTER 2022

Feb 7-11	M-F	Spring 2022 registration period
Feb 14	M	Open enrollment period begins
Feb 18	F	Last day to petition for graduate degrees to be conferred in June (Spring quarter) 2022
Mar 21	**M**	**Payment deadline for Spring 2022**
Mar 21	**M**	**Late registration; $100 fee if no previous enrollment and Drop/Swap $50 fee begins**
Mar 28	**M**	**Spring Classes begin**
Mar 30	W	New Student Orientation** (subject to change)
Apr 3	**Su**	**Last day to withdraw from classes with a 100% tuition refund (less fees) or add classes (Clear registration hold by Friday, 4/1 by 4 p.m.)**
Apr 4-8	M-F	Summer 2022 registration period for all three summer sessions
Apr 10	**Su**	**Last day to withdraw from classes with a 50% tuition refund (less fees)**
Apr 11	M	Summer 2022 Open enrollment period begins
Apr 15	F	Good Friday; academic and administrative holiday
Apr 17	**Su**	**Last day to withdraw from classes with a 25% tuition refund (less fees) No tuition refund after this date**
Apr 18	M	Last day to submit incomplete work to faculty for Winter 2022 to faculty
Apr 22	F	Last day for faculty to remove Winter 2022 incompletes
Apr 22	**F**	**Last day to drop classes without a W**
May 13	**F**	**Last day to drop classes with a W**

13	**F**	**Last day to drop classes with a W**
May 21	**Sa**	**Payment deadline for Summer 2022**
May 30	M	Memorial Day; academic and administrative holiday **(Consult instructor)**
Jun 3	**F**	**Classes end**
Jun 6-9	M-Th	Spring final examinations
Jun 10	F	Graduate Commencement
Jun 14	T	Spring quarter grades due

SUMMER SESSIONS 2022

Apr 4-8	M-F	Registration period for all three summer sessions
Apr 11	M	Open enrollment period begins
May 21	**Sa**	**Payment deadline for Summer 2022**
Jun 13	**M**	**Late registration; $100 fee if no previous enrollment and Drop/Swap $50 fee begins**
Jun 20	**M**	**Classes begin for summer sessions I and II**
Jun 24	**F**	**Last day to register for all three summer sessions**
Jul 1	F	Last day to petition for graduate degrees to be conferred in September (Summer Quarter) 2022
Jul 4	M	Independence Day (Observed); administrative holiday; **classes will meet**
Jul 22	**F**	**Last day to withdraw from classes for Session II only (no tuition refund)**
Jul 22	**F**	**Classes end for Session II only**
July 25-26	M-Tu	Summer Session II final examinations
Aug 1	**M**	**Classes begin for Summer Session III**
Aug 26	**F**	**Last day to withdraw from classes for Session I only (no tuition refund)**
Aug 26	**F**	**Classes end for Session I only**
Aug 29-Sep 2	M-F	Summer Session I final examinations
Sep 2	**F**	**Last day to withdraw from classes for Session III only (no tuition refund)**
Sep 2	**F**	**Classes end for Session III only**
Sep 5	M	Labor Day observed; administrative holiday; classes will meet
Sep 5-6	M-Tu	Summer Session III final examinations

Last day to withdraw from classes with 100% tuition refund (less fees) – End of 2nd scheduled class meeting

Last day to withdraw from classes with 50% tuition refund (less fees) – End of 3rd scheduled class meeting

All dates are inclusive and subject to change

Registration holds must be cleared with the appropriate office by 4 p.m. on Friday.

No tuition refunds after the third class meeting

For more information regarding Tuition Refund Policies, please see the Financial Information chapter. For additional information, you may contact onestop@scu.edu

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Chapter 1: Santa Clara University

Located in the heart of California's Silicon Valley, Santa Clara University is a comprehensive Jesuit, Catholic university with more than 8,800 students. Founded in 1851 by the Society of Jesus, California's oldest operating higher education institution offers a rigorous undergraduate curriculum in arts and sciences, business, and engineering, plus nationally recognized graduate and professional programs in business, law, engineering, education, counseling psychology, pastoral ministries, and theology. The University boasts a diverse community of scholars offering a values-oriented curriculum characterized by small class sizes and a dedication to educating students for competence, conscience, and compassion. The traditions of Jesuit education--educating the whole person for a life of service--run deep in all of its curricular and co-curricular programs.

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

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

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

University Vision, Mission And Fundamental Values

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

Strategic Vision

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

University Mission

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

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

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

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

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

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

Fundamental Values

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

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

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

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

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

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

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

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

Academic Programs

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

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

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

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

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

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

Centers of Distinction

Santa Clara University has three Centers of Distinction that serve as major points of interaction between the University and local and global communities. Each center focuses on a theme that is central to Santa Clara’s distinctive mission as a Jesuit university and offers an educational environment integrating rigorous inquiry and scholarship, creative imagination, reflective engagement with society, and a commitment to fashioning a more humane and just world. Each center engages faculty and students from different disciplines as well as experts and leaders from the community through speakers, conferences, workshops, and experiential learning opportunities.

Miller Center for Social Entrepreneurship

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

Ignatian Center for Jesuit Education

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

- The Bannan Forum provides year-long thematic programs, including academic events and scholarly activities that further the Jesuit, Catholic character of the University.
- Arrupe Engagement, a community-based learning program, places over 1,200 students each year with community partners, frequently in connection with an academic course.
- Thriving Neighbors extends the community-based learning experience by engaging teaching, scholarship, and sustainable development that links Santa Clara University with the predominantly Latino Greater Washington community in San Jose, CA.
- The Immersion programs offer students, during academic breaks, the opportunity to experience local, domestic, and international communities with little access to wealth, power, and privilege.
- The Ignatian Worldview program offers experiences grounded in the Spiritual Exercises of St. Ignatius 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 694full-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 100,000alumni living around the world--in all 50 states and more than 100 countries. More than half of the alumni live in the San Francisco Bay Area, where many are leaders in business, law, engineering, academia, and public service. These graduates connect with one another and the current campus community by engaging with over 45 different groups organized around identity, industry, and location.

Campus

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

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

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

Academic Facilities

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

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

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

University Library & Learning Commons

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

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

Schott Admission and Enrollment Services Building

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

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

Sobrato Campus for Discovery and Innovation

This new 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 cafe. The Miller Center for Social Entrepreneurship and the Frugal Innovation Hub will also find their new homes in this new state of the art building. The central landscaped courtyard and rooftop terraces, provide excellent places for gathering, which makes this new building a great addition to the heart of the campus.

Student Life

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

Another hotspot for student life, the Paul L. Locatelli, S.J., Student Activity Center includes a 6,000-square-foot gathering hall with a high ceiling that can accommodate dances and concerts as well as pre- and post-game activities. Designed with environmental sensitivity, the building is energy efficient and has daytime lighting controls and motion sensors to maximize use of natural light. For fitness-minded students, the Pat Malley Fitness and Recreation Center features a 9,500-square-foot weight training and cardiovascular exercise room, three basketball courts, a swimming pool, and other facilities to support the recreational and fitness needs of the campus community.

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

Athletics And The Arts

The importance of athletics to the University is evident everywhere on campus. Among the newest additions to Santa Clara's athletics facilities are the Stephen Schott Stadium, home field for the men's baseball team, and the state-of-the-art Stevens Soccer Training Center, funded by a gift from Mary and Mark Stevens. The gift also allowed Santa Clara to upgrade the stands in Stevens Stadium (formerly Buck Shaw Stadium), home to the men's and women's soccer programs, and build a plaza to celebrate Bronco sports---its past, present, and future. The plaza celebrates the history of Santa Clara University football as well as the legacy and future of men's and women's soccer at SCU. Bellomy Field, 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

More than 700 students attend Santa Clara University's graduate engineering programs each quarter. The School of Engineering offers a large variety of programs to meet the needs of these engineering professionals.

B.S./M.S. Five-year Dual Degree 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 in five years. This is an excellent way to save time and open-up more career possibilities early on. The degree is offered in Aerospace Engineering, Bioengineering, Computer Science 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 in Civil, Environmental, and Sustainable Engineering should consult the CESE department chapter of the graduate bulletin for details.

The application fee and GRE General Test requirement are waived. Automatic admission into the five-year program is based on a minimum GPA of 3.0 in the major. Upon notification of acceptance into the B.S./M.S. program, students may begin taking graduate-level courses in their senior year and a maximum of 20 units can be transferred into the graduate program. Students must meet with a graduate advisor and submit a program of studies with the undergraduate transfer credit listed when they officially start the master's program.

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

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

Certificate Programs

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

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

Certificate programs are offered in frugal innovation, renewable energy, digital system design, integrated circuit design and technology, digital signal processing and machine learning, digital signal processing theory, fundamentals of electrical and computer engineering, RF and applied electromagnetics, controls, dynamics and vibrations, materials engineering, mechanical design analysis, mechatronics systems engineering, and thermofluid,. For more specific information on each certificate, please see Chapter 18.

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

Master Of Science Program

The master's program is designed to extend the technical breadth and depth of an engineer's knowledge. Students in this program complete a program of studies approved by the faculty advisor in the major department. The program must include no less than 46 quarter units, and a 3.0 GPA (B average) must be earned in all coursework taken at Santa Clara. Residence requirements of the University are met by completing 36 quarter units of the graduate program at Santa Clara. MS students have six years to complete their Master's degree. A maximum of 9 quarter units (6 semester units) of graduate-level coursework may be transferred from other accredited institutions that have not been applied to a previous degree at the discretion of the student's advisor. All units applied toward the degree, including those transferred from other institutions, must be earned within a six-year period.

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

The School of Engineering offers Master's programs in 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. The coursework requirements for the degree are determined by each of the major departments. In order to graduate, students must complete the required coursework for the program to which they are admitted and must have a cumulative GPA of 3.0 in all coursework listed on their approved program of study. *In addition to this requirement, Engineering Management and Leadership degree candidates must earn a 3.0 GPA in those courses applied to their technical stem and a 3.0 GPA in their engineering management course stem.*

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

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

Graduate Minor In Science, Technology, And Society (STS)

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

For more comprehensive information, please see Chapter 17.

Engineer's Degree Program

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

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

Doctor Of Philosophy Program

The Doctor of Philosophy (Ph.D.) degree is sought by those engineers who wish to become experts in a specific area within their field. The work for the degree consists of engineering research, the preparation of a thesis based on that research, and a program of advanced studies in engineering, mathematics, and related physical sciences. The student's work is directed by the degree-conferring department, subject to the general supervision of the School of Engineering. The school grants the Ph.D. in computer science and engineering, electrical and computer engineering, and mechanical engineering.

Preliminary Examination

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

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

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

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

Thesis Advisor

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

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

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

Doctoral Committee

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

Residence

The Ph.D. degree is granted on the basis of academic achievement. The student is expected to complete a minimum of 72 units of graduate credit beyond the master's degree with an overall GPA of 3.0 or better. *Please note: Only classes with assigned grades of C- or higher will count toward the completion of the certificates, M.S., or Ph.D. degrees.* Of these, 36 quarter units may be earned through coursework, independent study and directed research, and 36 through the thesis. Deviation from this distribution must be approved by the student's doctoral committee and must not be more than six units. All Ph.D. thesis units are graded on a Pass/No Pass basis. A maximum of 18 quarter units (12 semester units), not previously used for the completion of another degree, may be transferred from any accredited institutions at the discretion of the student's advisor.

Comprehensive Examinations and Admission to Candidacy

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

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

Thesis Research and Defense

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

Thesis and Publication

At least one month before the degree is conferred, the candidate must submit one copy of the final version of the thesis to the department and one copy to the University Library. The thesis will not be considered as accepted until approved by the doctoral committee and one or more refereed articles based on it are accepted for publication in a professional or scientific journal approved by the doctoral committee. The quality of the refereed journal must be satisfied by 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 on satisfying the journal's quality should be obtained from the candidate's advisor, the doctoral committee, the department chair, and the dean's office. This written approval must be kept in the candidate's file.

Time Limit for Completing Degrees

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

Non-Enrollment Period

Ph.D. students are required to enroll in at least one unit for the fall, winter, spring quarters and their final graduating quarter. Those who do not wish to enroll must submit a leave of absence or a withdrawal form to the Engineering Graduate Programs office. A leave of absence form is required if a student plans to miss one or two quarters, while any longer absence requires a withdrawal form. Students who wish to resume their Ph.D. studies after a leave of absence or withdrawal must submit a returning student form. The forms can be found on the graduate engineering website, www.scu.edu/engineering/graduate under current student resources. Leave of absence or withdrawal forms must be submitted by the end of the first week of the quarter. Returning student forms must be submitted three weeks prior to the start of the quarter returning. Please note the request is not guaranteed.

Students are required to complete their degree within eight years from their original admit term date. The eight-year time frame includes quarters during which a student was not enrolled. Those who fail to complete their Ph.D. in eight years can request an extension only under special circumstances. In such cases, the student's advisor will need to discuss the case with the Graduate Program Leadership Council (GPLC), which will determine whether an extension is warranted (and for how long).

Please Note: Students who miss one or more quarters and fail to submit the appropriate form(s) will be discontinued automatically and will have to submit a returning student form or reapply to the Ph.D. program. They will need to follow the same procedure as students who withdrew from the program.

Additional Graduation Requirements

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

The Industrial Track

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

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

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

3. The full-time study component of the residence requirement is waived, but other residence requirements remain the same. Students who opt for this "industrial track" are responsible for meeting all other requirements for the Ph.D. The awarded degree will be the same for all students, regardless of the track that they choose to pursue.

Open University Program

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

If a student from the Open University program is accepted into a degree program, **a maximum of 16 units may apply toward the degree** (if the courses are in the same discipline to which the student is accepted). The general GRE test requirement for admission to the master's degree program will be waived if the student has completed a set of required courses in the department to which they are applying, and has earned a GPA of 3.5 or higher. Open University students who wish to pursue a M.S. degree must submit an online application.

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

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

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

Chapter 3: Admissions

Applications

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

Program **(See Program Details Below)**	**Application Requirements** **(See Application Requirement Details Below)**
BS/MS 5 Year Program **(Current SCU Undergraduate Students)**	• Online Application • Application Fee Waived • GRE Scores Waived
Open University	• Online Application • Nonrefundable Application Fee • Official Transcripts • TOEFL/IELTS/DUOLINGO (If Applicable)
Certificate	• Online Application • Nonrefundable Application Fee • Official Transcripts • TOEFL/IELTS/DUOLINGO (If Applicable)
Master's Degree	• Online Application • Nonrefundable Application Fee • Official Transcripts • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)
Engineer's Degree	• Online Application • Nonrefundable Application Fee • Official Transcripts • 3 Letters Of Recommendation • Statement Of Purpose • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)
Ph.D. Degree	• Online Application • Nonrefundable Application Fee • Official Transcripts • 3 Letters Of Recommendation • Statement Of Purpose • GRE Scores • TOEFL/IELTS/DUOLINGO (If Applicable)

Application Requirement Details

- **ONLINE APPLICATION.**
  - To submit your online application, go to https://slate.scu.edu/apply/. Create an application with your email as the username and create a password. Use this website to view application status and official decisions.
- **NONREFUNDABLE APPLICATION FEE:**
  - A completed online application for admission to engineering graduate programs, including a nonrefundable $90 application fee.
- **OFFICIAL TRANSCRIPTS:**

    - If you attended a university **WITHIN** the United States, one official transcript indicating the degree received and date of conferral must be sent from **EACH** institution. *Please note: we do NOT accept transcripts sent directly from the applicant, transcripts are ONLY ACCEPTED from the University.*
        - The institution can send an official electronic transcript to gradengineer@scu.edu.
    - If you attended a university **OUTSIDE** of the United States, applicants must submit a transcript evaluation report from Educational Credential Evaluators (ECE) or World Education Services (WES). 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 (There is no exception to this requirement). *Please note*: *A copy of your original transcripts will be attached to the report and* ***you do not need to send any additional transcripts.***
- **OFFICIAL GRE SCORES.** Official Graduate Record Examination (GRE) scores must be sent directly to Engineering Graduate Programs by the Educational Testing Service (ETS). Our institution code is 4851. Additionally, students can send a PDF copy of their results to gradengineer@scu.edu. For information on the GRE, please visit the website: www.ets.org/.
- **OFFICIAL TOEFL/IELTS/DUOLINGO SCORES.** For non-U.S. citizens or students who have received a degree from a university outside of the United States international students, we will accept scores from the Test of English as a Foreign Language (TOEFL), the International English Language Testing Systems (IELTS) or Duolingo. Our institution code is 4851. Test scores over three years old will not be accepted. Additionally, students can send a PDF copy of their results to gradengineer@scu.edu. This requirement is waived for those who attended an institution within the U.S.

Program Details

BS/MS 5 Year Program (Current undergraduate SCU students)

- Current undergraduate SCU students need to apply to the B.S./M.S. program at the end of their Junior year. Automatic admission into the five-year program is based on a minimum GPA of 3.0 in the major. Upon notification of acceptance into the B.S./M.S. program, students may begin taking graduate-level courses in their senior year 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 M.S. degree if the courses are in the same discipline to which the student is accepted. The general GRE test requirement for admission to the master's degree program will be waived if the student has completed a set of required courses in the department to which they are applying and has earned a GPA of 3.5 or higher. Open University students who wish to pursue and M.S. degree must submit an online application.

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

Note: Open University students are not eligible to enroll in undergraduate classes.

Certificate Programs

- Depending on the certificate program, students will complete 16-18 units of coursework.

- All certificate units in the discipline may be applied toward a master's degree. Students who wish to pursue a Master's degree must submit a separate online application. The application fee will be waived for currently enrolled certificate students. The general GRE and TOEFL test requirement for graduate admission to the master's degree will be waived for students who complete a certificate with a GPA of 3.5 or higher.

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

Master's Program

- The GRE waiver option is available to applicants for the Engineering Management Program who have two or more years of working experience in the U.S.

Engineer's Degree & Ph.D.

Ph.D. and Engineer's degrees are offered in the Departments of Computer Science and Engineering, Electrical and Computer Engineering, and Mechanical Engineering.

- **3 LETTERS OF RECOMMENDATION.** These letters should attest to the applicant's academic preparation and capability for advanced studies.
- **STATEMENT OF PURPOSE.** A 500-word statement of purpose emphasizing the applicant's research interests and outlining the applicant's professional and academic goals.

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 gradengineer@scu.edu for the deferral form.

Chapter 4: Financial Information

FINANCIAL RESPONSIBILITY

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

FINANCIAL TERMS AND CONDITIONS

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

TUITION AND FEES

Tuition, per quarter unit, for all courses...$1,088

Graduate Design Center and Student Association (AGES) fee...$180

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 $3,054.

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

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

Cowell Center

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

Attention: F-1 and J-1 International Students

F-1 VISA STUDENTS

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

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

J-1 VISA STUDENTS

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

OTHER FEES

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

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

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

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

Tuition Late payment fee...$100

Parking permits (subject to change)

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 via a third-party vendor that are accessible through eCampus. 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 2021 Billing available August 1; payment due August 21

Winter 2022 Billing available December 1; payment due December 21

Spring 2022 Billing available March 1; payment due March 21

Summer 2022 Billing available May 1; payment due May 21

PAYMENT METHODS

Santa Clara University offers a variety of payment methods to students to assist 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 eCampus system or SCU Pay site. Please note that a bank may reject a fund transfer if it exceeds a specific amount. Check with your bank about daily limits to prevent returned payment transactions. Payers are able to make electronic check payments without incurring a transaction fee.

Payment by Mail

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

Payment in Person

Payments for student account charges may be made in person by cash or check only at the OneStop Office in the Admissions & Enrollment Services Building. This office is not able to accept any electronic forms of 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 debit or credit card payments for student account charges.

International Payment by Wire Transfer

International students may submit payment quickly and securely through eCampus. 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.

EXTENDED PAYMENTS OPTIONS

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 are 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 eCampus and selecting the Financial Account Tile. Information about these plans is available on the Bursar's Office website: www.scu.edu/bursar/.

DELINQUENT PAYMENTS

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

BILLING DISPUTES

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

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

REFUND PAYMENTS

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

Fall, Winter, and Spring Quarters

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

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

Summer

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

- By the end of day of the second scheduled class meeting – 100% tuition refund, less any applicable fees
- By the end of day of the third scheduled class meeting – 50% tuition refund, less any applicable fees
- No tuition refund after these days
- Courses taught in an asynchronous manner meet M, W, R for tuition refund purposes.

Saturday/Sunday Courses/Off Cycle Courses

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

The following refund schedule applies:

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

To receive tuition refunds from the Bursar's Office, course drops must be handled administratively. **Students should NOT drop a weekend/off cycle course themselves through eCampus 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 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 medically related withdrawals that occur after the first week of the term.

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

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

TUITION INSURANCE PROTECTION

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

FINANCIAL AID

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

California State Graduate Fellowships

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

Loans

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

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

Deadlines

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

Veterans and Veterans' Dependents Assistance

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

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

Teaching and Research Assistantships

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

University-Awarded Aid

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

Cancellation of Financial Aid and Return of Funds

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

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

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

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

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

Chapter 5: Academic Information

Engineering Honor Code

The Engineering Honor Code is a long-standing Santa Clara tradition; instituted at the request of engineering students, it states: All students taking courses in the School of Engineering agree, individually and collectively, that they will not give or receive unpermitted aid in examinations or other coursework that is to be used by the instructor as the basis of grading. Students and teachers cooperate and share responsibilities under the code. Teachers are responsible for making clear what aid is permissible and for using procedures that minimize temptations to violate the code. Students are responsible for behaving honorably, for actively ensuring that others, as well as themselves, uphold the code, and for being responsive to violations. Alleged violations should be reported to the Office of the Dean.

Classes

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

Standards Of Scholarship

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

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

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

Note 1: Only classes with assigned grades of C- or higher will count toward the completion of the certificates, M.S., or Ph.D. degrees. The grades of all courses completed during the certificate, M.S. or Ph.D. program are used to compile the final grade point average (GPA).

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

Grading System

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

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

Non-graded Courses

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

Incomplete Grades

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

Auditing Courses

A student may take courses with a grading basis of "audit" but needs to keep in mind the following:

- The current graduate tuition rate of $1088.00 per unit + the $180.00 engineering fee will be charged.
- No grade points or credit will be earned so the class cannot be counted toward the completion of a certificate, M.S. or Ph.D.
- A student will need to register for the class, then send an email to the Director of Records requesting that the grading basis be changed to "Audit": lmjocewicz@scu.edu
- The last day to request to audit a course is at the end of the first week of the quarter.

Alumni students can request to audit a course with a reduced tuition fee. Alumni students will need to apply to the Open University program to enroll in classes as an audit. Please contact the Director of Records for the alumni audit form; lmjocewicz@scu.edu

Repeating Courses

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

Withdrawal From Courses

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

Program Of Studies

During the first quarter of enrollment, a student in the M.S. degree program is required to meet with a faculty advisor to complete a Program of Studies (POS) form. The program of studies can be found on our graduate engineering website under current student resources. www.scu.edu/engineering/graduate. Here are assigned advisors for the following departments

- Aerospace Engineering-Mohammad Ayoubi and Chris Kitts (Program Advisors)
- Applied Math-Stephen Chiappari (Department Chair)
- Bioengineering-Please contact the department for available advisors.
- Civil Engineering-Please contact the department for available advisors.
- Computer Science and Engineering- The CSE department will email your advisor information by the end of the first week of the quarter.
- Electrical and Computer Engineering-Please contact the department for available advisors.
- Engineering Management and Leadership-Paul Semenza (Department Chair)
- Mechanical Engineering-Please contact the department for available advisors.
- Power Systems and Sustainable Energy-Maryam Khanabaghi (Program Advisor)
- Robotics and Automation-Christopher Kitts (Program Advisor)

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

Please Note: Extension, online and continuing education units are not accepted for transfer credit.

Courses Transferred From Santa Clara University

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

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

Courses Transferred From Other Institutions

All M.S. students have the option to transfer a maximum of 6 semester or 9 quarter units of graduate level coursework from an accredited institution into their degree program with their advisor's approval. 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. Please keep the following in mind when transferring units:

- Only those courses completed with a C grade or higher will be eligible for transfer.
- Extension, continuing education, and online courses may not be transferred.
- The units will not transfer if they have been used for another degree.
- Only the credit will transfer, but not grades; so the overall grade point average will be based on coursework completed at Santa Clara University only.
- An official transcript and course syllabus is required for verification of the units by the student's advisor and Engineering Graduate Programs.
- In order to transfer units into a degree program, please follow this procedure:

- Include the units you wish to transfer in the “Transfer Credit” section of the Program of Studies form and include the Institution Name, Course Number and Title, Grade, Units*, Year and (if applicable) the SCU equivalent course. If no equivalent course is listed, the transfer credit will be processed as general transfer credit (TRCR 300).
  - (*Note that 1 semester unit is equivalent to 1.5 quarter units. Please put the quarter unit value on the Program of Studies so that the final total will be correct.)
- The student’s academic advisor must sign the Program of Studies form and submit it to the Engineering Graduate Programs Office.
- The Graduate Programs Office must have an official transcript from the school you are transferring units from to review and approve the transfer credit request.

NOTE: Courses that were taken more than 10 years ago are generally not acceptable for transfer credit. Students who wish to request an exception must petition the department Chair and receive a written approval with a justification. The final approval is given by the Associate Dean for Graduate Programs.

Petition For Graduation

It is a student’s responsibility to file an online petition for graduation no later than the last day to petition for graduate degrees as indicated in the Academic Calendar. The petition to graduate will only be accepted through online submission and may be found on the graduate engineering website under current student resources www.scu.edu/engineering/gradaute. All graduating students must submit a final program of studies and enroll in at least one unit for their final quarter.

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

Cooperative Education Option

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

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

***** Note 1: ENGR 288 is not offered in the summer quarter. Students who plan to participate in a summer internship need to enroll in ENGR 288 in the Spring quarter.***

Concurrent Enrollment

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

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

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

Non-enrollment Period

Students in the Master's and Ph.D. program are expected to enroll in at least one unit for the fall, winter and spring quarters, summer quarter is optional to enroll. Those students who do not wish to enroll must submit a leave of absence or a withdrawal form to the Engineering Graduate Programs Office. A leave of absence form is required if a student plans to miss one or two quarters, while a more prolonged absence requires a withdrawal form. Students who wish to resume their Master's or Ph.D. studies after a leave of absence or withdrawal from the program must submit a returning student request form. The forms can be found on the graduate engineering website; Current Student Resources. Leave of absence or withdrawal forms must be submitted by the end of the first week of the quarter. Returning student's request forms must be submitted three weeks prior to the start of the quarter returning. Please note the return request is not guaranteed.

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

Note that students who miss a quarter and fail to submit the appropriate form(s) with the Graduate Programs Office will be automatically discontinued as a no show status and will be required to submit a returning student form. This is the same procedure for students who took a leave of absence or withdrew from the program.

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.

Student Records And Release Of Information

The Family Educational Rights and Privacy Act of 1974 (FERPA) protects the confidentiality of the University records of Santa Clara University students. A student is any person who attends or has attended a class, which includes courses taken through videoconference, satellite, Internet, or other electronic and telecommunication technologies and for whom the institution maintains education records. The University is authorized under provisions of the Act to release directory information to any person on request, unless a student explicitly requests in writing that the University not do so and keep directory information confidential.

A student's directory information is designated as follows:

- Student's 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

During the registration period and throughout the academic year, students may request in writing through the Office of the Registrar that directory information be kept confidential. Once filed, the request remains in effect until the beginning of the next academic year or a shorter period if designated by the student. Graduating students must notify the Office of the Registrar in writing to remove the nondisclosure notation from their record.

The University is authorized under FERPA to release educational and directory information to appropriate parties without consent if the University finds an articulable and significant threat to the health or safety of a student or other individuals in light of the information available at the time.

Former or current borrowers of funds from any Title IV student loan program should note carefully that requests for nondisclosure of information 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.

Students have the right to inspect and review their educational records at the following offices:

- Official academic records, including application forms, admission transcripts, letters of acceptance, and a student's permanent academic record are on file and maintained in the Office of the Registrar and the Graduate Programs Office
- Records related to a student's nonacademic activities are maintained in the Office of Student Life
- Records relating to a student's financial status with the University are maintained in the various student financial services offices

Certain records are excluded by law from inspection, specifically those created or maintained by a physician, psychiatrist, or psychologist in connection with the treatment or counseling of a student. Parents' financial information, including statements submitted with scholarship applications, is also excluded by law from inspection. Third parties may not have access to educational records or other information pertaining to students without the written consent of the student about whom the information is sought.

Students have the right to request the amendment of their educational records to ensure that they are not inaccurate, misleading, or otherwise in violation of the student's privacy or other rights. Students may direct complaints regarding academic records to the dean of the college or school in which they are enrolled or to the University registrar. In addition, 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 the Act. Written complaints should be directed to the Family Policy Compliance Office, Department of Education, 400 Maryland Avenue SW, Washington, D.C. 20202-5920.

For further information regarding Santa Clara University's FERPA policy, please refer to www.scu.edu/ferpa/scu-ferpa-policy/

Clery Act

In accordance with 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. Information presented in compliance with this act is made available to assist current and potential students and employees in making informed decisions regarding their attendance or employment at the University. These reports and other information about the law are available on the Campus Safety website. 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.

Chapter 6: Enrichment Experience and Graduate Core Requirements

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

Through the Enrichment Experience, in conjunction with students' specific program of study, Engineering graduate students will achieve the following objectives:

1. Academic competence

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

2. Creative and collaborative learning

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

3. Professional development

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

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

In order to fulfill this requirement, students must take

- Graduate Core: (minimum of 4 units required) Must take a course in at least two of the three areas from
  - Emerging Topics in Engineering,
  - Engineering and Business/Entrepreneurship
  - Engineering and Society.
    - Below is the list of all classes approved for the graduate core in these three areas. Please check our current student resources on our graduate engineering website for the most current list of Graduate Core classes.
- The remaining 4 units can be accumulated by:
  - Taking one or more major technical electives.
    - *Directed Research, Independent Study, Capstone, Thesis and CSE foundation courses cannot be approved as a technical electives*
  - Taking additional classes from the Graduate Core List below
  - Taking Cooperative Education courses (Engr 288 and 289).
    - Can repeat Engr 289 up to 3 times.

  Combining courses from the categories above

GRADUATE CORE AREAS AND TOPICS

Emerging Topics in Engineering

- AMTH 308 Theory of Wavelets
- AMTH 351 Quantum Computing

- AMTH 367 Mathematical Finance
- AMTH 387 Cryptology
- BIOE 256/ENGR 256 Introduction to Nanobioengineering
- CENG 213 Sustainable Materials
- CENG 215 Sustainable Structural Engineering
- CENG 219 Designing for Sustainable Construction
- CENG 282 Introduction to Building Information Modeling
- ELEN 280/MECH 287 Introduction to Alternative Energy Systems
- ELEN 285 Introduction to the Smart Grid
- ENGR 260 Nanoscale Science and Technology
- ENGR 273 Sustainable Energy and Ethics
- ENGR 371/MECH 371 Space Systems Design and Engineering I
- ENGR 372/MECH 372 Space Systems Design and Engineering II
- MECH 268 Computational Fluid Dynamics I

Engineering and Business/Entrepreneurship

- AMTH 367 Mathematical Finance
- CENG 208 Engineering Economics and Project Finance
- CENG 292 Infrastructure Project Management
- COEN 287 Software Development Process Management
- ENGR 245 Innovation, Entrepreneurship and the Evolution of Silicon Valley
- ENGR 302 Managing in the Multicultural Environment
- ENGR 304 Building Global Teams
- ENGR 336 Engineering for the Developing World
- ENGR 338 Mobile Applications for Emerging Markets
- ENGR 350 Success in Global Emerging Markets
- ENGR 351 New Paradigm for Technology-Global Mindfulness Leadership
- Any 2-unit course in Engineering Management and Leadership (EMGT)

Engineering and Society

- BIOE 210 Ethical Issues in Bioengineering
- CENG 208 Engineering Economics and Project Finance
- COEN 250 Information Security Management
- COEN 288 Software Ethics
- ELEN 217 Chaos Theory, Metamathematics, and the Limits of Science: An Engineering Perspective on Religion
- ENGR 261 Nanotechnology and Society
- ENGR 272 Energy Public Policy
- ENGR 273 Sustainable Energy and Ethics
- ENGR 302 Managing in the Multicultural Environment
- ENGR 303 Gender and Engineering
- ENGR 304 Building Global Teams
- ENGR 306 Engineering and the Law
- ENGR 330 Law, Technology, and Intellectual Property
- ENGR 332 How Engineers, Businesspeople, and Lawyers Communicate With Each Other
- ENGR 334 Energy, Climate Change, and Social Justice
- ENGR 336 Engineering for the Developing World
- ENGR 340 Distributed & Renewable Energy for the Developing World
- ENGR 341 Innovation, Design and Spirituality
- ENGR 342 3D Print Technology and Society
- ENGR 343 Science, Religion and the Limits of Knowledge
- ENGR 344 Artificial Intelligence and Ethics

- ENGR 349 Topics in Frugal Engineering
- ENGR 351-New Paradigm for Technology-Global Mindfulness Leadership

Note 1: Although certain courses (such as ENGR 302, ENGR 304, ENGR 336, and AMTH 367 for example) may appear in multiple categories, they cannot be used to satisfy more than one Core requirement. Students are encouraged to periodically check for updates regarding new courses in these areas on the graduate engineering website under current student resources.

https://www.scu.edu/engineering/current-student-resources/current-graduate-students/graduate-core/

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

Chapter 7: Department of Applied Mathematics

Senior Lecturer: Stephen A. Chiappari *(Chair)*
Renewable Term Lecturer: Aaron Melman

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 minimum of 46 units. These units may include courses from other fields with permission of the Applied Mathematics Department advisor. A minimum of 12 quarter units must be in 300-level AMTH courses.

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

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

Course Descriptions

Undergraduate Courses

AMTH 106. Differential Equations

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

AMTH 108. Probability and Statistics

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

AMTH 112. Risk Analysis in Civil Engineering

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

AMTH 118. Numerical Methods

Numerical solution of algebraic and transcendental equations, numerical differentiation and integration, and solution of ordinary differential equations. Solution of representative problems on the digital computer. Prerequisites: AMTH 106 or MATH 22 and one of the following: COEN 11, 44 or 45 or CSCI 10. (4 units)

AMTH 120. Engineering Mathematics

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

AMTH 194. Peer Educator in Applied Mathematics

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

Graduate Courses

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

AMTH 200. Advanced Engineering Mathematics I

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

AMTH 201. Advanced Engineering Mathematics II

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

AMTH 202. Advanced Engineering Mathematics

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. Prerequisite: AMTH 106 or equivalent. (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 219. Analysis of Scientific Experiments

Continuation of AMTH 217. Emphasis on the analysis of scientific experiments. The theory of design of experiments so that maximal information can be derived. Prerequisites: AMTH 211 or 212 and 217. (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 222. Design and Analysis of Scientific Experiments

Combination of AMTH 217 and AMTH 219. Prerequisite: AMTH 211 or 212. (4 units)

AMTH 225. Vector Analysis I

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

AMTH 226. Vector Analysis II

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

AMTH 230. Differential Equations with Variable Coefficients

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

AMTH 231. Special Functions and Laplace Transforms

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

AMTH 232. Biostatistics

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

AMTH 232L. Biostatistics Laboratory

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

AMTH 235. Complex Variables I

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

AMTH 236. Complex Variables II

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

AMTH 240. Discrete Mathematics for Computer Science

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

AMTH 245. Linear Algebra I

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

AMTH 246. Linear Algebra II

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

AMTH 247. Linear Algebra I and II

Combination of AMTH 245 and 246. (4 units)

AMTH 256. Applied Graph Theory I

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

AMTH 257. Applied Graph Theory II

Extension of AMTH 256. Networks, Hamiltonian and planar graphs are covered in detail. Edge colorings and Ramsey numbers may also be covered. Prerequisite: AMTH 256. (2 units)

AMTH 258. Applied Graph Theory I and II

Combination of AMTH 256 and AMTH 257. Prerequisite: Mathematical maturity. (4 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 318. Advanced Topics in Wavelets

An overview of very recent developments in the theory and application of wavelets. Study of a new generation of wavelet-like objects, such as beamlets, which exhibit unprecedented capabilities for the compression and analysis of 3D data. The beamlet framework consists of five major components: The beamlet dictionary, a dyadically organized library of line segments over a range of locations, orientations, and scales. The beamlet transform, a collection of line integrals of the given 3D data along the line segments in the beamlet dictionary. The beamlet pyramid, the set of all beamlet transform coefficients arranged in a hierarchical data structure according to scale. The beamlet graph, the graph structure in which vertices correspond to voxel corners of the underlying 3D object, and the edges correspond to beamlets connecting pairs of vertices. The beamlet algorithms, to extract information from the beamlet graph consistent with the structure of the beamlet graph. Study of each component in detail. Implementation issues. Selected applications in the areas of computer graphics, pattern recognition, and data compression. Prerequisite: AMTH 308. (2 units)

AMTH 340. Linear Programming I

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

AMTH 341. Linear Programming II

Continuation of AMTH 340. Network problems, transportation problems, production problems. Prerequisite: AMTH 340. (2 units)

AMTH 342. Linear Programming

Combination of AMTH 340 and 341. (4 units)

AMTH 344. Linear Regression

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

AMTH 351. Quantum Computing

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

AMTH 358. Fourier Transforms

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

AMTH 360. Advanced Topics in Fourier Analysis

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

AMTH 362. Stochastic Processes I

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

AMTH 363. Stochastic Processes II

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

AMTH 364. Markov Chains

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

AMTH 367. Mathematical Finance

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

AMTH 370. Optimization Techniques I

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

AMTH 371. Optimization Techniques II

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

AMTH 372. Semi-Markov and Decision Processes

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

AMTH 374. Partial Differential Equations I

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

AMTH 375. Partial Differential Equations II

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

AMTH 376. Numerical Solution of Partial Differential Equations

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

AMTH 377. Design and Analysis of Algorithms

Techniques of design and analysis of algorithms: proof of correctness; running times of recursive algorithms; design strategies: brute-force, divide and conquer, dynamic programming, branch-and-bound, backtracking, and greedy technique; max flow/ matching. Intractability: lower bounds; P, NP, and NP-completeness. Also listed as BIOE 377. Prerequisite: COEN 912C or equivalent. (4 units)

AMTH 379. Advanced Design and Analysis of Algorithms

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

AMTH 387. Cryptology

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

AMTH 388. Advanced Topics in Cryptology

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

AMTH 397. Master’s Thesis

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

AMTH 399. Independent Study

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

Chapter 8: Department of Bioengineering

Professor: Yuling Yan
Associate Professors: Ismail Emre Araci, Prashanth Asuri, Unyoung (Ashley) Kim, Biao (Bill) Lu, Zhiwen (Jonathan) Zhang *(Department Chair)*
Lecturers: Maryam Mobed-Miremadi, Eun Ju (Emily) Park
Adjunct Faculty: Zeynep Araci, Eric Chan, Parsa Hosseini, Sathish Manickam, Verna Rodriguez, 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.

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

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

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

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

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

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

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

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

Degree Program

The bioengineering graduate program at Santa Clara University is designed to accommodate the needs of students interested in advanced study in the areas of medical devices/bioinstrumentation and molecular and cellular bioengineering. An individual may pursue the degree of Master of Science (M.S.), either as a full-time or part-time student, through a customized balance of coursework, directed research and/or thesis research. Students are also required to supplement their technical work with coursework on other topics that are specified in the graduate engineering core curriculum.

Master of Science in Bioengineering

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

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

Applicants who have taken graduate-level courses at other institutions may qualify to transfer a maximum of six semester units (nine quarter units) of approved credit to their graduate program at Santa Clara University. Please see Chapter 5 for additional information on the transfer credit process.

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

Course requirements

- Enrichment Experience Graduate Core- Students must take a course in at least two of the three areas for a minimum of 4 units
  - Emerging Topics in Engineering,
  - Engineering and Business Entrepreneurship
  - Engineering and Society
- The remaining four units can be accumulated by
  - A) Taking one or more major technical electives,
  - B) Taking additional classes from the Graduate Core,
  - C) Taking Cooperative Education courses or
  - D) Combining A, B and C (minimum eight units including BIOE 210 Bioethics) (See descriptions in Chapter 6 , Enrichment Experience and Graduate Core requirements)
- Applied Mathematics (4 units) Select from AMTH 200 & 201 (or 202), 210 & 211 (or 212), or AMTH 245 & 246
- Bioengineering Core (15 or 21* units)

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

Five primary focus areas are:

1. Biomolecular Engineering Biotechnology
   - BIOE 257, 282, 283, 286, 288, 300, 301
2. Biomaterials and Tissue Engineering
   - BIOE 208, 240, 245, 269, 273, 378

3. Microfluidics/Biosensors and Imaging
    - BIOE 203, 260, 267, 268, 276, 277, 308
4. Computational Bioengineering
    - BIOE 251, 252, 261, 263, 281, 310, 312
        - Advanced Applied Mathematics
        - AMTH 240, 364, 370, 371, 377
5. Translational Bioengineering
    - BIOE 206, 263, 279, 285, 302, 307, 320, 380
        - Graduate Capstone Project
        - BIOE 294, 295, 296

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

- Bioengineering Technical Electives (13* or 19 units)

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

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

Ph.D. in Electrical Engineering/Bioengineering

The departments of Electrical Engineering and Bioengineering are collaborating to offer a Ph.D. in interdisciplinary topics related to Bioengineering. Faculty from both departments will co-advise the Ph.D. students, and the degree will be awarded by the Department of Electrical Engineering.

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
a microscopy setup is used for measuring enzyme activity and single cell protein expression at the single molecular level.

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

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

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

Course Descriptions

Undergraduate Courses

BIOE 100. Bioengineering Research Seminar

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

BIOE 106. Design Control for Medical Devices

This course will cover the principles behind design control. All of the essential elements required in the regulated medical device environment will be covered from design planning, inputs and outputs to verification, validation, risk management and design transfer. A problem-based learning approach will be utilized so that students will develop proficiency to apply the principles. Knowledge will be acquired through lectures, class activities, industry guest lectures and field trips. Also listed as BIOE 206. (4 units)

BIOE 107. Medical Device Product Development

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

BIOE 108. Biomedical Devices: Role of Polymers

This course is designed to highlight the role that polymers play in the design and fabrication of various medical devices ranging from simple intravenous drip systems to complex cardiac defibrillator implants and transcatheter heart valves. Topics include polymer basics, biocompatibility, biodegradation, and other tangentially-related topics such as regulatory body approvals and intellectual property. Also listed as BIOE 208. Prerequisites: BIOE 10. (2 units)

BIOE 109. Translational Development for Emerging Biomedical Devices

This course exposes the student to ongoing case-based interventional cardiology diagnostic and therapeutic biomedical device and clinical translational problems, where real-world bioengineering innovative solutions are being envisioned, and at times successfully being applied by startup teams of bioengineers and medical professionals. Bioengineering device design concepts and clinical translational development considerations are analyzed and case-based team project reports are assigned for final grading. Prerequisites: BIOE 10 and BIOE 21, BIOE 108 or BIOE 153 preferred. (4 units)

BIOE 120. Experimental Methods in Bioengineering

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

BIOE 130. Immune System for Engineers

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

BIOE 131. Cancer Immunotherapy

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

BIOE 140. Biomaterials Engineering and Characterization

This course will cover the fundamental principles of soft biomaterials characterization in terms of mechanical and rheological properties related to biocompatibility. Areas of focus in the lab included study and fabrication of implantable hydrogels for eukaryotic cell immobilization in scaffold and microscapsules, cytotoxicity measurements in the engineered micro-environment and nutrient diffusion visualized by fluorescence microscopy. Prerequisite: CHEM 12. Also listed as BIOE 240. (2 units)

BIOE 140L. Biomaterials Engineering and Characterization Laboratory

Laboratory for BIOE 140. Co-requisite: BIOE 140. (1 unit)

BIOE 141. Biomaterials Engineering and Characterization II: Hard Materials

This course will cover materials characterization methods, phase equilibria and processing of first and second generation hard biomaterials with emphasis on bioceramics and metals. Instruction will be complemented by software-enabled simulation of prototyping into a device followed by mechanical and image analysis of defects. Prerequisite: CHEM 12. Also listed as BIOE 241. (2 units)

BIOE 141L. Biomaterials Engineering and Characterization II: Hard Materials Laboratory

Laboratory for BIOE 141. Co-requisite: BIOE 141. (1 unit)

BIOE 153. Biomaterials Science

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

BIOE 154. Introduction to Biomechanics

Engineering mechanics and applications in the analysis of human body movement, function, and injury. Review of issues related to designing devices for use in, or around, the human body including safety and biocompatibility. Prerequisites: BIOE 10, PHYS 33. (4 units)

BIOE 155. Biological Transport Phenomena

The transport of mass, momentum, and energy are critical to the function of living systems and the design of medical devices. This course develops and applies scaling laws and the methods of continuum mechanics to biological transport phenomena over a range of length and time scales. Prerequisites: BIOE 10, PHYS 33, AMTH 106. (4 units)

BIOE 157. Introduction to Biofuel Engineering

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

BIOE 161. Bioinstrumentation

Transducers and biosensors from traditional to nanotechnology; bioelectronics and measurement system design; interface between biological system and instrumentation; data analysis; clinical safety. Laboratory components will include traditional clinical measurements and design and test of a measurement system with appropriate transducers. Prerequisites: BIOE 10, BIOE 21 (or BIOL 1B), ELEN 50. Co-requisite: BIOE 161L. (4 units)

BIOE 161L. Bioinstrumentation Laboratory

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

BIOE 162. Signals and Systems for Bioengineers

Origin and characteristics of bioelectric, bio-optical, and bioacoustic signals generated from biological systems. Behavior and response of biological systems to stimulation. Acquisition and interpretation of signals. Signal processing methods include FFT spectral analysis and time-frequency analysis. Laboratory components will include modeling of signal generation and analysis of signals such as electrocardiogram (ECG), electromyogram (EMG), and vocal sound pressure waveforms. Prerequisites: BIOE 10, BIOE 45, ELEN 50, AMTH 106. Co-requisite: BIOE 162L. (4 units)

BIOE 162L. Signals and Systems for Bioengineers Laboratory

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

BIOE 163. Bio-Device Engineering

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

BIOE 163L. Bio-Device Engineering Laboratory

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

BIOE 167. Introduction to Medical Imaging

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

BIOE 168. Biophotonics and Bioimaging

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

BIOE 168L. Biophotonics and Bioimaging Laboratory

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

BIOE 171. Physiology and Anatomy for Engineers

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

BIOE 171L. Physiology and Anatomy for Engineers Laboratory

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

BIOE 172. Introduction to Tissue Engineering

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

BIOE 173. Advanced Topics in Tissue Engineering

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

BIOE 174. Microfabrication and Microfluidics for Bioengineering Applications

Microfluidics uses principles from a broad range of disciplines including fluid mechanics, material science and optics for miniaturization, and automation of biochemical applications. This course will introduce the basic physical and engineering concepts which have practical importance in microfluidics and will allow better understanding of molecule and cell manipulation in the micro-domain. The course aims to introduce students to the state-of-art applications of various microfluidic techniques (e.g. mLSI, droplet and paper-based), in biological and biomedical research through lectures and discussion of current literature. Prerequisites: BIOE 10, BIOE 21 (or BIOL 1B). Co-requisite: BIOE 174L. (4 units)

BIOE 174L. Microfabrication and Microfluidics for Bioengineering Applications Laboratory

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

BIOE 175. Biomolecular and Cellular Engineering I

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

BIOE 175L. Biomolecular and Cellular Engineering I Laboratory

Laboratory for BIOE 175. Co-requisite: BIOE 175. (1 unit)

BIOE 176. Biomolecular and Cellular Engineering II

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

BIOE 177A. Machine Learning and Applications in Biomedical Engineering

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

BIOE 177B. Machine Learning and Algorithm Implementation

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

BIOE 179. Introduction to Neural Engineering

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

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

This course will cover the principles behind the logistics of design and analysis of clinical trials from statistical and ethical perspectives. Topics include methods used for quantification of treatment effect(s) and associated bias interpretation, crossover designs used in randomized clinical trials, and clinical equipoise. Also listed as BIOE 380. Prerequisites: BIOE 10, BIOE 120 (or AMTH 108), or with consent of the instructor. (4 units)

BIOE 185. Physiology and Disease Biology

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

BIOE 186. Introduction to Biotechnology

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

BIOE 187. Biotechnology II

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

BIOE 188. Co-op Education

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

BIOE 189. Work Experience and Co-op Technical Report

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

BIOE 190. Biotechnology III - Drug Development Process

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

BIOE 194. Design Project I

Specification of an engineering project, selected with the mutual agreement of the student and the project advisor. Complete initial design with sufficient detail to estimate the effectiveness of the project. Initial draft of the project report. Prerequisite: Senior standing. (2 units)

BIOE 195. Design Project II

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

BIOE 196. Design Project III

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

BIOE 198. Internship

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

BIOE 199. Supervised Independent Research

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

Graduate Courses

BIOE 200. Bioengineering Research Seminar

A series of one-hour seminars will be presented by guest professors and researchers on their particular research topics in bioengineering or related fields. Students are required to attend 4 -5 seminars and submit a one-page report summarizing the presentation for each seminar. May be repeated for credits. Prerequisite: Sophomore standing or higher. P/NP grading. Also, listed as BIOE 100. (1 unit)

BIOE 203. Bio-Electromagnetics

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

BIOE 206. Design Control for Medical Devices

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

BIOE 207. Medical Device Invention - From Ideas to Business Plan

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 208. Biomedical Devices: Role of Polymers

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

BIOE 209. Development of Medical Devices in Interventional Cardiology

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

BIOE 210. Ethical Issues in Bioengineering

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

BIOE 226. Biomolecular and Cellular Engineering II

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

BIOE 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 240. Biomaterials Engineering and Characterization

This course will cover the fundamental principles of soft biomaterials characterization in terms of mechanical and rheological properties related to biocompatibility. Areas of focus in the lab include study and fabrication of implantable hydrogels for eukaryotic cell immobilization in scaffolds and microscapsules, cytotoxicity measurements in the engineered micro-environment and nutrient diffusion visualized by fluorescence microscopy. Prerequisite: CHEM 13. (2 units)

BIOE 241. Biomaterials Engineering and Characterization II: Hard Materials

This course will cover materials characterization methods, phase equilibria and processing of first and second generation hard biomaterials with emphasis on bioceramics and metals. Instruction will be complemented by software-enabled simulation of prototyping into a device followed by mechanical and image analysis of defects. Prerequisite: CHEM 12. Also listed as BIOE 141. (2 units)

BIOE 245. Introductory Biotribology for Orthopedic Implants

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

BIOE 249. Topics in Bioengineering

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

BIOE 251. Introduction to Bioinformatics

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

BIOE 252. Computational Neuroscience I

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

BIOE 252L. Computational Neuroscience Lab

Laboratory for BIOE 252. Co-requisite: BIOE 252. (1 unit)

BIOE 256. Introduction to NanoBioengineering

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

BIOE 257. Introduction to Biofuel Engineering

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

BIOE 258. Synthetic Biology & Metabolic Engineering

This course covers current topics and trends in the emerging field of synthetic biology. These topics include applying the retro-synthetic analysis approach in classic organic chemistry, identifying and engineering metabolic pathways and mechanisms for bioproduction of antibiotics, biofuel compounds, novel bio-building blocks, and non-natural proteins. Genetic regulation of biosynthetic pathways, e.g., genetic circuits will also be discussed. (2 units)

BIOE 259. Engineering In Drug Delivery

Engineering is a major contributor to the advancement of drug delivery systems, which improves treatment and enhances patients’ quality of life. In this course, we will explore engineering principles, applications, and techniques in drug delivery systems. The purpose of this course is to identify the roles of engineers in the pharmaceutical industry and how to propose a solution to an emerging topic in this subject. (2 units)

BIOE 260. Selected Topics in Bio-Transport Phenomena

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

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

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

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

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

BIOE 266. Advanced Nano-Bioengineering

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

BIOE 267. Introduction to Medical Imaging

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

BIOE 268. Biophotonics and Bioimaging

This course starts with an introduction of optics and basic optical components (e.g. lenses, mirrors, diffraction grating, etc.), then focuses on light propagation and propagation modeling to examine interactions of light with biological matter (e.g. absorption, scattering). Other topics that will be covered in this course are: laser concepts, optical coherence tomography, microscopy, confocal microscopy, polarization in tissue, absorption, diffuse reflection, light scattering, Raman spectroscopy, and fluorescence lifetime imaging. Graduate students will prepare a presentation/report on one of the state-of-the-art biophotonics technologies. Also listed as BIOE 168. Prerequisite: PHYS 33. (4 units)

BIOE 268L. Biophotonics and Bioimaging Laboratory

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

BIOE 269. Stem Cell Bioengineering

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

BIOE 270. Mechanobiology

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

BIOE 273. Advanced Topics in Tissue Engineering

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

BIOE 275. Introduction to Neural Engineering

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

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

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

BIOE 277. Biosensors

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

BIOE 279. Stem Cell & Regenerative Medicine

Few events in science have captured the same level of sustained interest and imagination of the non-scientific community as Stem Cells and Regenerative Medicine. The fundamental concept of Regenerative Medicine is appealing to scientists, physicians, and laypeople alike: to heal tissue or organ defects that the current medical practice deems difficult or impossible to cure. Regenerative medicine is a new branch of medicine that attempts to change the course of chronic disease; in many instances regenerating failing organ systems lost due to age, disease, damage, or congenital defects. The area is rapidly becoming one of the most promising treatment options for patients suffering from tissue failure. This course covers principles and real cases of stem cell and regenerative medicine. Its major applications will be discussed comparatively to understand the advantages/disadvantages of each system better. Overall, this course provides a more in-depth exploration of the next generation biotechnology - a wide variety of cells, biomaterials, interfaces and applications for tissue engineering. Prerequisite: BIOE 269. (2 units)

BIOE 280. Special Topics in Bio-therapeutic Engineering

This class will cover current topics on the engineering of biomimetic drugs, particularly protein drugs, and the development of vaccines, therapeutic antibodies and biomarkers. Prerequisite: BIOE 270 or equivalent. (2 units)

BIOE 281. Deep Learning in Medical Image Analysis and Disease Classification

This course covers the fundamentals of deep learning and methods for medical image analysis with focus on Convolutional Neural Network (CNN) and its applications in image-based disease classifications. The analysis of high-dimensional datasets with still images and volumetric data will be discussed. (2 units)

BIOE 282. BioProcess Engineering

This course will cover the principles of designing, production, and purification of biologicals using living cells in a large scale and industrial scale, including bio-reactor design. Prerequisite: BIOE 21 (or BIOL 1B), BIOE 10, AMTH 106 or equivalent. (2 units)

BIOE 283. BioProcess Engineering II

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

BIOE 285. Physiology and Disease Biology

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

BIOE 286. Biotechnology

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

BIOE 287. Pharmaceutical Drug Development and Chemical Analysis

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

BIOE 288. Biotechnology II

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

BIOE 290. Biotechnology III - Drug Development Process

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

BIOE 294. Graduate Capstone Project I

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

BIOE 295. Graduate Capstone Project II

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

BIOE 296. Graduate Capstone Project III

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

BIOE 297. Directed Research

By arrangement. (1–6 units)

BIOE 300. Antibody Bioengineering

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

BIOE 301. Protein Engineering and Therapeutics

Protein-based therapeutics 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. (2 units)

BIOE 308. Wearable Sensors and Actuators for Biomedical Applications

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

BIOE 310. Machine Learning in Biomedical Engineering

This course presents an overview of Machine Learning, the study of computing systems that improve their performance with learning abilities. The basic ideas and intuition behind modern methods, concepts, techniques, and algorithms are presented. The course has a special emphasis on deep learning as the most representative machine learning method. The applications of machine learning in biomedical engineering are presented and discussed during the course. (2 units)

BIOE 312. Deep Learning

This course is an introduction to deep learning, a cutting-edge artificial intelligence concerned with the structure, development, and application of modern neural networks. A range of topics from basic neural networks, convolutional architectures, unsupervised learning, recurrent network structures, non-convex optimization, and the mathematical, statistical and computational challenges of building stable representations and analysis for high-dimensional data, such as images and text are discussed. Programming and building projects in TensorFlow, Keras, and NumPy will be discussed. (4 units)

BIOE 320. Cancer Immunotherapy

This course aims to provide the scientific and clinical background necessary to understand cancer immunotherapy's fundamental topics and analyze its strengths and limitations. Emphasis will be on checkpoint blockades, CAR-T and other cell therapy, and cancer vaccines. These topics and the latest developments will be discussed through lectures and journal club presentations. Also listed as BIOE 131. (2 units)

BIOE 345. Applied Programming in MATLAB

Elements of computer programming in MATLAB include input/output, branching and loops, iterative solutions, function definition and invocation, top-down design, numerical overflow and underflow, symbolic algebra, and simple graphical user interfaces. Programming of elementary mathematical operations. Applications to engineering problems. Co-requisite: BIOE 345L. (2 units)

BIOE 345L. Applied Programming in MATLAB Laboratory

Laboratory for BIOE 345. Co-requisite: BIOE 345. (1 unit)

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

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

BIOE 378. Advanced Biomaterials

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

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

This course will cover the principles behind the logistics of design and analysis of clinical trials from the statistical and ethical perspectives. Topics include methods used for quantification of treatment effect(s) and associated bias interpretation, cross-over designs used in randomized clinical trials and clinical equipoise. Also listed as BIOE 180. Prerequisites: BIOE 10, BIOE 120 or AMTH 108, or instructor approval. (4 units)

BIOE 397. Master's Thesis Research

By arrangement. (1–9 units)

Chapter 9: Department of Civil, Environmental, and Sustainable Engineering

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

Overview

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

Degree Program

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

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

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

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

The water and environmental engineering (WEE) track 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 the Admissions section of the bulletin, with the following additional criteria:

Applicant's undergraduate degree must be:

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

Applicant's undergraduate record must show:

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

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

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

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

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

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

---	**Structural Engineering Track**	**General Civil Engineering Track**	**Construction Engineering and Management Track**	**Water and Environmental Engineering Track**
Required	CENG 205 (2) CENG 206 (2) CENG 222 (4) CENG 233* (4)	CENG 219^ (3) CENG 237 (4) CENG 238 (4/1)	CENG 218 (3) CENG 219^ (3) CENG 281 (3) CENG 282^ (3)	**At least 15 units from:** CENG 242 (4) CENG 249 (4)

Coursework	CENG 234 (4) CENG 236 (4) CENG 237 (4) **(24 units)**	CENG 249 (4) CENG 250 (4) CENG 282^ (3) **(24 units)**	CENG 284 (3) CENG 285 (3) CENG 286 (3) CENG 287 (3) **(24 units)**	CENG 253 (3/1) CENG 254 (3/1) CENG 258 (4) CENG 259 (3)
Elective Technical Coursework	**6 units from:** CENG 207 (2) CENG 213 (3/1) CENG 215 (3/1) 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 292 (2) CENG 293 CENG 295 CENG 297	**6 units from:** CENG 217 (4) 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 289 (3) CENG 292 (2) CENG 293 CENG 295 CENG 297 EMGT 255 (2) EMGT 289 (2) EMGT 292 (2) EMGT 295 (2) EMGT 330 (2) EMGT 335 (2) ENGR 329^ (3)	**At least 16 units from: **** CENG 217 (4) CENG 219 (3) CENG 252 (3) CENG 260 (3) CENG 261 (4) CENG 262 (3) CENG 263 (4) CENG 297 (3) MECH 266 (2) MECH 268 (2)
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)	**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)

		AMTH 245 (2) & 246 (2)	AMTH 370 (2) & 371 (2)	AMTH 245 (2) & 246 (2)
Project Management, Leadership and Communications	**5 units from:** CENG 282^ (3) EMGT 255^ (2) EMGT 271^ (2) EMGT 330^ (2) EMGT 335^ (2)	**5 units from:** CENG 260 (3) EMGT 255^ (2) EMGT 271^ (2) EMGT 330^ (2) EMGT 335^ (2)	**6 units from:** EMGT 270 (2) EMGT 271^ (2) EMGT 319 (2) EMGT 320 (2) EMGT 329 (2) EMGT 349 (2)	**4 units from:** CENG 208^ (2) CENG 292^ (2) EMGT 271^ (2 EMGT 330^ (2 EMGT 335^ (2) ENGR 304^ (2) ENGR 336^ (2)
Enrichment Experience	**[minimum 7 units] composed of:** **A minimum of 4 units from at least two of the three areas in the Graduate Core Areas (Emerging Topics in Engineering, Engineering and Business/Entrepreneurship and Engineering and Society). The remaining three units may be fulfilled by a) Taking additional classes from the Graduate Core, b)Taking one or more major technical electives, c) Taking Cooperative Education courses (ENGR 288, 299) and d) combining courses from categories a, b and c. See Chapter 6, Enrichment Experience and Graduate Core requirements for additional information.**			

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

* *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 (no more than 12 units total) that do not duplicate course content of graduate courses in the program of studies.*

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

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

Laboratories

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

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

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

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

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

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

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

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

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

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

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

Course Descriptions

Lower-Division Undergraduate Courses

CENG 7. Graphic Communication

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

CENG 7L. Laboratory for CENG 7

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

CENG 10. Surveying

The use and care of survey instruments. Principles of topographic mapping, linear measurements, leveling, traverses, curves, boundary, and public surveys. Co-requisite:

CENG 10L. (3 units)

CENG 10L. Laboratory for CENG 10

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

CENG 15. Computer Applications in Civil Engineering

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

CENG 20. Geology

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

CENG 20L. Laboratory for CENG 20

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

CENG 41. Mechanics I: Statics

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

CENG 43. Mechanics II: Strength of Materials

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

CENG 43L. Laboratory for CENG 43

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

CENG 44A. Strength of Materials I

Stress-strain relationships for structural elements subjected to axial, torsional, flexural, shear, and combined loading. Fundamental study of the behavior and response of deformable, statically determinate structural systems. Stress and strain transformations and analysis using Mohr’s circle. Prerequisite: CENG 41. Co-requisite: CENG 44AL. (3 units)

CENG 44AL. Strength of Materials Laboratory

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

CENG 44B. Strength of Materials II

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

CENG 45. Construction Materials

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

CENG 45L. Construction Materials Laboratory

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

Upper-Division Undergraduate Courses

CENG 115. Civil Engineering Materials

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

CENG 115L. Laboratory for CENG 115

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

CENG 118. Construction Engineering

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

CENG 119. Design for Sustainable Construction

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

CENG 121A. Geotechnical Engineering

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

CENG 121AL. Laboratory for CENG 121

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

CENG 121B. Geotechnical Engineering

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

CENG 123. Pollutant Fate and Transport

Study of reaction energetics, kinetics, interphase mass transfer, and partitioning as they relate to pollutant transformation in the environment. Application to surface waters and groundwater. Also listed as CENG 253. Prerequisites: CHEM 11 or CHEM 11T or equivalent, CENG 143, AMTH 106, and junior standing, or instructor's consent. Corequisite: CENG 123L (3 units)

CENG 123L. Laboratory for CENG 123

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

CENG 124. Water Law and Policy

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

CENG 125. Municipal Engineering Design

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

CENG 125L. Laboratory for CENG 125

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

CENG 128. Engineering Project Management

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

CENG 132. Structural Analysis

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

CENG 133. Wood Design

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

CENG 134. Structural Steel Design I

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

CENG 135. Reinforced Concrete Design

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

CENG 135L. Laboratory for CENG 135

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

CENG 135L. Laboratory for CENG 135

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

CENG 136. Advanced Concrete Structures

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

CENG 137. Earthquake Engineering Design

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

CENG 138. Geotechnical Engineering Design II

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

CENG 138L. Geotechnical Engineering Design Laboratory

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

CENG 139. Groundwater Hydrology

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

CENG 140. Water Resources Engineering

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

CENG 140L. Laboratory for CENG 140

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

CENG 141. Fluid Mechanics and Hydraulic Engineering

Fundamentals of fluid behavior with an emphasis on water. Covers basic fluid properties, flow classification, and fluid statics including forces on submerged surfaces. Introduces and applies fundamental relationships: conservation of mass, momentum, and energy. Hydraulic applications include flow in pipes and pipe networks, steady flow in open channels, and hydraulic machinery. Laboratory. Prerequisite: CENG 41, PHYS 31. Co-requisite: CENG 141L. (4 units)

CENG 141L. Fluid Mechanics and Hydraulic Engineering Laboratory

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

CENG 142. Water Resources Design

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

CENG 143. Environmental Engineering

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

CENG 143L. Laboratory for CENG 143

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

CENG 144. Water and Wastewater Treatment

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

CENG 144L. Laboratory for CENG 144

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

CENG 145. Transportation Engineering Design

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

CENG 146. Design of Cold-Formed Steel Frame Structures

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

CENG 147. Pavement Design

Paving materials. Geometric and structural design of highways. Urban street layout and details. Layout and design of airport runways. Also listed as CENG 247. Prerequisites: CENG 115 and 121A. (4 units)

CENG 148. Structural Systems

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

CENG 148L. Structural Systems Laboratory

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

CENG 149. Civil Systems Engineering

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

CENG 150. Traffic Engineering: Design and Operations

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

CENG 151. Special Topics in Transportation Engineering

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

CENG 160. GIS in Water Resources

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

CENG 161. Sustainable Water Resources

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

CENG 162. Computational Water Resources

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

CENG 163. Solid Waste Management

Characterization of solid waste streams. Overview of collection, transport, processing, and disposal options. Waste stream reduction and resource recovery strategies. Also listed as CENG 263. (4 units)

CENG 182. Introduction to Building Information Modeling

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

CENG 183. Building Systems

Introduction to the major systems within a building, including heating, ventilation, air conditioning, electrical, energy, life safety, and plumbing. The engineering, construction, and sustainability aspects of each system will be introduced. Also listed as CENG 283. Prerequisite: Junior standing. (3 units)

CENG 184. Construction Project Delivery

Project organization and delivery systems, Project stakeholders authorities and responsibilities, contractual payment schemes, bidding process, preconstruction administration, contracts, payment measurement, change orders, quality management, safety, claims and disputes, risk and liability sharing, project documentation and closeout, lean

CENG 186. Construction Planning and Control

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

CENG 187. Heavy Construction

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

CENG 188. Co-op Education

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

CENG 189. Co-op Technical Report

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

CENG 192A. Civil Engineering Project Development

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

CENG 192B. Elements of Civil Engineering Practice

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

CENG 192C. Professional Development Seminar

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

CENG 193. Detailed Project Design

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

CENG 194. Design Project Communication

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

CENG 197. Special Topics in Civil Engineering

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

CENG 198. Internship

Time off campus with an engineering organization. Different aspects of work in the assigned professional office. Oral and written reports. Prerequisites: Senior standing and approval of internship coordinator. (4–5 units)

CENG 197. Special Topics in Civil Engineering

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

CENG 198. Internship

Time off campus with an engineering organization. Different aspects of work in the assigned professional office. Oral and written reports. Prerequisites: Senior standing and approval of internship coordinator. (4–5 units)

CENG 199. Directed Research

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

Graduate Courses

CENG 205. Finite Element Methods I

Introduction to structural and stress analysis problems using the finite element method. Use of matrix methods, interpolation (shape) functions and variational methods. Formulation of global matrices from element matrices using direct stiffness approach. Development of element matrices for trusses, beams, 2D, axisymmetric and 3D problems. Theory for linear static problems and practical use of commercial FE codes. Also listed as MECH 250. (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. Also listed as MECH 251. Prerequisite: CENG 205. (2 units)

CENG 207. Finite Element Methods III

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

CENG 208. Engineering Economics and Project Finance

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

CENG 211. Advanced Strength of Materials

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

CENG 213. Sustainable Materials

Evaluation of material sustainability. Material characteristics, microstructure, and mechanical properties of non-conventional and emerging innovative building materials. Processing and durability considerations. Course project. Co-requisite: CENG 213L. (3 units)

CENG 213L. Laboratory for CENG 213

Sample preparation and evaluation of mechanical properties in the laboratory. Co-requisite: CENG 213. (1 unit)

CENG 215. Sustainable Structural Engineering

Use of sustainable materials in structural design; characteristics and design of systems such as bamboo frames and trusses, straw bale walls, low-cement concrete, and composite barrel vaults. Course project. Prerequisite: CENG 148 or instructor approval. Co-requisite: CENG 215L. (3 units)

CENG 215L. Laboratory for CENG 215

Preparation and testing of structural subassemblies in the laboratory. Co-requisite: CENG 215. (1 unit)

CENG 217. Sustainable Infrastructure for Developing Countries

Sustainable options for providing water and energy to communities, adaptation to local resources and constraints, processing and reuse of waste products, transportation alternatives. (4 units)

CENG 218. Construction Engineering

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

CENG 219. Designing for Sustainable Construction

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

CENG 220. Structural Dynamics

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

CENG 221. Advanced Dynamics

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

CENG 222. Advanced Structural Analysis

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

CENG 223. Stability of Structures

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

CENG 226. Plastic Theory of Structures

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

CENG 228. Fracture Mechanics of Solids

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

CENG 231. Bridge Engineering

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

CENG 232. Masonry Engineering

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

CENG 233. Wood Design

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

CENG 234. Structural Steel Design II

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

CENG 236. Advanced Concrete Structures

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

CENG 237. Earthquake Engineering Design

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

CENG 238. Geotechnical Engineering Design

Foundation exploration; bearing capacity and settlement analysis; spread foundations; piles and caissons; earth-retaining structures; loads on underground conduits; subsurface construction. Also listed as CENG 138. Prerequisite: CENG 121A/B. (4 units)

CENG 238L. Geotechnical Engineering Design Laboratory

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

CENG 239. Earthquake Engineering II

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

CENG 239L. Earthquake Engineering Laboratory

Co-requisite: CENG 239. (1 unit)

CENG 240. Soil-Structure Interaction

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

CENG 241. Introduction to Blast Analysis

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

CENG 242. Water Resources Design

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

CENG 243. Blast-Resistant Design of Concrete Structures

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

CENG 244. Progressive Collapse and Structural Integrity

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

CENG 246. Design of Cold-Formed Steel Frame Structures

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

CENG 247. Pavement Design

Paving materials. Geometric and structural design of highways. Urban street layout and details. Layout and design of airport runways. Also listed as CENG 147. Prerequisites: CENG 115 and 121A/B. (4 units)

CENG 249. Civil Systems Engineering

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

CENG 250. Traffic Engineering: Design and Operations

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

CENG 251. Special Topics in Transportation Engineering

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

CENG 252. Air Pollution

The study of generation of common air pollutants, their transport, effects, and state-of-the-art air pollution control strategies. Also listed as CENG 122. Prerequisite: CENG 143 or equivalent, consent of the instructor. (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 or equivalent, AMTH 106 or equivalent. Corequisite: CENG 253L (3 units)

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 equivalent, or instructor’s consent. Corequisite: CENG 254L. (3 units)

CENG 254L. Laboratory for CENG 254

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

CENG 256. Public Transportation

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

CENG 258. Water Law and Policy

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

CENG 259. Groundwater Hydrology

Groundwater occurrence, flow principles, flow to wells, and regional flow. Groundwater contamination, management, and modeling. Field methods. Field trips. Also listed as CENG 139. Prerequisite: CENG 141 or equivalent, or permission of instructor. (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 permission of instructor. (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 263. Solid Waste Management

Characterization of solid waste streams. Overview of collection, transport, processing, and disposal options. Waste stream reduction and resource recovery strategies. Also listed as CENG 163. (4 units)

CENG 263. Solid Waste Management

Characterization of solid waste streams. Overview of collection, transport, processing, and disposal options. Waste stream reduction and resource recovery strategies. Also listed as CENG 163. (4 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 283. Building Systems

Introduction to the major systems within a building, including heating, ventilation, air conditioning, electrical, energy, life safety, and plumbing. The engineering, construction, and sustainability aspects of each system will be introduced. Also listed as CENG 183. (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

Risk management, decision trees, fault trees, multi-attribute decision-making, sensitivity analysis, fuzzy numbers, fuzzy logic, optimization, reliability analysis, and Monte Carlo simulation. Group project on engineering decisions. Prerequisite: AMTH 108 or instructor approval. (4 units)

CENG 289. Construction Productivity Analysis

Productivity improvement as applied to construction operations. Quantitative methods and procedures for measuring, analyzing, and improving productivity at construction job sites. (3 units)

CENG 292. Infrastructure Project Management

Management concepts and strategies for civil infrastructure projects. Identification of scope, schedule, and budget. Quality assurance and control. Processes for tracking progress and budget. Examination of actual projects. (2 units)

CENG 293. Graduate Design Project

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

CENG 295. Master's Thesis Research

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

CENG 297. Directed Research

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

CENG 299. Independent Study

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

Chapter 10: Department of Computer Science and Engineering

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

Overview

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

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

Degree Programs

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

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

Master of Science in Computer Science and Engineering (MSCSE)

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

1) Logic design

- COEN 21 or 921C

2) Data structures

- COEN 12 or 912C

3) Computer organization & assembly language

- COEN 20 or 920C or ELEN 33

4) Discrete math

- AMTH 240

5) Probability

- AMTH 210

6) One of the following:

- Differential Equations (AMTH 106), Numerical Analysis (AMTH 220, 221), or Linear Algebra (AMTH 245, 246)

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

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

Degree Requirements

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

- A minimum of 4 units must be from the Graduate Core which requires at least two courses from the three areas
    - Emerging Topics in Engineering,
    - Engineering and Business/Entrepreneurship,
    - Engineering and Society.

  The remaining 4 units can be accumulated by the following
- a) Taking one or more major technical electives,
- b) Taking additional classes from the Graduate Core,
- c) Taking Cooperative Education course
- d) Combining courses from a, b and c.

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

MSCSE Core

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

MSCSE Electives

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

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

Doctor of Philosophy in Computer Science and Engineering

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

Preliminary Exam

A preliminary written exam is offered at least once per year by the School of Engineering as needed. The purpose is to ascertain the depth and breadth of the student's preparation and suitability for Ph.D. work.

Faculty Advisor

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

Doctoral Committee

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. In addition, acceptance of publications with the student as the primary (first) author is required. More details are described in Chapter 2: Academic Programs and Requirements.

Time Limit for Completing Degree

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

Engineer's Degree in Computer Science and Engineering

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

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

LABORATORIES

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

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

The ***Internet of Things Technologies Research Laboratory (SIOTLAB)*** focuses on the design and development of (1) systems with sensing and actuation capabilities, (2) energy-efficient and reliable networking protocols, and (3) data analytics, for applications such as healthcare, advanced manufacturing, and smart cities.

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

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

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

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

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

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

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

Course Descriptions

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

Lower-Division Undergraduate Courses

COEN 10. Introduction to Programming

Overview of computing. Introduction to program design and implementation: problem definition, functional decomposition, and design of algorithm programming in PHP and C: variables, data types, control constructs, arrays, strings, and functions. Program development in the Linux environment: editing, compiling, testing, and debugging. Credit is not allowed for more than one introductory class such as COEN 10, COEN 44, CSCI 10, or OMIS 30. Co-requisite: COEN 10L. (4 units)

COEN 10L. Introduction to Programming Laboratory

Laboratory for COEN 10. Co-requisite: COEN 10. (1 unit)

COEN 11. Advanced Programming

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

COEN 11L. Advanced Programming Laboratory

Laboratory for COEN 11. Co-requisite: COEN 11. (1 unit)

COEN 12. Abstract Data Types and Data Structures

Data abstraction: abstract data types, information hiding, interface specification. Basic data structures: stacks, queues, lists, binary trees, hashing, tables, graphs; implementation of abstract data types in the C language. Internal sorting: review of selection, insertion, and exchange sorts; quicksort, heapsort; recursion. Analysis of run-time behavior of algorithms; Big-O notation. Introduction to classes in C++. Credit not allowed for more than one introductory data structures class, such as COEN 12 or CSCI 61. Prerequisite: A grade of C- or better in either COEN 11 or COEN 44. Co-requisite: COEN 12L. Recommended co-requisite: COEN 19 or MATH 51. (4 units)

COEN 12L. Abstract Data Types and Data Structures Laboratory

Laboratory for COEN 12. Co-requisite: COEN 12. (1 unit)

COEN 19. Discrete Mathematics

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

COEN 20. Introduction to Embedded Systems

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

COEN 20L. Embedded Systems Laboratory

Laboratory for COEN 20. Co-requisite: COEN 20. (1 unit)

COEN 21. Introduction to Logic Design

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

COEN 21L. Logic Design Laboratory

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

COEN 29. Current Topics in Computer Science and Engineering

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

COEN 44. Applied Programming in C

Computer programming in C, including input/output, selection structures, loops, iterative solutions, function definition and invocation, macros, pointers, memory allocation, and top-down design. Programming of elementary mathematical operations. Applications to engineering problems. Prerequisite: MATH 13.
Co-requisite: COEN 44L. (4 units)

COEN 44L. Applied Programming in C Laboratory

Laboratory for COEN 44. Co-requisite: COEN 44. (1 unit)

COEN 60. Introduction to Web Technologies

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

COEN 60L. Introduction to Web Technologies Laboratory

Laboratory for COEN 60. Co-requisite: COEN 60. (1 unit)

COEN 79. Object-Oriented Programming and Advanced Data Structures

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

COEN 79L. Object-Oriented Programming and Advanced Data Structures Laboratory

Laboratory for COEN 79. Co-requisite: COEN 79. (1 unit)

Upper-Division Undergraduate Courses

COEN 100. Research Seminar

Introduction to research in computing, covering several research areas. (1 unit)

COEN 120. Real Time Systems

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

COEN 120L. Real Time Systems Laboratory

Laboratory for COEN 120. Co-requisite: COEN 120. (1 unit)

COEN 122. Computer Architecture

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

COEN 122L. Computer Architecture Laboratory

Laboratory for COEN 122. Co-requisite: COEN 122. (1 unit)

COEN 123. Mechatronics

Introduction to behavior, design, and integration of electromechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and integration of transducers, microcontrollers, and actuators. Also listed as ELEN 123 and MECH 143. Prerequisites: ELEN 50 with a grade of C– or better and COEN 11 or 44. Co-requisite: COEN 123L. (4 units)

COEN 123L. Mechatronics Laboratory

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

COEN 127. Advanced Logic Design

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

COEN 127L. Advanced Logic Design Laboratory

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

COEN 129. Current Topics in Computer Science and Engineering

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

COEN 140. Machine Learning and Data Mining

Machine learning as a field has become increasingly pervasive, with applications from the web (search, advertisements, and recommendation) to national security, from analyzing biochemical interactions to traffic and emissions to astrophysics. This course presents an introduction to machine learning and data mining, the study of computing systems that improve their performance through learning from data. This course is designed to cover the main principles, algorithms, and applications of machine learning and data mining. Prerequisites: A grade of C- or better in AMTH 108, MATH 53, and COEN 12. (4 units)

COEN 140L. Machine Learning and Data Mining Laboratory

Laboratory for COEN 140. Co-requisite: COEN 140. (1 unit)

COEN 143. Internet of Things

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

COEN 143L. Internet of Things Laboratory

Laboratory for COEN 143. Co-requisite: COEN 143. (1 unit)

COEN 145. Introduction to Parallel Computing

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

COEN 145L. Introduction to Parallel Computing Laboratory

Laboratory for COEN 145. Co-requisite: COEN 145. (1 unit)

COEN 146. Computer Networks

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

COEN 146L. Computer Networks Laboratory

Laboratory for COEN 146. Co-requisite: COEN 146. (1 unit)

COEN 148. Computer Graphics Systems

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

COEN 150. Introduction to Information Security

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

COEN 150L. Introduction to Information Security Laboratory

Laboratory for COEN 150. Corequisite: COEN 150. (1 unit)

COEN 152. Introduction to Computer Forensics

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

COEN 152L. Introduction to Computer Forensics Laboratory

Laboratory for COEN 152. Co-requisite: COEN 152. (1 unit)

COEN 160. Object-Oriented Analysis, Design and Programming

Four important aspects of object-oriented application development are covered: fundamental concepts of the OO paradigm, building analysis and design models using UML, implementation using Java, and testing object-oriented systems. Prerequisite: A grade of C- or better in COEN 79 or CSCI 61. Co-requisite: COEN 160L. Co-located with COEN 275. (4 units)

COEN 160L. Object-Oriented Analysis, Design and Programming Laboratory

Laboratory for COEN 160. Co-requisite: COEN 160. (1 unit)

COEN 161. Web Development

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

COEN 161L. Web Development Laboratory

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

COEN 162. Web Infrastructure

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

COEN 163. Web Usability

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

COEN 163L. Web Usability Laboratory

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

COEN 164. Advanced Web Development

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

COEN 164L. Advanced Web Development Laboratory

Laboratory for COEN 164. Co-requisite: COEN 164. (1 unit)

COEN 165. Introduction to 3D Animation & Modeling/Modeling & Control of Rigid Body Dynamics

Mathematical and physical principles of motion of rigid bodies, including movement, acceleration, inertia and collision. Modeling of rigid body dynamics for three-dimensional graphic simulation; controlling the motion of rigid bodies in robotic applications. May be repeated twice for credit. Also listed as ARTS 173. (5 units)

COEN 166. Artificial Intelligence

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

COEN 166L. Artificial Intelligence Laboratory

Laboratory for COEN 166. Co-requisite: COEN 166. (1 unit)

COEN 168. 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, touchscreen. Optimizing user interface for a small screen. Effective memory management on a constrained device. Embedded graphics. Persistent data storage. Prerequisite: a grade of C- or better in COEN 20 or COEN 79 or equivalent. Co-requisite: COEN 168L. Co-located with COEN 268. (4 units)

COEN 168L. Mobile Application Development Laboratory

Laboratory for COEN 168. Co-requisite: COEN 168. (1 unit)

COEN 169. Web Information Management

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

COEN 171. Principles of Design and Implementation of Programming Languages

High-level programming language concepts and constructs. Costs of use and implementation of the constructs. Issues and trade-offs in the design and implementation of programming languages. Critical look at several modern high-level programming languages. Prerequisite: A grade C- or better in COEN 12 or CSCI 61. (4 units)

COEN 174. Software Engineering

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

COEN 174L. Software Engineering Laboratory

Laboratory for COEN 174. Co-requisite: COEN 174. (1 unit)

COEN 175. Introduction to Formal Language Theory and Compiler Construction

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

COEN 175L. Introduction to Formal Language Theory and Compiler Construction Laboratory

Laboratory for COEN 175. Co-requisite: COEN 175. (1 unit)

COEN 177. Operating Systems

Introduction to operating systems. Operating system concepts, computer organization models, storage hierarchy, operating system organization, processes management, inter process communication and synchronization, memory management and virtual memory, I/O subsystems, and file systems. Design, implementation, and performance issues. Prerequisites: A grade of C- or better in either COEN 12 or CSCI 61 and in COEN 20. Co-requisite: COEN 177L. (4 units)

COEN 177L. Operating Systems Laboratory

Laboratory for COEN 177. Co-requisite: COEN 177. (1 unit)

COEN 178. Introduction to Database Systems

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

COEN 178L. Introduction to Database Systems Laboratory

Laboratory for COEN 178. Co-requisite: COEN 178. (1 unit)

COEN 179. Theory of Algorithms

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

COEN 180. Introduction to Information Storage

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

COEN 188. Co-op Education

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

COEN 189. Co-op Technical Report

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

COEN 193. Undergraduate Research

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

COEN 194. Design Project I

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

COEN 195. Design Project II

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

COEN 196. Design Project III

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

COEN 199. Directed Research/Reading

Special problems. By arrangement. (1–5 units)

Graduate Courses

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

COEN 200. Logic Analysis and Synthesis

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

COEN 201. Digital Signal Processing I

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

COEN 201E. Digital Signal Processing I & II

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

COEN 202. Digital Signal Processing II

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

COEN 203. VLSI Design I

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

COEN 204. VLSI Design II

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

COEN 207. SoC (System-on-Chip) Verification

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

COEN 210. Computer Architecture

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

COEN 218. Input-Output Structures

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

COEN 225. Secure Coding in C and C++

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

COEN 233. Computer Networks

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

COEN 234. Network Management

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

COEN 235. Client/Server Programming

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

COEN 238. Multimedia Information Systems

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

COEN 239. Network Design Analysis

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

COEN 240. Machine Learning

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

COEN 241. Cloud Computing

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

COEN 242. Big Data

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

COEN 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: COEN 12 or 912C and COEN 146 or 233. (4 units)

COEN 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)

COEN 251. Network Security

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

COEN 252. Computer Forensics

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

COEN 252L. Laboratory for COEN 252

Co-requisite: COEN 252. (1 unit)

COEN 253. Secure Systems Development and Evaluation

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

COEN 259. Advanced Compilers Design

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

COEN 266. Artificial Intelligence

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

COEN 268. Mobile Application Development

Design and implementation of applications running on a mobile platform such as smartphones and tablets. Programming languages and development tools for mobile SDKs. Writing code for peripherals—GPS, accelerometer, and touchscreen. Optimizing user interface for a small screen. Effective memory management on a constrained device. Embedded graphics. Persistent data storage. Prerequisite: COEN 12 or 912C or equivalent. (4 units)

COEN 272. Web Search and Information Retrieval

Basic and advanced techniques for organizing large-scale information on the Web. Search engine technologies. Big data analytics. Recommendation systems. Text/Web clustering and classification. Text mining. Prerequisites: AMTH 108 or AMTH 210, MATH 53 or AMTH 246, and COEN 179 or 279. (4 units)

COEN 275. Object-Oriented Analysis, Design, and Programming

Four important aspects of object-oriented application development are covered: fundamental concepts of the OO paradigm, building analysis and design models using UML, implementation using Java, and testing object-oriented systems. Prerequisite: COEN 12 or 912C. (4 units)

COEN 277. Human-Computer Interaction

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 guidelines, principles, theories, techniques, and applications. Prerequisite: COEN 12 or 912C or equivalent. (2 units)

COEN 278. Advanced Web Programming

Advanced topics in Web Application Development; Development with Web Frameworks (Ruby with Rails), implement web services and management of web security. Prerequisites: COEN 60 and 161 or demonstrated proficiency. (4 units)

COEN 279. Design and Analysis of Algorithms

Techniques of design and analysis of algorithms: proof of correctness; running times of recursive algorithms; design strategies: brute-force, divide and conquer, dynamic programming, branch-and-bound, backtracking, and greedy technique; max flow/ matching. Intractability: lower bounds; P, NP, and NP-completeness. Also listed as AMTH 377. Prerequisite: COEN 912C or equivalent. (4 units)

COEN 280. Database Systems

Data models. Relational databases. Database design (normalization and decomposition). Data definition and manipulation languages (relational algebra and calculus). Architecture of database management systems. Transaction management. Concurrency control. Security, distribution, and query optimization. Prerequisites: COEN 12 or 912C or Data Structures class and COEN 283 or equivalent. (4 units)

COEN 281. Pattern Recognition and Data Mining

Provides an overview of data analytics methods, including data representation and preprocessing, proximity, finding nearest neighbors, exploratory analysis, dimensionality reduction, association analysis and sequential patterns, supervised inference and prediction, classification, regression, model selection and evaluation, overfitting, clustering, and advanced topics. Students will analyze real-world data using state-of-the-art data science libraries. Prerequisites: AMTH 210 and 245 or equivalent, COEN 12 or 912C or equivalent. (4 units)

COEN 282. Energy Management Systems

Energy Management Systems (EMS) is a class of control systems that electric utility companies utilize for three main purposes: monitoring, engagement and reporting. Monitoring tools allow electric utility companies to manage their assets to maintain the sustainability and reliability of power generation and delivery. Engagement tools help in reducing energy production costs, transmission and distribution losses by optimizing utilization of resources and/or power network elements. Reporting tools help track operational costs and energy obligations. Also listed as ELEN 288. (2 units)

COEN 283. Operating Systems

Fundamentals of operating systems. Processes, Memory, I/O, and File Systems. Implementation and performance issues. Security, multimedia systems, multiple-processor systems. Prerequisites: COEN 12 or 912C and 20 or 920C or equivalent. (4 units)

COEN 285. Software Engineering

Systematic approaches to software design, project management, implementation, documentation, and maintenance. Software design methodologies: SA/SD, OOA/OOD. Software quality assurance; testing. Reverse engineering and re-engineering. CASE. Term project. (4 units)

COEN 286. Software Quality Assurance and Testing

Social factors. Configuration management. Software complexity measures. Functional and structuring testing. Test coverage. Mutation testing. Trend analysis. Software reliability. Estimating software quality. Testing OOPs. Confidence in the software. Software quality control and process analysis. Managerial aspects. Prerequisite: COEN 285 or equivalent. (2 units)

COEN 287. Software Development Process Management

Management of the software development process at both the project and organization levels. Interrelationship of the individual steps of the development process. Management techniques for costing, scheduling, tracking, and adjustment. Prerequisite: COEN 285 or equivalent. (2 units)

COEN 288. Software Ethics

Broad coverage of ethical issues related to software development. Formal inquiry into normative reasoning in a professional context. Application of ethical theories to workplace issues, viz., cost-benefit analysis, externalities, individual and corporate responsibility, quality and authorship of product. Case studies and in-class topics of debate include computer privacy, encryption, intellectual property, software patents and copyrights, hackers and break-ins, freedom of speech and the internet, error-free code, and liability. (2 units)

COEN 290. Computer Graphics

Raster and vector graphics image generation and representation. Graphics primitives, line and shape generation. Scan conversion anti-aliasing algorithms. Simple transformation, windowing and hierarchical modeling. Interactive input techniques. 3D transformations and viewing, hidden surface removal. Introduction to surface definition with B-spline and Bezier techniques. Surface display with color graphics. Prerequisites: AMTH 245 and COEN 12 or 912C. (4 units)

COEN 291 Computational Creativity

Computational Creativity is a subfield of Artificial Intelligence that intersects with the arts, philosophy, and cognitive psychology. The goal of computational creativity is to model, simulate or replicate creativity using computer systems, through the creation of either autonomous creative systems or collaborative systems that engage with humans on creative tasks. The course will enable students to critically analyze questions concerning the creative capabilities of computer systems and the impact of computing on the arts and society at large, and prepare students to contribute to research in this field. Prerequisites: Good programming skills. (4 units)

COEN 296A. Topics in Computer Science and Engineering

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

COEN 296B. Topics in Computer Science and Engineering

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

COEN 303. Logic Design Using HDL

Algorithmic approach to design of digital systems. Use of hardware description languages for design specification. Structural, register transfer, and behavioral view of HDL. Simulation and synthesis of systems descriptions. Also listed as ELEN 603. Prerequisite: ELEN/COEN 127 or equivalent. (2 units).

COEN 305. VLSI Physical Design

Physical design is the phase that follows logic design, and it includes the following steps that precede the fabrication of the IC logic partitioning: cell layout, floor planning, placement, routing. These steps are examined in the context of very deep submicron technology. Effects of parasitic devices and packaging are also considered. Power distribution and thermal effects are essential issues in this design phase. Also listed as ELEN 389. Prerequisites: COEN 204/ELEN 388 or equivalent. (2 units)

COEN 307. Digital Computer Arithmetic

Fixed-point and floating-point number representation and arithmetic. High-speed addition and subtraction algorithms and architectures. Multiplication and division algorithms and architectures. Decimal arithmetic. Serial vs. parallel arithmetic circuits. Residue number arithmetic. Advanced arithmetic processing units. High-speed number crunchers. Arithmetic codes for error detection. VLSI perspective and reliability issues. Signed-digit (SD) representation of signed numbers. Prerequisite: COEN 210. (2 units)

COEN 308. Design for Testability

Principles and techniques of designing circuits for testability. Concept of fault models. The need for test development. Testability measures. Ad hoc rules to facilitate testing. Easily testable structures, PLAs. Scan-path techniques, full and partial scan. Built-in self-testing (BIST) techniques. Self-checking circuits. Use of computer-aided design (CAD) tools. Also listed as ELEN 608. Prerequisite: COEN 200 or equivalent. (2 units)

COEN 313. Advanced Computer Architecture

Advanced system architectures. Overview of different computer architecture paradigms. Hardware-supported instruction level parallelism, VLIW architectures, multithreaded processors. Performance and correctness issues (coherency, consistency, and synchronization) for different multiprocessor configuration alternatives (UMA, NUMA). SIMD architecture alternatives. Warehouse massive-scale computing. Prerequisite: COEN 210. (4 units)

COEN 315. Web Architecture and Protocols

History and overview of World Wide Web technology. Web clients and browsers. State management, session persistence, and cookies. Spiders, bots, and search engines. Web proxies. Web servers and server farms. HTTP and web protocols. Web caching and content distribution. Load balancing. Web security and firewalls. Web workload and traffic characterization. Future of web technology. Prerequisite: COEN 233 or equivalent. (4 units)

COEN 317. Distributed Systems

Fundamental algorithms for distributed system architectures, inter-process communications, data consistency and replication, distributed transactions and concurrency control, distributed file systems, network transparency, fault tolerant distributed systems synchronization, reliability. Prerequisites: COEN 233 and 283 or equivalent. (4 units)

COEN 318. Parallel Computation Systems

Introduction to parallel processing. Parallel system classifications. Parallel computation models and algorithms. Performance analysis and modeling. Interconnection networks. Vector processors. SIMD and MIMD architectures and their hybrid. Systolic arrays. Dataflow architectures. Introduction to parallel languages and parallelizing compilers. Prerequisites: COEN 210 and AMTH 247 or instructor approval. (4 units)

COEN 319. Parallel Computing

How to effectively program parallel computers, from smartphones to large clusters. Types of parallel architectures, routing, data parallel, shared-memory, and message-passing parallel programming, load balancing, evaluation of parallel algorithms, advanced topics. Students will implement select parallel algorithms for solving real-world data analytics problems, including parallel algorithms for sparse matrix and graph operations. Prerequisites: COEN 12 or 912C or CSCI 61 or equivalent. (4 units)

COEN 320. Computer Performance Evaluation

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

COEN 329. Network Technology

Advanced technologies and protocols for broadband LAN, MAN, WAN, L2 VPN, and L3 VPN, Pseudo Wire, VPLS (Virtual Private LAN Services). Current technologies: tunneling, QoS and security in content delivery, PON (Passive Optical Networks), support for multimedia communication, server farms, server redundancy, GMPLS (Generalized Multi-Protocol Label Switching). Hot Standby Router Protocol. Emerging technologies, e.g., Carrier Ethernet. Prerequisite: COEN 233 or equivalent. (4 units)

COEN 331. Wireless and Mobile Networks

TCP/IP architecture. Fundamentals of wireless transmission. IEEE 802.11 architecture and protocols. Bluetooth protocol stack. BLE. IEEE 802.15.4 and ZigBee. Real-time networks. Cellular communication fundamentals. Long-Term Evolution (LTE). Software-defined networking. 5G. Prerequisite: COEN 233 or equivalent. (4 units)

COEN 332. Wireless/Mobile Multimedia Networks

This course will cover IMS (Internet Protocol Multimedia Subsystem), an architectural framework for providing IP-based real-time traffic, such as voice and video, in wireless networks. IMS aims at the convergence of data, speech, fixed, and mobile networks and provides real-time services on top of the UMTS (Universal Mobile Telecommunication System) packet-switched domain. Prerequisite: COEN 331. (4 units)

COEN 335. High-Performance Networking

High-speed networks requirements, i.e., quality of service (QoS). Technologies and protocols for high-speed LAN, MAN, WAN, Layer 2 and Layer 3 switching, giga-bit Ethernet (1GE, 10GE), signaling protocols, fibre channel, Ethernet over SONET/SDH, PoS, fiber optics communications, DWDM, and CWDM. Tera-bit routers. Infiniband switching technology, End-to-End Layer 2 and Layer 3 management. Emerging technologies: 40GE, 100GE. Prerequisite: COEN 233 or equivalent. (2 units)

COEN 337. Internet Architecture and Protocols

In-depth and quantitative study of Internet algorithms, protocols, and services. Topics include: scheduling and buffer/queue management, flow/congestion control, routing, traffic management, support for multimedia/real-time communication. Prerequisite: COEN 233 or equivalent. (4 units)

COEN 338. Image and Video Compression

Image and video compression. Entropy coding. Prediction. Quantization. Transform coding and 2-D discrete cosine transform. Color compression. Motion estimation and compensation. Digital video. Image coding standards such as JPEG 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. Rate-distortion theory and optimization. Visual quality and coding efficiency. Brief intro to 3D video coding and 3D-HEVC. Deep learning approaches. Applications. Also listed as ELEN 641. Prerequisites: AMTH 108, AMTH 245 and basic knowledge of algorithms. (4 units)

COEN 339. Audio and Speech Compression

Audio and speech compression. Digital audio signal processing fundamentals. Non-perceptual coding. Perceptual coding. Psychoacoustic model. High-quality audio coding. Parametric and structured audio coding. Audio coding standards. Scalable audio coding. Speech coding. Speech coding standards. Also listed as ELEN 639. Prerequisites: AMTH 108, AMTH 245 and COEN 279 or equivalent. (2 units)

COEN 340. Digital Image Processing I

Digital image representation and acquisition, color representation; point and neighborhood processing; image enhancement; morphological filtering; Fourier, cosine, and wavelet transforms. Also listed as ELEN 640. Prerequisite: COEN 201 or equivalent. (2 units)

COEN 341. Information Theory

Introduction to the fundamental concepts of information theory. Source models. Source coding. Discrete channel without memory. Continuous channel. Alternate years. Also listed as ELEN 244. Prerequisites: ELEN 241 and AMTH 211. (2 units)

COEN 342. Deep Learning

Deep neural networks and their applications to various problems, e.g., speech recognition, image segmentation, and natural language processing. Will cover the underlying theory of various types of neural networks including feed-forward, convolutional, and recurrent neural networks, the range of applications to which it has been applied, and current trends in the field. Prerequisite: COEN 240 or COEN 281. (4 units)

COEN 343. Digital Image Processing II

Image restoration using least squares methods in image and spatial frequency domain; matrix representations; blind deconvolution; reconstructions from incomplete data; image segmentation methods; three-dimensional models from multiple views. Also listed as ELEN 643. Prerequisite: COEN 340. (2 units)

COEN 344. Computer Vision I

Introduction to image understanding, feature detection, description, and matching; feature based alignment; structure from motion; stereo correspondence. Also listed as ELEN 644. Prerequisites: COEN 340 and knowledge of linear algebra. (2 units)

COEN 345. Computer Vision II

Learning and inference in vision; regression models; deep learning for vision; classification strategies; detection and recognition of objects in images. Also listed as ELEN 645. Prerequisites: COEN 340 and knowledge of probability. (2 units)

COEN 347. Advanced Image and Video Coding

Advanced topics in image and video coding, selected from: Wavelet transform and compression. Sparse coding. Compressive sensing. Standards such as JPEG 2000, JPEG XT, JPEG PLENO, VVC, and HEVC extensions such as SHVC, MV-HEVC, 3D-HEVC, and SCC. Scalable video coding. Multiview and 3D video coding. Screen content coding. High dynamic range HDR. Light-field, point-cloud, and holographic imaging. Distributed video coding. Video communications systems. Congestion control. Rate control. Error control. Transcoding. Machine and deep learning approaches. Image/video coding for machines. Other advanced topics. Prerequisite: COEN 338 or ELEN 641. (4 units)

COEN 348. Speech Processing I

Review of sampling and quantization. Introduction to digital speech processing. Elementary principles and applications of speech analysis, synthesis, and coding. Speech signal analysis and modeling. The LPC Model. LPC parameter quantization using line spectrum pairs (LSPs). Digital coding techniques: quantization, waveform coding, predictive coding, transform coding, hybrid coding, and sub-band coding. Applications of speech coding in various systems. Standards for speech and audio coding. Also listed as ELEN 421. Prerequisite: ELEN 233 and/or ELEN 334 or equivalent. (2 units)

COEN 349. Speech Processing II

Advanced aspects of speech analysis and coding. Analysis-by-Synthesis (AbS) coding of speech, Analysis-as-Synthesis (AaS) coding of speech. Code-excited linear prediction speech coding. Error-control in speech transmission. Application of coders in various systems (such as wireless phones). International standards for speech (and audio) coding. Real-time DSP implementation of speech coders. Speech recognition and biometrics. Research project on speech processing. Also listed as ELEN 422. Prerequisite: ELEN 421. (2 units)

COEN 351. Internet and E-Commerce Security

Special security requirements of the internet. Secure electronic business transactions. Email security. CGI scripts, cookies, and certified code. Intrusion prevention strategies. Designing secure E-commerce systems. AGENT technologies. Legal requirements for E-Commerce. Prerequisite: COEN 253. Co-requisite: COEN 351L. (3 units)

COEN 351L. Laboratory for COEN 351

Co-requisite: COEN 351. (1 unit)

COEN 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 COEN 250. (2 units)

COEN 353. Trust and Privacy in Online Social Network

This course will introduce fundamental concepts in trustworthy computing and privacy; discuss classic (1) trust models, such as direct/indirect model, belief theory based model, entropy based model, fuzzy model, and (2) privacy models, such as k-anonymity, l-diversity, t-closeness models; investigate evolution of trust/privacy attacks and defenses in online social networks; and discuss state-of-the-art trust/privacy researches in online social networks. Prerequisites: AMTH 108 or AMTH 210, and COEN 179 or 279. (4 units)

COEN 354. Social Network Analysis and Risk

Social network analysis. Cybersecurity risks. Network measurement. Centrality. Random networks. Submodularity. Diffusion models. Community detection. Sybil defense. Adaptive crawling. Influence maximization. Misinformation containment. Prerequisites: AMTH 108 or AMTH 210, and COEN 179 or 279. (4 units)

COEN 359. Design Patterns

Software design patterns and their application in developing reusable software components. Creational, structural, and behavioral patterns are studied in detail and are used in developing a software project. Prerequisite: COEN 275. (4 units)

COEN 376. Expert Systems

Overview of tools and applications of expert systems, as well as the theoretical issues: What is knowledge, can it be articulated, and can we represent it? Stages in the construction of expert systems: problem selection, knowledge acquisition, development of knowledge bases, choice of reasoning methods, life cycle of expert systems. Basic knowledge of representation techniques (rules, frames, objects) and reasoning methods (forward-chaining, backward-chaining, heuristic classification, constraint reasoning, and related search techniques). Requires completion of an expert systems project. Prerequisite: COEN 266 and a course including predicate logic and lambda calculus. (4 units)

COEN 379. Advanced Design and Analysis of Algorithms

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

COEN 380. Advanced Database Systems

Database system design and implementation. Disk and file organization. Storage and indexes; query processing and query optimization. Concurrency control; transaction management; system failures and recovery. Parallel and distributed databases. MapReduce. Prerequisite: COEN 280 or equivalent. (4 units)

COEN 383. Advanced Operating Systems

Advanced topics beyond the fundamentals of operating systems, including a look at different systems software concepts within different components of a modern operating system, and applications beyond the scope of an individual operating system. Prerequisite: COEN 283 or equivalent. (4 units)

COEN 385. Formal Methods in Software Engineering

Specification, verification, validation. Notations and the models they support. Classes of specification models: algebraic, state machine, model theoretic. Appropriate use of formal methods: requirements, design, implementation, testing, maintenance. Data and program specification and design using Z or any other modern formal method. Case studies. Prerequisites: Course including predicate logic and lambda calculus. (2 units)

COEN 386. Software Architecture

Understanding and evaluating software systems from an architectural perspective. Classification, analysis, tools, and domain-specific architectures. Provides intellectual building blocks for designing new systems using well-understood architectural paradigms. Examples of actual system architectures that can serve as models for new designs. Prerequisite: COEN 385. (2 units)

COEN 389. Energy-Efficient Computing

This course covers energy-efficient software practices. Historically, software has always been written to run faster and faster, and energy has always been considered a plentiful resource. However, it has been shown that computers use a lot of energy, which may not always be so plentiful, leading to the redesign of traditional software solutions in different areas. The focus of the course will be on operating systems, networks, compilers, and programming. Prerequisites: COEN 233 or equivalent and COEN 283 or equivalent. (2 units)

COEN 396A. Advanced Topics in Computer Science and Engineering

Various subjects of current interest. May be taken more than once if topics differ. See department website for current offerings and descriptions. (2 units)

COEN 396B. Advanced Topics in Computer Science and Engineering

Various subjects of current interest. May be taken more than once if topics differ. See department website for current offerings and descriptions. (4 units)

COEN 400. Computer Science and Engineering Graduate Seminar

Regularly scheduled seminars on topics of current interest in the field of computer science and engineering. May apply a maximum of 1 unit of credit from COEN 400 to any graduate degree in the Department of Computer Science and Engineering. Consult the department office for additional information. Prerequisite: Completion of 12 or more graduate units at SCU. P/NP grading. (1 unit)

COEN 485. Software Engineering Capstone

A capstone course in which the student applies software engineering concepts and skills to a software engineering project. Team projects are strongly encouraged. Projects will cover all aspects of the software life-cycle: specification of requirements and functionality; project planning and scoping; system and user interface definition; analysis of architectural solutions; detailed system design; implementation and integration; testing and quality assurance; reliability, usability, and performance testing, documentation, evolution, and change management. The course is typically restricted only to MSSE students. Students enrolled must complete three one-quarter (preferably consecutive) sections. Prerequisites: COEN 286 and COEN 386. (2 units)

COEN 490. Mathematical Reasoning in Computer Science

(Seminar Style) Short introduction to the praxis of mathematical proofs. Students will write and present proofs and papers on instructor-approved topics related to computer science and engineering. Stress is on mathematical exactness. Maximum enrollment of 10. Enrollment is by preference to Ph.D. students, but is open to other students as space allows. Prerequisite: Open to Ph.D. students or with instructor approval. (2 units)

COEN 493. Directed Research

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

COEN 497. Master's Thesis Research

By arrangement. Research must be directed by a tenure-track faculty member in computer science and engineering. Limited to master's students in computer science and engineering. Must be supervised by a regular CSE full-time faculty. Prerequisite: Registration requires the faculty member's and department chair approval. (1–9 units per quarter, for a total of at least 8 units)

COEN 498. Ph.D. Thesis Research

By arrangement. Research must be directed by a tenure-track faculty member in computer science and engineering. Limited to Ph.D. students in computer science and engineering. Must be supervised by a regular CSE full-time faculty Prerequisite: Registration requires the faculty member's and department chair approval. (1–15 units per quarter, for a total of 36 units)

COEN 499. Independent Study

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

COEN 912C. Abstract Data Types and Data Structures

Intense coverage of topics related to abstract data types and data structures. Data abstraction: abstract data types, information hiding, interface specification. Basic data structures: stacks, queues, lists, binary trees, hashing, tables, graphs; implementation of abstract data types in the C language. Internal sorting: review of selection, insertion, and exchange sorts; quicksort, heapsort; recursion. Analysis of run-time behavior of algorithms; Big-O notation. Introduction to classes in C++. Foundation course not for graduate credit. Prerequisite: A grade of B or higher in a programming language course. (2 units)

COEN 920C. Embedded Systems and Assembly Language

Intense coverage of topics related to embedded systems and assembly language. Introduction to computer organization: CPU, registers, buses, memory, I/O interfaces. Number systems: arithmetic and information representation. Assembly language programming: addressing techniques, arithmetic and logic operations, branching and looping, stack operations, procedure calls, parameter passing, and interrupts. C language programming: pointers, memory management, stack frames, interrupt processing. Foundation course not for graduate credit. Prerequisite: A grade of B or higher in a programming language course. (2 units)

COEN 921C. Logic Design

Intense coverage of topics related to logic design. Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flip-flops; timing; registers; counters. Programmable logic, PLD, and FPGA. Use of industry quality CAD tools for schematic capture and HDL in conjunction with FPGAs. Foundation course not for graduate credit. Also listed as ELEN 921C. (2 units)

Chapter 11: Department of Electrical and Computer Engineering

Professors Emeritus: Dragoslav D. Siljak
Thomas J. Bannan Professor: Sally L. Wood
Professors: Shoba Krishnan *(Chair)*, Timothy J. Healy, Tokunbo Ogunfunmi, Sarah Kate Wilson, Cary Y. Yang, Aleksandar Zecevic
Associate Professor: M. Mahmudur Rahman
Assistant Professors: Maryam Khanbaghi, Maria Kyrarini, Kurt Schab, Sara Tehranipoor, 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.

Master's Degree Program And Requirements

The master's degree will be granted to degree candidates who complete a program of studies approved by a faculty advisor. The degree does not require a thesis, but students may include a thesis in their program with up to nine units for their thesis work. The program must consist of no less than 46 units. In addition, a 3.0 cumulative GPA (B average) must be earned in all coursework taken at Santa Clara University. Residence requirements are met by completing no less than 37 units of the graduate program at Santa Clara University. A maximum of nine quarter units (six-semester units) of graduate-level coursework may be transferred from other accredited institutions at the discretion of the student's advisor. All units applied toward the degree, including those transferred from other institutions, must be earned within six years from initial enrollment.

Students must develop a program of studies with an academic advisor and file the approved program during their first term of enrollment at Santa Clara University. The program of studies must contain a minimum of 46 units of graduate-level engineering courses which include at least 27 units of courses offered within the electrical and computer department and no more than four units of engineering management courses.

The program of studies must include the following:

1. Graduate Core-Enrichment Experience (minimum 8 units): Students must take a minimum of 8 units of the Graduate Core Enrichment Experience.
    - A minimum of 4 units must be from the Graduate Core which requires at least two courses from the three areas
        - Emerging Topics in Engineering,
        - Engineering and Business/Entrepreneurship,
        - Engineering and Society).

- The remaining 4 units can be accumulated by the following
  - a) Taking one or more major technical electives,
  - b)Taking additional classes from the Graduate Core,
  - c) Taking Cooperative Education course
  - d) combining courses from a, b and c.

  For additional information please see Chapter 6: Enrichment Experience and Graduate Core Requirements.

2. Applied Mathematics (4 units)
3. Electrical and Computer Engineering primary focus area (minimum 6 units). Students must select and meet the requirements of one of the six focus areas listed below.
   - **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)\
4. 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.
5. Additional graduate courses recommended and approved by the graduate program advisor.

These M.S. degree requirements may be adjusted by the advisor based on the student's previous graduate work.

An advisor may approve selected undergraduate classes that do not duplicate course content of graduate courses in the program of studies. No more than 15 units of electives may be selected from the following upper-division undergraduate courses: 105, 112, 116, 117, 118, 130, 133, 141, 144, 151, 152, 156, 160, 164, 183 and 184.

Alterations in the approved program, consistent with the above departmental requirements, may be requested at any time by a petition initiated by the student and approved by the advisor.

Students with relevant technical backgrounds may be admitted to the master's program without an undergraduate degree in electrical or electrical and computer engineering from an accredited program. In order to guarantee prerequisites for graduate courses, those students must take sufficient additional courses beyond the 46-unit minimum to ensure coverage of all areas of the undergraduate EE core requirements. A student who has earned a Fundamentals of Electrical and Computer Engineering Certificate will have satisfied these background requirements.

Undergraduate Core Courses

- ELEN 21 Introduction to Logic Design
- ELEN 50 Electric Circuits I
- ELEN 100 Electric Circuits II
- ELEN 115 Electronic Circuits I
- ELEN 120 Microprocessor System Design

The advisor will determine which courses must be taken to meet these requirements. Undergraduate core courses will not be included in the 46 units required for the master's degree.

Please Note: In general, no credit will be allowed for courses that duplicate prior coursework, including courses listed above as degree requirements. (However, graduate-level treatment of a topic is more advanced than an undergraduate course with a similar title.) Students should discuss any adjustments of these requirements with their academic advisor before filing their program of studies. In all cases, prerequisite requirements should be interpreted to mean the course specified or an equivalent course taken elsewhere.

Engineer's Degree Program And Requirements

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

Electrical and Computer Engineering courses at the introductory Master of Science level (e.g., ELEN 210, 211, 212, 230, 231, 236, 241, 250, 261; and AMTH 210, 211, 220, 221, 230, 231, 235, 236, 240, 245, 246) are not generally acceptable in an Engineer's Degree program of studies. However, with the approval of the advisor, the student may include up to three of these courses in the Engineer's Degree program. The department also requires that at least 15 units of the program of studies be in topics other than the student's major field of concentration. Candidates admitted to the Electrical and Computer Engineering Program who have M.S. degrees in fields other than electrical and computer engineering must include in their graduate programs (M.S. and Engineer's Degree combined) a total of at least 46 units of graduate-level electrical and computer engineering coursework approved by an academic advisor.

Ph.D. Program And Requirements

The Doctor of Philosophy (Ph.D.) degree is conferred by the School of Engineering primarily in recognition of competence in the subject field and the ability to investigate engineering problems independently, resulting in a new contribution to knowledge in the field. The work for the degree consists of engineering research, the preparation of a thesis based on that research, publication of the research, and a program of advanced studies in engineering, mathematics, and related physical sciences.

The Department of Electrical and Computer Engineering and the Department of Bioengineering are collaborating to offer a Ph.D. in interdisciplinary topics related to Bioengineering. Faculty from both departments will co-advise the Ph.D. students and the degree will be awarded by the Department of Electrical and Computer Engineering

Preliminary Examination

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

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

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

General Requirements

Thesis Advisor

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

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

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

Doctoral Committee

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

Residence

The doctoral degree is granted based on achievement, rather than on the accumulation of units of credit. However, the candidate is expected to complete a minimum of 72 quarter units of graduate credit beyond the master's degree. Of these, 36 quarter units may be earned through coursework and independent study, and 36 through the thesis. All Ph.D. thesis units are graded on a Pass/No Pass basis. 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 his/her research proposal as part of a comprehensive oral examination on the coursework and the subject of his/her research work. The student should make arrangements for the comprehensive examinations through the doctoral committee. A student who passes the comprehensive examinations is considered a degree candidate. The comprehensive examinations typically must be completed within four years from the time the student is admitted to the doctoral program. Comprehensive examinations may be repeated once, in whole or in part, at the discretion of the doctoral committee.

Thesis Research and Defense

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

Thesis and Publication

At least one month before the degree is to be conferred, the candidate must submit to the Office of the Dean of Engineering two copies of the final version of the thesis describing the research in its entirety. The thesis will not be considered as accepted until approved by the doctoral committee and one or more refereed articles based on it are accepted for publication in a first-tier professional or scientific journal approved by the doctoral committee. All doctoral theses must also be archived in the University library.

Time Limit for Completing Degree

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

Additional Graduation Requirements

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

Certificate Programs

General Information

Certificate programs are designed to provide an intensive background in a narrow area at the graduate level. At roughly one-third of the units of a master's degree program, the certificate is designed to be completed in a much shorter period of time. These certificate programs are appropriate for students working in the industry who wish to update their skills or those interested in changing their career path. Students can only take courses that are required for the certificate. Please see Chapter 18 for additional information.

Admission

To be accepted into a certificate program, the applicant must have a bachelor's degree and meet any additional requirements for the specific certificate. Exceptions based on work experience may be granted for the Certificate in Fundamentals of Electrical and Computer Engineering. Admitted students are responsible for ensuring that they have the prerequisites for all courses they take in the Certificate Program.

Grade Requirements

Students must receive a minimum grade of C in each course and have an overall GPA of 3.0 or better to earn a certificate.

Continuation for a Master's Degree

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 3.5 or higher.

Academic Requirements

Digital System Design

Advisor: Dr. Sara Tehranipoor

This certificate program has a triple purpose: (a) to increase design skills in digital system development, (b) to strengthen fundamental knowledge of computer architecture, digital design and embedded systems; and (c) to introduce the digital system designer to state-of-the-art tools and techniques. The program consists of the courses listed below totaling 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (6 units)

- ELEN 501 (Embedded Systems) 2 units
- ELEN 511 Advanced Computer Architecture (2 units)
- ELEN 603 Logic Design Using HDL (2 units)

Elective Courses (10 units)

- ELEN 387 VLSI Design I (2 units)
- ELEN 388 VLSI Design II (2 units)
- ELEN 500 Logic Analysis and Synthesis (2 units)
- ELEN 502 Real Time Systems (2 units)
- ELEN 503 Hardware-Software Co-design (2 units)
- ELEN 512 Advanced Computer Architecture II (2 units)
- ELEN 513 Parallel System Architectures (2 units)
- ELEN 530 Hardware Security and Trust (2 units)
- ELEN 608 Design for Testability (2 units)
- ELEN 613 SoC (System-on-Chip) Verification (2 units)

Integrated Circuit Design and Technology

Advisors: Dr. Shoba Krishnan, Dr. Cary Yang, Dr. Mahmudur Rahman

The study of integrated circuits consists of three interconnected areas: Design, Devices and Process Technology. This certificate provides the necessary fundamentals in these areas and advanced concepts and applications in integrated circuit design, devices, and process technology. The program will also introduce the IC designer to state-of-the-art tools and techniques. The program consists of the courses listed below; students are required to complete a total of 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (8 units)

- ELEN 252 Analog Integrated Circuits I (2 units)
- ELEN 261 Fundamentals of Semiconductor Physics (2 units)
- ELEN 270 Introduction to IC Materials (2 units)
- ELEN 387 VLSI Design I (2 units)

Elective Courses (8 units)

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

- ELEN 388 VLSI Design II (2 units)

Digital Signal Processing and Machine Learning

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a basic understanding of digital signal processing theory, machine learning and modern implementation methods as well as advanced knowledge of at least one specific application area. Digital signal processing and machine learning have become important across many areas of engineering, and this certificate prepares students for traditional or novel applications.

Required Courses (11 units minimum)

- ELEN 233 Digital Signal Processing I (2 units)
- ELEN 520 and ELEN 520L Introduction to Machine Learning Lecture and Lab (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: ELEN 223 Digital Signal Processing System Development (4 units) or ELEN 226 Machine Learning and Signal Processing Using FPGAs (2 units) or ELEN 234 Digital Signal Processing II (2 units)
- At least one course from: ELEN 421 Speech Processing I or ELEN 640 Digital Image Processing I (2 units)

Note: ELEN 233E Digital Signal Processing I, II (4 units) is equivalent to both ELEN 233 and ELEN 234.

Elective Courses (Additional courses to make a total of 16 units) selected from the list below:

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ELEN 241 Introduction to Communications (2 units)
- ELEN 243 Digital Communications Systems (2 units)
- ELEN 244 Information Theory (2 units)
- ELEN 247 Communication Systems Modeling Using Simulink I (2 units)
- ELEN 334 Introduction to Statistical Signal Processing (2 units)
- ELEN 422 Speech Coding II (2 units)
- ELEN 431 Adaptive Signal Processing I (2 units)
- ELEN 521 and 521L Deep Learning (3 units)
- ELEN 643 Digital Image Processing II (2 units)
- ELEN 644 Computer Vision I (2 units) or ELEN 645 Computer Vision II (2 units)

Digital Signal Processing Theory

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a firm theoretical grounding in fundamentals of digital signal processing (DSP) technology and its applications. It is appropriate for engineers involved with any application of DSP who want a better working knowledge of DSP theory and its applications. A novel feature of the program is a hands-on DSP hardware/software development laboratory course in which students design and build systems for various applications using contemporary DSP hardware and development software.

Required Courses (8 units)

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ELEN 233E or ELEN 233 and 234 Digital Signal Processing I, II (4 units)
- ELEN 334 Introduction to Statistical Signal Processing (2 units)

Elective Courses (8 units)

- ELEN 223 Digital Signal Processing System Development (4 units)
- ELEN 226 Machine Learning and Signal Processing Using FPGAs (2 units)
- ELEN 235 Estimation I (2 units)
- ELEN 241 Introduction to Communications (2 units)
- ELEN 244 Information Theory (2 units)
- ELEN 336 Detection (2 units)
- ELEN 431 Adaptive Signal Processing I (2 units)
- ELEN 640 Digital Image Processing I (2 units)
- ELEN 641 Image and Video Compression (2 units)
- ELEN 643 Digital Image Processing II (2 units

Fundamentals of Electrical and Computer Engineering

Advisor: Dr. Shoba Krishnan

This certificate has been designed for those individuals who have significant work experience in some area of electrical and computer engineering and wish to take graduate-level courses but may lack some prerequisite knowledge because they have not earned a BS degree in electrical and/or computer engineering. This one-year program consists of 16 to 28 units, depending on the background of the individual student, and covers electrical and computer engineering core areas. Units from courses at or above the 200 level may be credited toward the Master of Science Degree in Electrical and Computer Engineering after successful completion of the certificate.

The specific required courses for a certificate are selected with the help of the program advisor according to the student's background.

- ELEN 21 Introduction to Logic Design (5 units)
- ELEN 50 Electric Circuits I (5 units)
- ELEN 100 Electric Circuits II (5 units)
- ELEN 104 Electromagnetics I (5 units)
- ELEN 110 Linear Systems (5 units) or ELEN 210 (2 units)
- ELEN 115 Electronic Circuits I (5 units) or ELEN 250 (2 units)
- ELEN 120 Microprocessor System Design (5 units)

RF and Applied Electromagnetics

Advisors: Dr. Timothy Healy, Dr. Kurt Schab

The purpose of this certificate is to meet the increasing need for the knowledge in microwave, antenna and RF integrated circuits in existing electronic products. This program is offered for students who have a B.S. in Electrical Engineering. Students are expected to have knowledge of multivariate calculus and preferably partial differential equations and they must ensure that they have prerequisites for the courses in their program.

The curriculum consists of 16 units: two required courses (4 units) and 12 units of elective courses listed below:

Required Courses (4 units)

- ELEN 201 Electromagnetic Field Theory I (2 units)
- ELEN 701 Microwave System Architecture (2 units)

Elective Courses (12 units)

- ELEN 202 Computational Electromagnetics (2 units)
- ELEN 203 Bio-Electromagnetics (2 units)
- ELEN 204 Magnetic Circuits for Electric and Autonomous Vehicles (2 units)
- ELEN 351 RF Integrated Circuit Design or ELEN 354 Advanced RFIC Design (2 units each)
- ELEN 624 Signal Integrity in IC and PCB Systems (2 units)
- ELEN 706 Microwave Circuit Analysis and Design (2 units) (Passive Component)

- ELEN 711 Active Microwave Devices I or ELEN 712 Active Microwave Devices II (2 units each) (Active Components)
- ELEN 715 Antennas I or ELEN 716 Antennas II (2 units each)
- ELEN 726 Microwave Measurements, Theory and Tech (3 units) (Laboratory Oriented)

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

Electrical And Computer Engineering Laboratories

The Electrical and Computer Engineering program is supported by a set of well-equipped laboratories. Some are dedicated solely for lower division courses such as circuits and electronics. In addition, the department has a diversity of research and teaching laboratories listed next.

The ***Electromagnetics and Communications Laboratory*** provides a full range of modern RF measurement capabilities up to 22 GHz, including a number of vector network analyzers, spectrum analyzers, and antenna measurement systems. This lab also includes complete production facilities for prototyping printed microwave circuits and antennas. Further, the lab has extensive computer-aided design and simulation capability, including both commercial packages and research-grade in-house solvers. In both research and teaching, connections between physical hardware measurements and computer simulations are stressed.

The ***Cybersecurity Laboratory*** provides various research projects in different aspects of cybersecurity including hardware, network, internet of things (IoT), mobile, etc. The Cybersecurity Laboratory supports both graduate and undergraduate student research. This lab has the following facilities for experiments, tests, and data collection and analysis: Oscilloscopes, Logic Analyzers, Thermal Chamber, FPGAs, microcontrollers, hacking tools, and more.

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.

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 Processing and Machine Learning Laboratory*** supports research in theoretical algorithm development in digital signal processing, adaptive and nonlinear signal processing, machine learning, and deep learning. Application areas include speech, audio, image and video processing for computer vision, communications, biological testing and diagnostics, artificial intelligence (AI), Voice-over-IP networking. The lab supports student research in algorithms and real-time implementations on Graphical Processing Units (GPUs), digital signal processors (DSPs) and field programmable gate arrays (FPGAs). Laboratory equipment includes digital oscilloscopes, video cameras and wireless LAN networking equipment.

Course Descriptions

Lower-Division Undergraduate Courses

ELEN 20. Emerging Areas in Electrical and Computer Engineering

Introduction to new frontiers in electrical and computer engineering. Hands-on activities and visits to research and production facilities in Silicon Valley companies to learn how the fundamentals of electrical and computer engineering are enabling new emerging technologies. (2 units)

ELEN 21. Introduction to Logic Design

Boolean functions and their minimization. Combinational circuits: adders, multipliers, multiplexers, decoders. Sequential logic circuits: latches and flip-flops, registers, counters. Memory. Busing. Programmable logic. Use of industry quality CAD tools for schematic capture and HDL in conjunction with FPGAs. Also listed as COEN 21. Co-requisite: ELEN 21L. (4 units)

ELEN 21L. Logic Design Laboratory

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

ELEN 49. Fundamentals of Electricity for Civil Engineers

Transducers. Motors, generators, and efficiency. DC and AC circuits. One and three-phase power systems. Sources of electricity. Hydroelectric power, generation, and pumps. Electrical diagrams and schematics. (4 units)

ELEN 50. Electric Circuits I

Physical basis and mathematical models of circuit components and energy sources. Circuit theorems and methods of analysis are applied to DC and AC circuits. Co-requisite: ELEN 50L, PHYS 33. (4 units)

ELEN 50L. Electric Circuits I Laboratory

Laboratory for ELEN 50. Co-requisite: ELEN 50. (1 unit)

Upper-Division Undergraduate Courses

ELEN 100. Electric Circuits II

Continuation of ELEN 50. Sinusoidal steady state and phasors, transformers, resonance, Laplace analysis, transfer functions. Frequency response analysis. Bode diagrams. Switching circuits. Prerequisite: ELEN 50 with a grade of C− or better, or PHYS 70. Co-requisite: ELEN 100L, AMTH 106. (4 units)

ELEN 100L. Electric Circuits II Laboratory

Laboratory for ELEN 100. Co-requisite: ELEN 100. (1 unit)

ELEN 104. Electromagnetics I

Vector analysis and vector calculus. The laws of Coulomb, Lorentz, Faraday, and Gauss. Dielectric and magnetic materials. Energy in electric and magnetic fields. Capacitance and inductance. Maxwell's equations. Wave equation. Pointing vector. Wave propagation and reflection in transmission lines. Radiation. Prerequisites: PHYS 33 and ELEN 50 with a grade of C− or better. Co-requisite: ELEN 104L. (4 units)

ELEN 104L. Electromagnetics I Laboratory

Laboratory for ELEN 104. Co-requisite: ELEN 104. (1 unit)

ELEN 105. Electromagnetics II

In-depth study of several areas of applied electromagnetics such as transmission lines circuits including microstrip and strip lines, Smith Chart and bounce diagram, magnetic circuits, antennas, and antenna arrays. Prerequisite: ELEN 104. Co-requisite: ELEN 105L. (4 units)

ELEN 105L. Electromagnetics II Laboratory

Laboratory for ELEN 105. Co-requisite: ELEN 105. (1 unit)

ELEN 110. Linear Systems

Signals and system modeling. Laplace transform. Transfer function. Convolution. Discrete systems. Frequency analysis. Fourier series and transform. Filtering. State-Space models. Prerequisite: ELEN 100. Co-requisite: ELEN 110L. (4 units)

ELEN 110L. Linear Systems Laboratory

Laboratory for ELEN 110. MATLAB laboratory/problem sessions. Co-requisite: ELEN 110. (1 unit)

ELEN 112. Modern Network Synthesis and Design

Approximation and synthesis of active networks. Filter design using positive and negative feedback biquads. Sensitivity analysis. Fundamentals of passive network synthesis. Design project. Prerequisite: ELEN 110. Co-requisite: ELEN 112L. (4 units)

ELEN 112L. Modern Network Synthesis and Design Laboratory

Laboratory for ELEN 112. Co-requisite: ELEN 112. (1 unit)

ELEN 115. Electronic Circuits I

Study of basic principles of operation, terminal characteristics, and equivalent circuit models for diodes and transistors. Analysis and design of diode circuits, transistor amplifiers, and inverter circuits. Prerequisite: ELEN 50 with a grade of C− or better. Co-requisite: ELEN 115L. (4 units)

ELEN 115L. Electronic Circuits I Laboratory

Laboratory for ELEN 115. Co-requisite: ELEN 115. (1 unit)

ELEN 116. Analog Integrated Circuit Design

Design and analysis of multistage analog amplifiers. Study of differential amplifiers, current mirrors, and gain stages. Frequency response of cascaded amplifiers and gain-bandwidth considerations. Concepts of feedback, stability, and frequency compensation. Prerequisite: ELEN 115. Co-requisite: ELEN 116L. (4 units)

ELEN 116L. Analog Integrated Circuit Design Laboratory

Laboratory for ELEN 116. Co-requisite: ELEN 116. (1 unit)

ELEN 117. Advanced Analog Integrated Circuits

Design and analysis of BJT and MOSFET analog ICs. Study of analog circuits such as comparators, sample/hold amplifiers, and switched capacitor circuits. Architecture and design of analog to digital and digital to analog converters. Reference and biasing circuits. Study of noise and distortion in analog ICs. Prerequisite: ELEN 116. Co-requisite: ELEN 117L. (4 units)

ELEN 117L. Advanced Analog Integrated Circuits Laboratory

Laboratory for ELEN 117. Co-requisite: ELEN 117. (1 unit)

ELEN 118. Fundamentals of Computer-Aided Circuit Simulation

Introduction to algorithms and principles used in circuit simulation packages (such as SPICE). Formulation of equations for linear and nonlinear circuits. Detailed study of the three different types of circuit analysis (AC, DC, and transient). Discussion of computational aspects, including sparse matrices, Newton's method, numerical integration, and parallel computing. Applications to electronic circuits, active filters, and CMOS digital circuits. Course includes a number of design projects in which simulation software is written in MATLAB and verified using SPICE. Prerequisites: ELEN 21, with a grade of C− or better; ELEN 100 and 115. Co-requisite: ELEN 118L. (4 units)

ELEN 118L. Fundamentals of Computer-Aided Circuit Simulation Laboratory

Laboratory for ELEN 118. Co-requisite: ELEN 118. (1 unit)

ELEN 119. Current Topics in Electrical and Computer Engineering

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

ELEN 120. Microprocessor System Design

Design and analysis of microprocessor-based systems for embedded applications. Assembly Language programming. Integration of digital and analog input/output devices with microprocessor hardware and software. Low-level programming techniques specialized for hardware interfacing and precise control of timing. Structure and operation of embedded computing platforms. Prerequisites: A grade of C- or better in ELEN 21 and COEN 11. Co-requisite: ELEN 120L. (4 units)

ELEN 120L. ***Microprocessor System Design***

Lab projects based on an embedded computer module to practical applications that reinforce class concepts and provide some opportunities for creative design. Prerequisites A grade of C- or better in ELEN 21 and COEN 11. Co-requisite: ELEN 120 (1 unit)

ELEN 121. Real-Time Embedded Systems

Computing systems that measure, control, and interact. Real-time principles (multitasking, scheduling, synchronization), interfacing sensors, actuators and peripherals, implementation trade-offs, low-power high-performance systems (code profiling and optimization) embedded software (exception handling, loading, mode-switching, programming embedded systems). Real-time multimedia. Prerequisites: A grade of C- or better in ELEN-120. Co-requisite: ELEN 121L. (4 units)

ELEN 121L. Real-Time Embedded Systems Lab

Lab projects based on an embedded computer module to practical applications that reinforce class concepts and provide some opportunities for creative design. Prerequisites: A grade of C- or better in ELEN-120. Co-requisite: ELEN 121. (1 unit)

ELEN 122. Computer Architecture

Application of logic design concepts to computer architecture. Computation state machines. Computer instruction definition and formatting, the use of opcodes and operands. Memory, and how it is used to store instructions and data. Instruction execution, control transfer. Application of critical path concepts and pipelining. Hazards. Caches. Hardware support for virtual memory. Prerequisites: A grade of C- or better in either COEN or ELEN 21. Co-requisite: ELEN 122L. (4 units)

ELEN 122L. Computer Architecture Lab

Laboratory for ELEN 122. Co-requisite: ELEN 122. (1 unit)

ELEN 123. Mechatronics

Introduction to behavior, design, and integration of electromechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and integration of transducers, microcontrollers, and actuators. Also listed as COEN 123 and MECH 143. Prerequisite: ELEN 50 with a grade of C− or better and COEN 11 or 44. Co-requisite: ELEN 123L. (4 units)

ELEN 123L. Mechatronics Laboratory

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

ELEN 127. Advanced Logic Design

Contemporary design of finite-state machines as system controllers using FPGA devices. Minimization techniques, performance analysis, and modular system design. HDL simulation and synthesis. Also listed as COEN 127. Prerequisite: ELEN 21 with a grade of C− or better. Co-requisite: ELEN 127L. (4 units)

ELEN 127L. Advanced Logic Design Laboratory

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

ELEN 130. Control Systems

Applications of control systems in engineering. Principle of feedback. Performance specifications: transient and steady-state response. Stability. Design of control systems by frequency and root locus methods. Computer-controlled systems. State-variable feedback design. Problem sessions. Prerequisite: ELEN 110. Co-requisite: ELEN 130L. (4 units)

ELEN 130L. Control Systems Laboratory

Laboratory for ELEN 130. Co-requisite: ELEN 130. (1 unit)

ELEN 131. Introduction to Robotics

Overview of robotics: control, artificial intelligence, and computer vision. Components and structure of robots. Kinematics and dynamics of robot manipulators. Servo-control design, PID control. Trajectory planning, obstacle avoidance. Sensing and vision. Robot intelligence and task planning. Prerequisite: ELEN 110. Co-requisite: ELEN 131L. (4 units)

ELEN 131L. Introduction to Robotics Laboratory

Laboratory for ELEN 131. Co-requisite: ELEN 131. (1 unit)

ELEN 133. Digital Signal Processing

Discrete signals and systems. Difference equations. Convolution summation. Z-transform, transfer function, system response, stability. Digital filter design and implementation. Frequency domain analysis. Discrete Fourier transform and FFT. Audio, video, and communication applications. Prerequisites: ELEN 110 or both ELEN 50 with a grade of C− or better and COEN 19. Co-requisite: ELEN 133L. (4 units)

133L. Digital Signal Processing Laboratory

Laboratory for ELEN 133. Laboratory for real-time processing. Co-requisite: ELEN 133. (1 unit)

ELEN 134. Applications of Signal Processing

Current applications of signal processing. Topics may vary. Example topics include Speech Coding, Speech Recognition, and Biometrics. Prerequisite: ELEN 133, MATLAB. Co-requisite: ELEN 134L. (4 units)

ELEN 134L. Applications of Signal Processing Laboratory

Laboratory for ELEN 134. Co-requisite: ELEN 134. (1 unit)

ELEN 139. Special Topics in Signals and Systems

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

ELEN 141. Communication Systems

Modulation and demodulation of analog and digital signals. Baseband to passband conversion. Random processes, Signal-to-noise ratios, and Bandwidth Considerations. Prerequisites: ELEN 110 and AMTH 108. Co-requisite: ELEN 141L. (4 units)

ELEN 141L. Communication Systems Laboratory

Laboratory for ELEN 141. Co-requisite: ELEN 141. (1 unit)

ELEN 142. Communications and Networking

Networking in different media. Effects of the media on data rate. Error detection and correction. Routing algorithms. Collision and retransmission in networks. Prerequisite: AMTH 108 with a grade of C- or better; or its equivalent. Co-requisite: ELEN 142L (4 units)

ELEN 142L. **Communications and Networking Lab**

Lab component; Networking in different media. Effects of the media on data rate. Error detection and correction. Routing algorithms. Collision and retransmission in networks. Prerequisite: AMTH 108 with a grade of C- or better; or its equivalent. Co-requisite: ELEN 142. (1 unit)

ELEN 144. RF and Microwave Components

The fundamental characteristics of passive and active electrical components. Parasitics, models, and measurements. Modeling of circuit interconnects. Study of crosstalk in high-speed digital circuits, matching circuits, power dividers, and microwave filters. Prerequisite: ELEN 105. Co-requisite: ELEN 144L. (4 units)

ELEN 144L. RF and Microwave Components Laboratory

Laboratory for ELEN 144. Co-requisite: ELEN 144. (1 unit)

ELEN 151. Device Electronics for IC Design

Properties of materials, crystal structure, and band structure of solids. Carrier statistics and transport; p-n junction electrostatics, I-V characteristics, equivalent circuits. Metal-semiconductor contacts, Schottky diodes. MOS field-effect transistors, bipolar junction transistors. This course covers the essential device concepts necessary for analog, digital, and/or mixed signal circuit design. Credit not allowed for both ELEN 151 and ELEN 267. Prerequisite or corequisite: ELEN 104. Corequisite: ELEN 151L. (4 units)

ELEN 151L. Device Electronics Laboratory

Laboratory for ELEN 151. Co-requisite: ELEN 151. (1 unit)

ELEN 152. Integrated Circuit Fabrication Process Technology

Fundamental principles of processes essential for fabricating micro- and nano-electronic hardware ranging from Integrated circuits, MEMS and biosensors to power, control and optoelectronic devices. Physical and chemical models of semiconductor crystal growth, thermal oxidation and diffusion, ion implantation, Lithography, etching and cleaning, epitaxy, chemical and physical vapor deposition, metallization, etc. Process integration and simulation using TCAD. (4 units). Also listed as ELEN 276. (4 units)

ELEN 152L. Integrated Circuit Fabrication Process Technology Laboratory

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

ELEN 153. Digital Integrated Circuit Design

Introduction to VLSI design and methodology. Study of basic principles, material for CMOS transistors. Study of CMOS digital integrated circuits and technology scaling. Physical design and layout principles. Interconnect modelling. Semiconductor memories. Use of state-of-the-art CAD tools. Prerequisites: ELEN/COEN 21 and ELEN 50 with a grade of C− or better. Co-requisite: ELEN 153L. (4 units)

ELEN 153L. Digital Integrated Circuit Design Laboratory

Laboratory for ELEN 153. Co-requisite: ELEN 153. (1 unit)

ELEN 156. Introduction to Nanotechnology

Introduction to the field of nanoscience and nanotechnology. Properties of nanomaterials and devices. Nanoelectronics: from silicon and beyond. Measurements of nanosystems. Applications and implications. Laboratory experience is an integral part of the course. Also listed as MECH 156. Prerequisites: PHYS 33 and either PHYS 34 or MECH 15. Co-requisite: ELEN 156L. (4 units)

ELEN 156L. Introduction to Nanotechnology Laboratory

Laboratory for ELEN 156. Also listed as MECH 156L. Co-requisite: ELEN 156. (1 unit)

ELEN 160. Chaos Theory, Metamathematics and the Limits of Science: An Engineering Perspective on Religion

Limitations of science are examined in the framework of nonlinear system theory and metamathematics. Strange attractors, bifurcations, and chaos are studied in some detail. Additional topics include an introduction to formal systems and an overview of Godel’s theorems. The mathematical background developed in the course is used as a basis for exploring the relationship between science, aesthetics, and religion. Particular emphasis is placed on the rationality of faith. Also listed as ELEN 217. Prerequisites: AMTH 106 (or an equivalent course in differential equations), and a basic familiarity with MATLAB. Co-requisite: ELEN 160L. (4 units)

ELEN 160L. Chaos Theory, Metamathematics and the Limits of Science: An Engineering Perspective on Religion Laboratory

Laboratory for ELEN 160. Co-requisite: ELEN 160. (1 unit)

ELEN 161. The Beauty of Nature and the Nature of Beauty

Beauty is examined from an interdisciplinary perspective, taking into account insights from mathematics, physics, engineering, neuroscience, and psychology, as well as philosophy, art history, and theology. Technical topics include information theory, quantum computing, fractal geometry, complex systems, cellular automata, Boolean networks, and set theory. Prerequisite: AMTH 106 (or equivalent). Familiarity with basic concepts in probability theory is expected, as is some experience with MATLAB. Co-requisite: ELEN 161L. (4 units)

ELEN 161L. The Beauty of Nature and the Nature of Beauty Laboratory

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

ELEN 164. Introduction to Power Electronics

Power and efficiency computations, rectifiers, power devices, DC-to-DC converters, AC-to-DC converters, and DC-to-AC inverters. Prerequisite: ELEN 115. Co-requisite: ELEN 164L. (4 units)

ELEN 164L. Introduction to Power Electronics Laboratory

Laboratory for ELEN 164. Co-requisite: ELEN 164. (1 unit)

ELEN 167. Medical Imaging Systems

Overview of medical imaging systems including sensors and electrical interfaces for data acquisition, mathematical models of the relationship of structural and physiological information to sensor measurements, resolution, and accuracy limits, and the conversion process from electronic signals to image synthesis. Analysis of the specification and interaction of the functional units of imaging systems and the expected performance. Focus on MRI, CT, and ultrasound, PET, and impedance imaging. Also listed as BIOE 167, BIOE 267. Prerequisite: BIOE 162 or ELEN 110 or MECH 142. (4 units)

ELEN 180. Introduction to Information Storage

Storage hierarchy. Design of memory and storage devices, with a particular emphasis on magnetic disks and storage-class memories. Error detection, correction, and avoidance fundamentals. Disk arrays. Storage interfaces and buses. Network attached and distributed storage, interaction of economy, and technological innovation. Also listed as COEN 180. Prerequisites: ELEN 21 or COEN 21, and COEN 20; COEN 122 is recommended. (4 units)

ELEN 182. Energy Systems Design

Introduction to alternative energy systems with emphasis on those utilizing solar technologies; system analysis including resources, extraction, conversion, efficiency, and end-use; project will design power system for a house off or on grid making best use of renewable energy; system design will include power needs, generation options, storage, back-up power. Prerequisite: ELEN 50. (4 units)

ELEN 183. Power Systems Analysis

Analysis, design, and optimization of power systems for traditional and renewable power generation. Balanced three-phase circuits. Transformers and transmission lines. Prerequisite: ELEN 100 or PHYS 12. Co-requisite: ELEN 183L. (4 units)

ELEN 183L. Power Systems Analysis Laboratory

Laboratory for ELEN 183. Co-requisite: ELEN 183. (1 unit)

ELEN 184. Power System Stability and Control

Examine power system stability and power system control, including load frequency control, economic dispatch, and optimal power flow. Also listed as ELEN 231. Prerequisite: ELEN 183 or equivalent. (4 units)

ELEN 188. Co-op Education

Integration of classroom study and practical experience in a planned program designed to give students practical work experience related to their academic field of study and career objectives. The course alternates (or parallels) periods of classroom study with periods of training in industry or government. Satisfactory completion of the assignment includes preparation of a summary report on co-op activities. P/NP grading. May be taken twice. May not be taken for graduate credit. (2 units)

ELEN 189. Co-op Technical Report

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

ELEN 192. Introduction to Senior Design Project

Junior preparation for senior project. An introduction to project requirements and participation in the coordination of the senior conference. Tentative project selection. (2 units)

ELEN 194. Design Project I

Specification of an engineering project, selected with the mutual agreement of the student and the project advisor. Complete initial design with sufficient detail of target specification. Incorporation of relevant engineering standards and appropriate realistic constraints. Initial draft of the project report. Co-requisite: ENGL 181. (2 units)

ELEN 195. Design Project II

Implementation, construction, and testing of the project, system, or device. Sustainability analysis. Demonstration of project and formal design review. Prerequisite: ELEN 194. (2 units)

ELEN 196. Design Project III

Continued design, implementation, and testing of the project, system, or device to improve function and add capability. Reliability analysis. Formal public presentation of results. Final report. Prerequisite: ELEN 195. (1 unit)

ELEN 199. Directed Research/Reading

Investigation of an approved engineering problem and preparation of a suitable project report. Open to electrical engineering and computer majors only. (1–6 units)

* Eligible for graduate credit in electrical and computer engineering

Graduate Courses

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

ELEN 200. Electrical and Computer Engineering Graduate Seminars

Regularly scheduled seminars on topics of current interest in the fields of electrical and computer engineering and computer engineering. Consult the department office for detailed information. P/NP grading. (1 or 2 units)

ELEN 201. Electromagnetic Field Theory I

Time-varying electromagnetic field concepts starting with Maxwell’s equations. Wave propagation in free space and in lossy media. Near and far-field effects. Fundamental theorems in electromagnetics. Transmission line propagation of harmonic waves and of pulse and transient signals. Dispersion effects. Prerequisites: An undergraduate electromagnetic field course. (2 units)

ELEN 202. Computational Electromagnetics

Numerical solution of Maxwell’s Equations for engineering problems. Foundations and mathematical development of finite difference time domain (FDTD) and method of moments (MoM) solvers. Methods for numerical validation and robust simulation-based experiment design. Prerequisite: ELEN 201. (2 units)

ELEN 203. Bio-Electromagnetics

Fundamentals of bioelectromagnetics. Tissue characterization, dielectrophoresis electrodes, RF/Microwave Interaction mechanisms in biological materials. Electromagnetic field absorption, and SAR, Power transfer in biological environment, On-body and implant antennas, microwave hyperthermia. Also listed as BIOE 203. Prerequisite: ELEN 201 (or equivalent) or BIOE 168/268. (2 units)

ELEN 204. Magnetic Circuits for Electric and Autonomous Vehicles

Fundamentals of magnetic circuits, transformers, DC motors, induction motors, transducers, stationary and mobile wireless charging. Prerequisite: Introduction to Electromagnetic Field Theory. (2 units)

ELEN 210. Signals, Circuits, and Systems

Continuous and discrete signals. Circuit equations and time response. Laplace transform. Difference equations and discrete systems. Z-transform. Convolution. Transfer function. Frequency response. Fourier series and transform. Matrix representations of circuits and systems. The notion of state. State transition matrix. State and output response. Equivalent to ELEN 110. May not be included in the minimum required units of Electrical and Computer Engineering courses. (2 units)

ELEN 211. Modern Network Analysis I

Graph theory and its applications to network matrix equations. Network component magnitude and frequency scaling. Network topology, graph theory, graph matrices, oriented and non-oriented graphs. Fundamental network laws. Topologically dependent matrix equations. Circuit simulation. N Planar and dual graphs. Nondegenerate network state equations. Prerequisites: AMTH 246 and knowledge of Laplace transforms. (2 units)

ELEN 216. Modern Network Synthesis and Design

Approximation and synthesis of active networks. Filter design using positive and negative feedback biquads. Sensitivity analysis. Fundamentals of passive network synthesis. Credit not allowed for both 112 and 216. Prerequisite: ELEN 210 or its undergraduate equivalent of ELEN 110. (4 units)

ELEN 217. Chaos Theory, Metamathematics and the Limits of Knowledge: A Scientific Perspective on Religion

Limitations of science are examined in the framework of nonlinear system theory and metamathematics. Strange attractors, bifurcations, and chaos are studied in some detail. Additional topics include an introduction to formal systems and an overview of Godel's theorems. The mathematical background developed in the course is used as a basis for exploring the relationship between science, aesthetics, and religion. Particular emphasis is placed on the rationality of faith. Also listed as ELEN 160. Prerequisites: AMTH 106 or an equivalent course in differential equations, and a basic familiarity with MATLAB. (4 units)

ELEN 219. Fundamentals of Computer-Aided Circuit Simulation

Introduction to the algorithms and principles used in circuit simulation packages (such as SPICE). Formation of equations for linear and nonlinear circuits. Detailed study of three different types of circuit analysis (AC, DC, and transient). Discussion of computational aspects, including sparse matrices, Newton's method, numerical integration, and parallel computing. Applications to electronic circuits, active filter, and CMOS digital circuits. Course includes a number of design projects in which simulation software is written in Matlab and verified using SPICE. Credit not allowed for both 118 and 219. Prerequisites: ELEN 21, ELEN 100, and ELEN 115. (4 units)

ELEN 223. Digital Signal Processing System Development

Hands-on experience with hardware and software development for real-time DSP applications. Students design, program, and build a DSP application from start to finish. Such applications include image processing, speech/audio/video compression, multimedia, etc. The development environment includes Texas Instruments TMS320C6X development systems. Prerequisites: ELEN 234 or ELEN 233E and knowledge of "C" programming language. (4 units)

ELEN 226. Machine Learning and Signal Processing using FPGAs

Implementation of machine learning inference pipelines in an FPGA; signal processing and hardware architecture to take a trained network through to a hardware realization; overview of the latest generation FPGA technology and C++ High Level Synthesis (HLS) FPGA design flows. Students will learn how to implement, in fixed-point arithmetic, in hardware, the linear-algebra operations that are at the center of virtually all ML networks such as GoogleNet, ResNet and other well-known network architectures. Implementation of the common linear algebra functions and nonlinear functions that form the core components of many common networks will be covered. FPGA implementation of a multi-layer perceptron network and a CNN (convolutional neural network) accelerator using a HLS design flow. Prerequisites: (ELEN 133, ELEN 233E or ELEN 234) and (ELEN 127 or the equivalent) and C++ programming experience. (2 units)

ELEN 229. Topics in Network Theory

Various topics. (2 units)

ELEN 230. Introduction to Control Systems

Applications of control systems in engineering. Principle of feedback. Performance specifications: transient and steady-state response. Stability. Design of control systems by frequency and root-locus methods. Computer-controller systems. State-variable feedback design. Problem sessions. Credit not allowed for both ELEN 130 and ELEN 230. Prerequisite: ELEN 210 or its undergraduate equivalent of ELEN 110. (4 units)

ELEN 231. Power System Stability and Control

Examine power system stability and power system control, including load frequency control, economic dispatch and optimal power flow. Also listed as ELEN 184. Prerequisite: ELEN 183 or equivalent. (4 units)

ELEN 232. Introduction to Nonlinear Systems

Basic nonlinear phenomena in dynamic systems. State space and phase plane concepts. Equilibria. Linearization. Stability. Liapunov's method. Prerequisite: ELEN 230E or 236. (2 units)

ELEN 233. Digital Signal Processing

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

ELEN 233E. Digital Signal Processing I and II

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

ELEN 234. Digital Signal Processing II

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

ELEN 235. Estimation I

Introduction to Classical estimation. Minimum Variance Unbiased Estimator (MVUE) from Cramer-Rao theorem, sufficient statistics, and linear estimator constraint. Maximum Likelihood Estimation (MLE) method. Least Square (LS) methods. Prerequisites: AMTH 211 or AMTH 212, AMTH 246 or AMTH 247, familiarity with MATLAB. (2 units)

ELEN 236. Modern Control Systems I

Concept of state-space descriptions of dynamic systems. Relations to frequency domain descriptions. State-space realizations and canonical forms. Stability. Controllability and observability. State feedback and observer design. Also listed as MECH 323. Prerequisite: ELEN 130 or its undergraduate equivalent. (2 units)

ELEN 237. Optimal Control I

Introduction to the principles and methods of the optimal control approach: performance measure criteria including the definition of minimum-time, terminal control, minimum-control effort, tracking and regulator problems, calculus of variation applied to optimal control problems including Euler-Lagrange equation, transversality condition constraint, Pontryagin's minimum principle (PMP), linear quadratic regulator (LQR) and tracking control problems. Also listed as MECH 429. Prerequisite: ELEN 236. Students are expected to be proficient in MATLAB/Simulink. (2 units)

ELEN 238. Model Predictive Control

Review of state-space model in discrete time, stability, optimal control, prediction, Kalman filter. Measurable and unmeasurable disturbance, finite and receding horizon control, MPC formulation and design. Also listed as MECH 420. Prerequisite: ELEN 237 or MECH 324 or equivalent. (2 units)

ELEN 239. Topics in Systems Theory

Various topics. (2 units)

ELEN 241. Introduction to Communication

Power spectral density and correlation; bandwidth; random processes; carrier frequency, modulation and baseband versus passband modulation. Prerequisite: ELEN 210 or its undergraduate equivalent of ELEN 110. (2 units)

ELEN 241E. Modern Communications

Power spectral density and correlation; bandwidth; carrier frequencies, baseband vs. passband, random processes and noise; digital modulation techniques including QAM, PAM, PSK, and FSK; matched-filter receivers; maximum-likelihood and maximum a priori detection; Signal-to-Noise ratio evaluation and its impact on error rate. If students have taken ELEN 241 or ELEN 243, credit is not allowed for 241E. Similarly, if a student has taken 241E, credit is not allowed for 241 or 243. Prerequisites: ELEN 110 or its equivalent and AMTH 108 or its equivalent. (4 units)

ELEN 243. Digital Communication Systems

Digital modulation techniques including: QAM, PSK, FSK; matched-filter receivers; maximum-likelihood and maximum a priori detection. Signal-to-Noise ratio evaluation and its impact on error rate. Prerequisite: ELEN 241 or equivalent. (2 units)

ELEN 244. Information Theory

Introduction to the fundamental concepts of information theory. Source models. Source coding. Discrete channel without memory. Continuous channel. Alternate years. Also listed as COEN 341. Prerequisite: AMTH 211. (2 units)

ELEN 247. Communication Systems Modeling Using Simulink I

The objective of this course is for students to acquire and consolidate their practical skills of digital communication systems design through building simulation of some carefully selected prototype systems using MATLAB® and Simulink.® Examples include communication systems. The components and the principle of operation of each system will be presented in a lecture, together with key simulation techniques required. Topics include digital modulation and synchronization. Prerequisites: ELEN 233 and 243. (2 units)

ELEN 248. Communication Systems Modeling Using Simulink II

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

ELEN 249. Topics in Communication

Various topics. (2 units)

ELEN 250. Electronic Circuits

Introductory presentation of semiconductor circuit theory. The p-n junction, bipolar junction transistors (BJT), field-effect transistors and circuit models for these devices. DC biasing required of small-signal amplifier circuits. Analysis and design of small-signal amplifiers. The ideal operational amplifier and circuit applications. May not be taken for credit by a student with an undergraduate degree in electrical engineering. Not for graduate credit. Prerequisite: ELEN 50 or equivalent. (2 units)

ELEN 251. Transistor Models for IC Design

Semiconductor device modeling methods based upon device physics, process technology, and parameter extraction. Model derivation for bipolar junction transistors and metal-oxide-semiconductor field-effect transistors for use in circuit simulators. Model parameter extraction methodology utilizing linear regression, data fitting, and optimization techniques. Prerequisite: ELEN 265 or ELEN 267. (2 units)

ELEN 252. Analog Integrated Circuits I

Design and analysis of multi-stage BJT and CMOS analog amplifiers. Study of differential amplifiers, current mirrors, and gain stages. Frequency response of cascaded amplifiers and gain-bandwidth considerations. Concepts of feedback, stability, and frequency compensation. Prerequisite: ELEN 115 or equivalent. (2 units)

ELEN 253. Analog Integrated Circuits II

Design of operational amplifiers and wideband amplifiers. Design of output stages and power amplifiers. Reference and biasing circuits. Study of noise and distortion in analog ICs and concepts of low noise design. Selected applications of analog circuits such as comparators. Prerequisite: ELEN 252. (2 units)

ELEN 254. Advanced Analog Integrated Circuit

Design and analysis of BJT and MOSFET analog ICs. Study of analog circuits such as comparators, sample/hold amplifiers, and continuous time switch capacitor filters. Architecture and design of analog to digital and digital to analog convertors. Reference and biasing circuits. Study of noise and distortion in analog ICs. Prerequisite: ELEN 116. Co-requisite: ELEN 117L. (4 units)

ELEN 259. Topics in Circuit Design

Various topics. (2 units)

ELEN 261. Fundamentals of Semiconductor Physics

Wave mechanics. Crystal structure and energy band structure of semiconductors. Carrier statistics and transport. Electrical and optical properties. (2 units)

ELEN 264. Semiconductor Device Theory I

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

ELEN 265. Semiconductor Device Theory II

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

ELEN 266. Semiconductor Device Theory I and II

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

ELEN 267. Device Electronics for IC Design

Properties of materials, crystal structure, and band structure of solids. Carrier statistics and transport; p-n junction electrostatics, I-V characteristics, equivalent circuits. Metal-semiconductor contacts, Schottky diodes. MOS field-effect transistors, bipolar junction transistors. This course covers the essential device concepts necessary for analog, digital, and/or mixed signal circuit design. Credit not allowed for both ELEN 151 and ELEN 267. Prerequisite or corequisite: ELEN 104 or basic knowledge of electrostatics. (4 units)

ELEN 270. Introduction to IC Materials

Materials issues in IC, classification of IC materials, Historical perspective. IC materials electrical conductivity, high-k, low-k materials. IC processing materials; solid liquid, gaseous dopants, chemicals and gases for etching and cleaning; IC lithography materials; photo-, e-beam-, x-ray resists, resist developers; IC packaging materials; IC thin film materials; adhesion, thermal conductivity and stress, electrical conductivity and sheet resistance. (2 units)

ELEN 271. Microsensors: Components and Systems

Microfabrication technologies, bulk and surface micromachining, sensor fundamentals, electronic, chemical, and mechanical components as sensors, system level issues, technology integration; application and examples of sensors. (2 units)

ELEN 274. Integrated Circuit Fabrication Processes I

Fundamental principles of silicon-integrated circuit fabrication processes. Practical and theoretical aspects of microelectronic fabrication. Basic materials properties, including crystal structure and crystallographic defects; physical and chemical models of crystal growth; and doping, thermal oxidation, diffusion, and ion implantation.
Prerequisite: ELEN 270. (2 units)

ELEN 275. Integrated Circuit Fabrication Processes II

Physical and chemical models of etching and cleaning, epitaxy, deposited films, photolithography, and metallization. Process simulation and integration. Principles and practical aspects of fabrication of devices for MOS and bipolar integrated circuits.
Prerequisite: ELEN 270. (2 units)

ELEN 276. Integrated Circuit Fabrication Process Technology

Fundamental principles of processes essential for fabricating micro- and nanoelectronic hardware ranging from Integrated circuits, MEMS and biosensors to power, control and optoelectronic devices. Physical and chemical models of semiconductor crystal growth, thermal oxidation and diffusion, ion implantation, Lithography, etching and cleaning, epitaxy, chemical and physical vapor deposition, metallization, etc. Process integration and simulation using TCAD. Also listed as ELEN 152. Prerequisite: ELEN 270. (4 units)

ELEN 276L. Integrated Circuit Fabrication Process Technology Laboratory

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

ELEN 277. IC Assembly and Packaging Technology

IC assembly techniques, assembly flow, die bond pad design rules, eutectic bonding and other assembly techniques, package types and materials, package thermal and electrical design and fabrication, special package considerations, future trends, and package reliability. Prerequisite: ELEN 201. (2 units)

ELEN 279. Topics in Semiconductor Devices and Processing

Various topics. (2 units)

ELEN 280. Introduction to Alternative Energy Systems

An introduction to such alternative energy systems with an emphasis on those utilizing solar technologies. Learn how the technologies work to provide electrical power today and the capabilities foreseen for the future. The material is designed to be suitable for both undergraduate and graduate students in engineering and related applied sciences. Also listed as MECH 287. (2 units)

ELEN 281A. Power Systems: Generation and Transmission

Electricity is the most versatile and widely used form of energy, and as such, it is the backbone of today’s and tomorrow’s global society. The course deals with the power system structure and components, electric power generation, transmission, and distribution. It also examines how these components interact and are controlled to meet the requirement of capacity, energy demand; reliability, availability, and quality of power delivery; efficiency, minimization of power loss; sustainability, and integration of low carbon energy sources. Prerequisite: ELEN 100 or equivalent. (2 units)

ELEN 281B. Power Systems: Distribution

The objective of this course is to cover the fundamental as well as wider aspects of Electric Power Transmission and Distribution networks including monitoring and control application tools typically provided by Energy Management Systems that enable electric utility companies to manage these assets to achieve their goals. Prerequisite: ELEN 281A. (2 units)

ELEN 282. Photovoltaic Devices and Systems

This course begins with a discussion of the sun as a source of energy, emphasizing the characteristics of insolation which then leads to a study of solar cells, their performance, their models, and the effects on their performance of factors such as atmospheric attenuation, incidence angle, shading, and others. Cells are connected together to become modules, which in turn are connected in arrays. This leads to a discussion of power electronic devices used to control and condition the DC solar voltage, including charge controllers, inverters, and other devices. Energy storage is studied. These components are then collected together in a solar PV system. The course concludes with a discussion of system sizing. (2 units)

ELEN 283. Characterization of Photovoltaic Devices

This course consists of five pre-lab lectures and five experiments exploring different aspects of photovoltaic cells and modules, including cell characterization under controlled conditions using a solar simulator; determining the spectral response and quantum efficiency of cells; measurement of solar irradiance and insolation; characterization of photovoltaic modules under real sun conditions; study of solar-related power electronics. Prerequisite: ELEN 282 or equivalent. (2 units)

ELEN 284. Solar Cell Technologies & Simulation Tools

Review of concepts needed to understand function, design, and manufacturing of PV cells and modules. PV cell physics leading to derivation of the I-V curve and equivalent circuit, along with contact and optical design, and use of computer-aided design tools. Manufacturing processes for silicon and thin film cells and modules. Cell measurements, including simulators, quantum efficiency, and parameter extraction. Cell types include silicon, thin film, organics, and concentrators. Markets, drivers, and LCOE (levelized cost of electricity) are surveyed. (2 units)

ELEN 284L. Solar Cell Technologies and Simulation Tools Laboratory

Co-requisite: ELEN 284. (1 unit)

ELEN 285. Introduction to the Smart Grid

The smart grid initiative calls for the construction of a 21st-century electric system that connects everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It is envisioned that it will seamlessly integrate many types of generation and storage systems with a simplified interconnection process analogous to "plug and play." This course describes the components of the grid and the tools needed to realize its main goals: communication systems, intelligent meters, and appropriate computer systems to manage the grid. (2 units)

ELEN 286. Introduction to Wind Energy Engineering

Introduction to renewable energy, history of wind energy, types and applications of various wind turbines, wind characteristics and resources, introduction to different parts of a wind turbine including the aerodynamics of propellers, mechanical systems, electrical and electronic systems, wind energy system economics, environmental aspects and impacts of wind turbines, and the future of wind energy. Also listed as MECH 286. (2 units)

ELEN 287. Energy Storage Systems

Energy storage systems play an essential role in the utilization of renewable energy. They are used to provide reserve power under different circumstances and needs such as peak shaving, load leveling, and ancillary services. Power electronics equipment converts the battery power into usable grid power. The course will survey batteries, pumped storage, flywheels, ultracapacitors, etc., with an analysis of the advantages and disadvantages, and uses of each. Also listed as ENGR 339. (2 units)

ELEN 288. Energy Management Systems

Energy Management Systems (EMS) is a class of control systems that electric utility companies utilize for three main purposes: monitoring, engagement, and reporting. Monitoring tools allow electric utility companies to manage their assets to maintain the sustainability and reliability of power generation and delivery. Engagement tools help in reducing energy production costs, transmission and distribution losses by optimizing utilization of resources and/or power network elements. Reporting tools to track operational costs and energy obligations. Also listed as COEN 282. (2 units)

ELEN 289. Topics in Energy Systems

Various topics (2 units)

ELEN 296. Independent Study

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

ELEN 297. Master's Thesis Research

By arrangement. Limited to department majors only (1–9 units)

ELEN 298. Ph.D. Thesis Research

By arrangement. Limited to department Ph.D. candidates only. A nominal number of 36 units is expected toward the Ph.D. degree. (1–15 units per quarter)

ELEN 299. Directed Research

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

ELEN 329. Introduction to Intelligent Control

Intelligent control, AI, and system science. Adaptive control and learning systems. Artificial neural networks and Hopfield model. Supervised and unsupervised learning in neural networks. Fuzzy sets and fuzzy control. Also listed as MECH 329. Prerequisite: ELEN 236. (2 units)

ELEN 330. Introduction to Stochastic Control for Supply and Demand Network

Managing inventories plays an important role in supply and demand network optimization. This course covers basic inventory models. The foundations needed to characterize optimal policies using deterministic and stochastic control strategies. Markov chain. Optimal control. Stochastic control. Prerequisites: Statistics, Probability, ELEN 238 or equivalent. (2 units)

ELEN 331. Autonomous Driving Systems

This course introduces students to autonomous driving systems. Through lectures, labs, and assignments, students will gain hands-on experience on the major modules of the system including localization, sensor fusion, perception, detection, segmentation, scene understanding, tracking, prediction, path planning, control, routing, and decision making. Prerequisites: First-year graduate standing in ELEN, CSEN or MECH and knowledge of programming. (2 units)

ELEN 331L. Autonomous Driving Systems Lab

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

ELEN 333. Digital Control Systems

Difference equations. Sampling. Quantization. Z-transform. Transfer functions. State-Space models. Controllability and observability. Stability. Pole-placement by feedback. Frequency response methods. Prerequisites ELEN 230 or 236. (2 units)

ELEN 334. Introduction to Statistical Signal Processing

Introduction to statistical signal processing concepts. Random variables, random vectors, and random processes. Second-moment analysis, estimation of first and second moments of a random process. Linear transformations; the matched filter. Spectral factorization, innovation representations of random processes. The orthogonality principle. Linear predictive filtering; linear prediction and AR models. Levinson algorithm. Burg algorithm. Prerequisites: AMTH 211 and ELEN 233 or ELEN 233E. (2 units)

ELEN 335. Estimation II

Introduction to Bayesian estimation. Minimum mean square error estimator (MMSE), Maximum a posteriori estimator (MAP). Wiener filter and Kalman filter. Prerequisite: ELEN 235. (2 units)

ELEN 336. Detection

Hypothesis testing. Neyman-Pearson lemma. Generalized matched filter. Detection of deterministic and random signals in Gaussian and non-Gaussian noise environments. Prerequisite: AMTH 362, ELEN 243, or ELEN 335. (2 units)

ELEN 337. Robotics I

Overview of robotics: control, AI, and computer vision. Components and structure of robots. Homogeneous transformation. Forward kinematics of robot arms. Denavit-Hartenberg representation. Inverse kinematics. Velocity kinematics. Manipulator Jacobian. Singular configurations. Euler Lagrange equations. Dynamic equations of motion of manipulators. Task planning, path planning, and trajectory planning in the motion control problem of robots. Also listed as MECH 337. Prerequisite: AMTH 245. (2 units)

ELEN 338. Robotics II

Joint-based control. Linear control of manipulators. PID control and set-point tracking. Method of computer-torque in trajectory following control. Also listed as MECH 338. Prerequisites: ELEN 236 and 337. (2 units)

ELEN 339. Robotics III

Intelligent control of robots. Neural networks and fuzzy logic in robotic control. Selected topics of current research in robotics. Also listed as MECH 339. Prerequisite: ELEN 338. (2 units)

ELEN 345. Phase-Locked Loops

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

ELEN 347. Advanced Digital Communication Systems

Receiver design, equalizers, and maximum likelihood sequence detection. Modulation and receiver design for wireline and wireless communications. Particular emphasis on intersymbol interference and equalizers. Offered every other year. Prerequisite: ELEN 243. (2 units)

ELEN 348. FPGA for Communications Applications

This course is a project-based course to introduce students to architectures and implementations of Field-Programmable Gate Arrays (FPGAs) for DSP for communications applications. Examples of a final project include implementing a significant application in communications such as Software-Defined Radio (SDR) or, Wi-Fi. Prerequisites: ELEN 226 and 247. (2 units)

ELEN 351. RF Integrated Circuit Design

Introduction to RF terminology, technology tradeoffs in RFIC design. Architecture and design of radio receivers and transmitters. Low noise amplifiers, power amplifiers, mixers, oscillators, and frequency synthesizers. Prerequisites: ELEN 252 and 387. (2 units)

ELEN 352. Mixed Signal IC Design for Data Communications

Design and analysis of mixed-signal circuits for data communications. Introduction to data communications terminology and signaling conventions. Data transmission media, noise sources. Data transceiver design: Signal coding/decoding, transmit signal waveshaping, receive equalization. Timing Circuits: Clock generation and recovery techniques. Prerequisites: ELEN 252 and 387. (2 units)

ELEN 353. DC to DC Power Conversion

Basic buck, boost, and buck-boost DC to DC converter topologies in both continuous and discontinuous conduction modes (CCM and DCM). Analog and digital controlled pulse width modulation techniques. Efficiency and control loop stability analysis. Critical MOSFET parameters and non-ideal circuit behavior will be studied using time and frequency domain computer modeling. Prerequisites: ELEN 230 and ELEN 252 or 116. (2 units)

ELEN 354. Advanced RFIC Design

Design and analysis of passive circuits (filters, splitters, and couplers), Gilbert cell mixers, low phase noise VCOs, frequency translators, and amplifiers. Advanced simulation methods, such as envelope and time domain simulations. Class project designed to meet specifications, design rules, and device models of RFIC foundry. Prerequisite: ELEN 351. (2 units)

ELEN 359. Advanced Topics in Circuit Design

Various topics. (2 units)

ELEN 360. Nanomaterials

Physics, chemistry, and materials science of materials in the nanoscale. Thin films, inorganic nanowires, carbon nanotubes, and quantum dots are examples covered in detail as well as state-of-the-art synthesis processes and characterization techniques for these materials as used in various stages of technology development. Also listed as ENGR 262. Prerequisites: ENGR 260 and ELEN 261. (2 units)

ELEN 361. Nanoelectronics

Silicon-based technology in the sub-90nm regime. General scaling trend and ITRS Roadmap. Novel device architectures, logic and memory nanodevices, critical enabling device design and process technologies, interconnects, molecular electronics, and their potential usage in future technology nodes. Prerequisite: ELEN 265 or ELEN 267. (2 units)

ELEN 375. Semiconductor Surfaces and Interfaces

Structural and electronic properties of semiconductor surfaces, semiconductor/oxide interfaces, and metal/semiconductor interfaces. Relationship between interface morphology/composition and electrical properties. Modern techniques for characterizing surfaces and interfaces. Derivation of interface properties from electrical characterization of devices. Prerequisite: ELEN 265 or ELEN 267. (2 units)

ELEN 379. Topics in Micro/Nanoelectronics

Various Topics. (2 units)

ELEN 380. Economics of Energy

The focus of the course is the finances of power and energy, including applications of blockchain ledgers, and transactive energy. Roles of policy, regulation and markets that govern production and supply of electricity will be examined. Operational aspects of making and moving electricity are discussed and Levelized Cost of Energy (LOCE) models are developed. Distributed resource management, power flow optimization and integration of large-scale renewables will be considered. Prerequisite: ELEN 183 or ELEN 281A and ELEN 281B. (2 units)

ELEN 387. VLSI Design I

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

ELEN 388. VLSI Design II

Continuation of VLSI design and methodology. Design of arithmetic circuits and memory. Comparison of semi-custom versus fully custom design. General concept of floor planning, placement, and routing. Introduction of signal integrity through the interconnect wires. Also listed as COEN 204. Prerequisite: COEN 203/ELEN 387 or equivalent, or ELEN 153. (2 units)

ELEN 389. VLSI Physical Design

Physical design is the phase that follows logic design, and it includes the following steps that precede the fabrication of the IC logic partitioning: cell layout, floor planning, placement, routing. These steps are examined in the context of very deep submicron technology. Effects of parasitic devices and packaging are also considered. Power distribution and thermal effects are essential issues in this design phase. Also listed as COEN 305. Prerequisite: COEN 204/ELEN 388 or equivalent. (2 units)

ELEN 390. Semiconductor Device Technology Reliability

Reliability challenges in device design, fabrication technology, and test methodology. Device design issues such as design tolerances for latch-up, hot carrier injection, and electromigration. Fabrication technology challenges for sub-micron processes. Test methodology in terms of design feasibility and high-level test/fault coverage. IC yield models and yield enhancement techniques. (2 units)

ELEN 391. Process and Device Simulation with Technology Computer Aided Design (TCAD)

Review of semiconductor technology fundamentals. TCAD tools and methods as a design aid for visualizing physical device quantities at different stages of design and influencing device process parameters and circuit performance. Introduction to numerical simulation and TCAD, 2D process and device simulation, CMOS process flow and device design, device characterization and parameter extraction, circuit simulation. Introduction to virtual IC factory concept, integration of process, device and circuit simulation tools. The concept of process variation, statistical analysis and modeling methods, such as Monte Carlo sampling, correlation analysis, response surface modeling. Prerequisite: ELEN 274. (2 units)

ELEN 421. Speech Coding I

Review of sampling and quantization. Introduction to Digital Speech Processing. Elementary principles and applications of speech analysis, synthesis, and coding. Speech signal analysis and modeling. The LPC Model. LPC Parameter quantization using Line Spectrum Pairs (LSPs). Digital coding techniques: Quantization, Waveform coding. Predictive coding, Transform coding, Hybrid coding, and Sub-band coding. Applications of speech coding in various systems. Standards for speech and audio coding. Also listed as COEN 348. Prerequisite: ELEN 233 and/or 334 or equivalent. (2 units)

ELEN 422. Speech Coding II

Advanced aspects of speech analysis and coding. Analysis-by-Synthesis (AbS) coding of speech, Analysis-as-Synthesis (Aas) coding of speech. Code-Excited Linear Prediction speech coding. Error-control in speech transmission. Application of coders in various systems (such as wireless phones). International Standards for Speech (and Audio) Coding. Real-Time DSP implementation of speech coders. Speech recognition and Biometrics. Research project on speech processing. Also listed as COEN 349. Prerequisite: ELEN 421. (2 units)

ELEN 423. Introduction to Voice-over-IP

Overview of voice encoding standards relevant to VoIP: G.711, G.726, G.723.1, G.729, G.729AB. VoIP packetization and signaling protocols: RTP/RTCP, H.323, MGCP/MEGACO, SIP. VoIP impairments and signal processing algorithms to improve QoS. Echo cancellation, packet loss concealment, adaptive jitter buffer, Decoder clock synchronization. Network convergence: Soft-switch architecture, VoIP/PSTN, interworking (Media and Signaling Gateways), signaling translation (SS7, DTMF/MF, etc.), fax over IP. Prerequisite: ELEN 233 or knowledge of basic digital signal processing concepts. (2 units)

ELEN 431. Adaptive Signal Processing I

Theory of adaptive filters, Wiener filters, the performance surface, gradient estimation. The least-mean-square (LMS) algorithm, other gradient algorithms, transform-domain LMS adaptive filtering, block LMS algorithm. IIR adaptive filters. The method of least squares. Recursive least squares (RLS) adaptive transversal filters; application of adaptive filters in communications, control, radar, etc. Projects. Prerequisites: ELEN 233 and ELEN 334 or AMTH 362 or knowledge of random processes. (2 units)

ELEN 431E. Adaptive Signal Processing I and II

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

ELEN 432. Adaptive Signal Processing II

Linear prediction. Recursive least squares lattice filters. Applications of Kalman filter theory to adaptive transversal filters. Performance analysis of different algorithms. Fast algorithms for recursive least squares adaptive transversal filters. Applications of adaptive filters in communications, control, radar, etc. Projects. Offered in alternative years. Prerequisite: ELEN 431. (2 units)

ELEN 439. Topics in Adaptive Signal Processing

Various topics. (2 units)

ELEN 441. Communications Satellite Systems Engineering

Satellite systems engineering considerations. Spacecraft. Satellite link design. Communication systems techniques for satellite links. Propagation on satellite-earth paths. Earth station technology. Prerequisite: ELEN 243 or equivalent. (2 units)

ELEN 444. Error-Correcting Codes

Theory and implementation of error-correcting codes. Linear block codes, cyclic codes. Encoding and decoding techniques and implementations analysis of code properties and error probabilities. Offered in alternate years. Prerequisite: Knowledge of probability. (2 units)

ELEN 446. Introduction to Wireless Communication Systems

Overview of digital communications. Topics include bit rate and error performance. Long-term and short-term propagation effects. Link budgets. Diversity techniques. Prerequisite: Knowledge of random processes, AMTH 210, ELEN 241 or its equivalent. (2 units)

ELEN 446E Wireless Communications and Networking

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

ELEN 447. Wireless Network Architecture

Issues in wireless management. Topics include: multiple access techniques, cellular and local area network standards, scheduling of users, handoff and channel assignment. Prerequisite: ELEN 446 or equivalent. (2 units)

ELEN 460. Advanced Mechatronics I

Theory of operation, analysis, and implementation of fundamental physical and electrical device components: basic circuit elements, transistors, op-amps, sensors, electro-mechanical actuators. Application to the development of simple devices. Also listed as MECH 207. Prerequisite: MECH 141 or ELEN 100. (3 units)

ELEN 461. Advanced Mechatronics II

Theory of operation, analysis, and implementation of fundamental controller implementations: analog computers, digital state machines, microcontrollers. Application to the development of closed-loop control systems. Also listed as MECH 208. Prerequisites: ELEN 460 or MECH 207, and MECH 217. (3 units)

ELEN 462. Advanced Mechatronics III

Electro-mechanical modeling and system development. Introduction to mechatronic support subsystems: power, communications. Fabrication techniques. Functional implementation of hybrid systems involving dynamic control and command logic. Also listed as MECH 209. Prerequisite: MECH 208 or ELEN 461. (2 units)

ELEN 500. Logic Analysis and Synthesis

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

ELEN 501. Embedded Systems

Embedded Systems are computing systems that measure, control, and interact. This course considers cost, speed, and power optimizations in design. The course and accompanying lab will create real systems with physical device interfaces and consider real-time behaviors. The course will design with embedded development environments, and explore bare-metal programming and debugging techniques, and embedded system validation. Co-requisite: ELEN 501L. (2 units)

ELEN 501L. Embedded Systems Lab

Lab projects based on an embedded computer module to practical applications that reinforce class concepts and provide some opportunities for creative design. Co-requisite: ELEN 501. (1 unit)

ELEN 502. Real-Time Systems

Formal methods and practical solutions related to embedded computing systems with time-critical deadlines. This includes hard real-time systems such as vehicular control and industrial machinery as well as soft real-time systems such as audio streaming or video games. Distributed real-time, timing analysis, and adaptation. Prerequisites: A grade of C- or better in ELEN 501 or equivalent. (2 units)

ELEN 503. Hardware-Software Codesign

The design, analysis, and verification of mixed hardware-software systems focusing on underlying modeling concepts, the design of hardware-software interfaces, hardware/software partitioning, and the trade-offs between hardware and software components. Real-time operating systems, hardware/software project management, and documentation. Co-simulation and mixed-mode testing and verification. Prerequisite: A grade of C- or better in ELEN-502 or equivalent. (2 units)

ELEN 510. Computer Architecture Fundamentals

Computer instruction definition and formatting, the use of opcodes and operands. Instruction execution, control transfer. Pipelining. Hazards. Caches. Prerequisites: A grade of C- or better in either COEN or ELEN 21, or equivalent. (2 units)

ELEN 511. Advanced Computer Architecture

Advanced architectural concepts built upon fundamentals. Superscalar and out-of-order execution. Memory system implementation concepts. DMA and virtual memory. Multiprocessing, including multi-core and multi-threaded architectures. Shared memory and cache coherence. Prerequisite: ELEN 122 or COEN 122 or ELEN 510 or equivalent. (2 units)

ELEN 512. Advanced Computer Architecture II

Continuation of advanced architectural concepts. Hardware support for virtualization. CPU microarchitecture concepts such as branch prediction and non-blocking caches. More on cache coherence protocols. Multi-level cache hierarchies. Memory consistency and synchronization. Prerequisite: ELEN 511 or equivalent. (2 units)

ELEN 513. Parallel System Architectures

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

ELEN 519. Special Topics in Advanced Computer Architecture

Support for virtual memory, shared memory synchronization, transactional memory, multithreading, chip multiprocessors, deep learning, SIMD, warehouse-scale computing. (2 units)

ELEN 520. Introduction to Machine Learning

Classification models, cross-validation; supervised learning, linear and logistic regression, support vector machines; unsupervised learning, dimensionality reduction methods; tree based methods, and kernel methods, principal component analysis, K-means; reinforcement learning. Prerequisites: Python programming, elementary statistics. Co-requisites: ELEN 520L, (2 units)

ELEN 520L. Introduction to Machine Learning Laboratory

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

ELEN 521. Deep Learning

Convolutional neural networks; analysis of selected architectures: GoogleNet, ResNet, Moblenet, Capsule networks; transfer learning; recurrent neural networks and applications; autoencoders; adversarial generative networks. Prerequisite: ELEN 520. Co-requisite: ELEN 521L. (2 units)

ELEN 521L. Deep Learning Laboratory

Laboratory component of ELEN 521. Corequisite: ELEN 521. (1 unit)

ELEN 522. Reinforcement Learning

Introduction to the foundational ideas of reinforcement learning, which provides a way to model the interaction of autonomous agents with the world and emphasizes learning without supervision, and often without any knowledge of the rules of the task it is trying to learn; Markov decision processes, value functions, Monte Carlo estimation, dynamic programming, temporal difference learning, function approximation, scaling to large domains. Prerequisite: ELEN 521. (3 units)

ELEN 523. Natural Language Processing with Deep Learning

Computational properties of natural language; simple word level to syntactic level; design and implementation of neural network models used in NLP for applications such as question answering, language translation, language understanding, and natural language generation. Prerequisite: ELEN 521. (2 units)

ELEN 530. Hardware Security and Trust

New techniques for securing hardware from malicious attacks. Hardware security primitives. Hardware Trojan detection and prevention. Hardware-based obfuscation techniques. Side-channel attacks and countermeasures. Cryptographic algorithms. FPGA security. Hardware Metering. Watermarking. IP piracy. IoT security. Counterfeit detection and prevention. Prerequisite: ELEN 127 OR ELEN 603 with a grade of C- or better. (2 units)

ELEN 601. Low Power Designs of VLSI Circuits and Systems

Design of digital circuits for reduced power consumption. Sources of power consumption in ICs and analysis algorithms for their estimation at different stages of design. Various power reduction techniques and their trade-offs with performance, manufacturability, and cost are analyzed. Project to design a digital circuit with power reduction as the primary objective. Prerequisite: ELEN 387. (2 units)

ELEN 602. Modern Time Analysis

Analysis in logic design review of background materials and introduction of concepts of false path, combinational delay, and minimum cycle time of finite state machines. Study of efficient computational algorithms. Examination of retiming for sequential circuits, speed/area trade-off. Prerequisite: ELEN 500. (2 units)

ELEN 603. Logic Design Using HDL

Algorithmic approach to design of digital systems. Use of hardware description languages for design specification. Structural, register transfer, and behavioral views of HDL. Simulation and synthesis of systems descriptions. Also listed as COEN 303. Prerequisite: ELEN 127 or equivalent. (2 units)

ELEN 608. Design for Testability

Principles and techniques of designing circuits for testability. Concept of fault models. The need for test development. Testability measures. Ad hoc rules to facilitate testing. Easily testable structures, PLAs. Scan-path techniques, full and partial scan. Built-in self-testing (BIST) techniques. Self-checking circuits. Use of computer-aided design (CAD) tools. Also listed as COEN 308. Prerequisite: ELEN 500 or equivalent. (2 units)

ELEN 609. Mixed-Signal DA and Test

Mixed-Signal test techniques using PLL and behavioral testing as major examples. Overview of the IEEE 1149.4 Mixed-Signal standard. Mixed-Signal DFT and BIST techniques with emphasis on test economics. Most recent industrial mixed-signal design and test EDA tools and examples of leading state-of-the-art SoCs. Prerequisites: ELEN 500 or COEN 200 and ELEN 387 or COEN 203. (2 units)

ELEN 613. SoC (System-on-Chip) Verification

This course presents various state-of-the-art verification techniques used to ensure the corrections of the SoC (System-on-Chip) design before committing it to manufacturing. Both Logical and Physical verification techniques will be covered, including Functional Verification, Static Timing, Power, and Layout Verification. Also, the use of Emulation, Assertion-based Verification, and Hardware/Software Co-Verification techniques will be presented. Also listed as COEN 207. Prerequisites: ELEN 500 or COEN 200 and ELEN 603 or equivalent. (2 units)

ELEN 617. Storage Systems – Technology and Architecture

The course will address the developments in storage systems. Increase in data storage has led to an increase in storage needs. This arises from the increase of mobile devices as well as increase in internet data storage. This course will provide the students good knowledge of different storage systems as well as challenges in data integrity. A discussion of the next generation of storage devices and architectures will also be done. (2 units)

ELEN 620. Digital Systems Design Project

By arrangement. An individual or group project that progresses through multiple phases of a complete design flow, leveraging and applying concepts learned in other courses. Projects can be pure hardware designs, or hardware/software co-designs. Prerequisites: ELEN 501, ELEN 511, ELEN 603. (1-6 units)

ELEN 624. Signal Integrity in IC and PCB Systems

Analysis, modeling, and characterization of interconnects in electronic circuits; Transmission line theory; losses and frequency dependent parameters. Signal Integrity issues in high-speed/high-frequency circuits; means of identifying signal integrity problems. Reflection and crosstalk; analysis of coupled-line systems. Power distribution networks in VLSI and PCB environments and power integrity. Signal/Power integrity CAD. Prerequisite: ELEN 201. (2 units)

ELEN 639. Audio and Speech Compression

Audio and speech compression. Digital audio signal processing fundamentals. Non-perceptual coding. Perceptual coding. Psychoacoustic model. High-quality audio coding. Parametric and structured audio coding. Audio coding standards. Scalable audio coding. Speech coding. Speech coding standards. Also listed as COEN 339. Prerequisites: AMTH 245 and COEN 279 or equivalent. (2 units)

ELEN 640. Digital Image Processing I

Digital image representation and acquisition, color representation; point and neighborhood processing; image enhancement; morphological filtering; Fourier, cosine and wavelet transforms. Also listed as COEN 340. Prerequisite: ELEN 233 or equivalent. (2 units)

ELEN 641. Image and Video Compression

Image and video compression. Entropy coding. Prediction. Quantization. Transform coding and 2-D discrete cosine transform. Color compression. Motion estimation and compensation. Digital video. Image coding standards such as JPEG and JPEG family. Video coding standards such as the MPEG series and the H.26x series. H.264/MPEG-4 AVC coding. HEVC/H 265/MPEG-H Part 2 coding. VVC. Future JVET standard Rate-distortion theory and optimization. Visual quality and coding efficiency. Brief introduction to 3D video coding and 3D-HEVC. Deep learning approaches. Applications. Also listed as COEN 338. Prerequisites: AMTH 108, AMTH 245, basic knowledge of algorithms. (4 units)

ELEN 642. Computational and Medical Imaging

Algorithms for indirect image formation using both optimization and model-based methods. Application includes computed tomography, magnetic resonance imaging, microscopy, remote sensing, super-resolution. Fourier-based and sparse iterative algorithms. Analysis of accuracy and resolution of image formation based on measurement geometry and statistics. Offered in alternate years. Also listed as BIOE 642. Prerequisites: AMTH 211 and either ELEN 233 or AMTH 358 or equivalent. (2 units)

ELEN 643. Digital Image Processing II

Image restoration using least squares methods in image and spatial frequency domains; matrix representations; blind deconvolution; super-resolution methods; reconstructions from incomplete data; image segmentation methods, three-dimensional models from multiple views. Also listed as COEN 343. Prerequisite: COEN 340. (2 units)

ELEN 644. Computer Vision I

Introduction to image understanding, feature detection, description, and matching; feature based alignment; structure from motion stereo correspondence. Also listed as COEN 344. Prerequisites: ELEN 640 and knowledge of linear algebra. (2 units)

ELEN 645. Computer Vision II

Learning and inference in vision; regression models; deep learning for vision; classification strategies; detection and recognition of objects in images. Also listed as COEN 345. Prerequisites: ELEN 640 and knowledge of probability. (2 units)

ELEN 649. Topics in Image Processing and Analysis

Various topics. (2 units)

ELEN 701. RF and Microwave Systems

The purpose of this class is to introduce students to the general hardware components, system parameters, and architectures of RF and microwave wireless systems. Practical examples of components and system configurations are emphasized. Communication systems are used to illustrate the applications. Other systems, such as radar, the global positioning system (GPS), RF identification (RFID), and direct broadcast systems (DBS) are introduced. (2 units)

ELEN 706. Microwave Circuit Analysis and Design

Microwave circuit theory and techniques. Emphasis on passive microwave circuits. Planar transmission lines. Field problems formulated into network problems for TEM and other structures, scattering and transmission parameters, Smith chart, impedance matching, and transformation techniques. Design of power dividers, couplers, hybrids and microwave filters. Microwave CAD. Prerequisite: ELEN 201. (4 units)

ELEN 711. Active Microwave Devices I

Scattering and noise parameters of microwave transistors, physics of silicon bipolar and gallium arsenide MOSFET transistors, device physics, models, and high-frequency limitations. Applications to microwave amplifier and oscillator designs. Prerequisite: ELEN 706. (2 units)

ELEN 712. Active Microwave Devices II

Continuation of ELEN 711. Nonlinear active circuits and computer-aided design techniques. Nonlinear models of diodes, bipolar transistors and FET’s applied to the design of frequency converters, amplifiers, and oscillators. Techniques. Prerequisite: ELEN 711. (2 units)

ELEN 715. Antennas I

Fundamentals of radiation, antenna pattern, directivity and gain. Dipole and wire antennas. Microstrip Patch Antennas. Broadband antennas. Antennas as components of communications and radar systems. Antenna measurement. Antenna CAD. Prerequisite: ELEN 201. (2 units)

ELEN 716. Antennas II

Continuation of ELEN 715. Aperture antennas. Traveling-wave antennas. Antenna Arrays. Linear arrays with uniform and non-uniform excitations. Beam scanning and phased arrays; Planar arrays; Array Synthesis. Prerequisite: ELEN 715. (2 units)

ELEN 717. Antennas III

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

ELEN 725. Optics Fundamentals

Fundamental concepts of optics: geometrical and wave optics. Optical components–-free space, lenses, mirrors, prisms. Optical field and beams. Coherent (lasers) and incoherent (LED, thermal) light sources. Elements of laser engineering. Optical materials. Fiber optics. Polarization phenomena and devices. Also listed as PHYS 113. Prerequisite: ELEN 201 or equivalent. (4 units)

ELEN 726. Microwave Measurements, Theory, and Techniques

Theory comprises six classroom meetings covering signal flow graphs, error models and corrections, S-parameter measurements, Vector analyzers, microwave resonator measurements, noise figure measurements, signal generation and characterization, spectrum analyzers, and phase noise measurements. Four laboratory meetings. Offered in alternate years. Prerequisite: ELEN 711. (3 units)

ELEN 729. Topics in Electromagnetics and Optics

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

ELEN 921C. Introduction to Logic Design

Boolean functions and their minimization. Designing combinational circuits, adders, multipliers, multiplexers, decoders. Noise margin, propagation delay. Bussing. Memory elements: latches and flip-flops; timing; registers; counters. Introduction to FPGAs and the need for the use of HDL. Taught in the graduate time format. Foundation course not for graduate credit. Also listed as COEN 921C. (2 units)

Chapter 12: Department of Engineering

Coordinator: Dr. Aleksandar Zecevic

The Graduate Core is one of the distinguishing features of the Master's program at Santa Clara University. Because of its breadth and interdisciplinary nature, the Core requires courses that transcend departmental boundaries, and address questions that relate to the societal impact of engineering, as well as ways in which this impact can be shaped. We offer a wide range of such courses, which are designated with the prefix ENGR (to emphasize the fact that they belong to the category of General Engineering).

Course Descriptions

ENGR 256. Introduction to NanoBioengineering*

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

ENGR 257. Introduction to Biofuels Engineering*

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

ENGR 260. Nanoscale Science and Technology*

Overview of key elements of physics, chemistry, biology, and engineering underlying this interdisciplinary field. Bulk vs. surface properties of materials. Surface phenomena and quantum phenomena. Self-assembly and soft lithography. Nanoscale materials characterization. Carbon nanotubes, inorganic nanowires, organic molecules for electronics, biological and bio-inspired materials. Emerging applications of nanoscale materials. Prerequisite: Graduate standing. (2 units)

ENGR 261. Nanotechnology and Society

Addresses the fundamental scientific and technological underpinnings of the
important new field of nanotechnology. Examines how our understanding and our technological capabilities have evolved over the past century, and how nanotechnology proposes new applications that can address social and economic goals. An appreciation of the interaction between these goals and the evolution of the technology is central to the course. Students will develop critical thinking about the prospects for nanotechnology in order to be able to assess the relevant ethical and social issues, and also the possibility and/or likelihood of the development of specific applications. (4 units)

ENGR 262. Nanomaterials*

Physics, chemistry, and materials science of materials in the nanoscale. Thin films, inorganic nanowires, carbon nanotubes, and quantum dots are examples covered in detail as well as state-of-the-art synthesis processes and characterization techniques for these materials as used in various stages of technology development. Also listed as ELEN 360. Prerequisites: ENGR 260 and ELEN 261 or Elen 151. (2 units)

ENGR 271. Energy Conservation

It is by no means clear that the shortage of carbon-free energy can be resolved by identifying alternative resources. As a result, conservation must play a key role in the development of new energy policies, both locally and globally. This course explores how conservation and sustainability relate to each other, with special emphasis on the value of cost-effective, innovative water recycling, and strategies for reducing the use of electrical energy. (2 units)

ENGR 272. Energy Public Policy

The class will survey the types of energy used historically from traditional biomass to coal, to natural gas, to nuclear and renewables, as well as the increasingly diverse possibilities for future use discussed in current policy debates. Coverage will also include a historical review of regulation and policy in the energy industry. The geographic scope will be international. The field of energy analysis and policy is inherently interdisciplinary. Prerequisite: ELEN 280/MECH 287. (2 units)

ENGR 273. Sustainable Energy and Ethics

This course explores the ethical implications of energy production, distribution, and consumption, with the aim of understanding those normative considerations that motivate public, institutional and private bodies to develop sustainable energy policies and practices. Through examination of texts and case studies, students will learn to critically analyze, develop and defend ethical judgments and practices with respect to energy. Topics include considerations of environmental justice; tension between global and local spheres of ethical concern; the rights and interests of potential stakeholders, both human and non-human; our duties with respect to prevention or mitigation of harms and management of risk; our ethical obligations to future generations; and the role of personal, civic and professional virtues in guiding sustainable energy practices. (2 units)

ENGR 288. Co-op Education

The primary purpose of Co-op education is to give students an opportunity to gain practical knowledge in their field of study. This course is designed to prepare them for such an experience. It consists of a series of lectures on topics that will familiarize them with the Silicon Valley working environment and will enable them to relate their experience in the industry to their academic program. **This course is required for all international students who wish to do Curricular Practical Training (CPT). ENGR 288 is not offered in the summer quarter. Attendance is mandatory. P/NP grading. (1 unit)**

> *Note: ENGR 288 can be taken during the first quarter of CPT, or before the training begins.*

ENGR 289. Extended Co-op Education

Students who extend their co-op experience beyond one quarter 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 new supervisor report, which evaluates their performance during the most recent ten week period. P/NP grading. Prerequisite: ENGR 288. (1 unit)

ENGR 293. Directed Research

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

ENGR 302. Managing in the Multicultural Environment

Provides practical, theoretical, and experiential tools to manage a multicultural workforce. Cases from Silicon Valley engineering environments will be studied. Topics will include: (1) insights into various cultures’ approaches to time, information, planning, decision making, relationships, power, and change; (2) developing leadership, motivation, and participation in multicultural teams; (3) creating an environment that maximizes the benefits of diversity and retains workers from a variety of cultural backgrounds; (4) resolving conflict when there are different cultural approaches; and (5) the role of corporate culture for multicultural and global companies. (2 units)

ENGR 303. Gender and Engineering

This course, based on brain science, culture, and communication, provides a foundation for managing the different worlds—the various cultural lenses, paradigms, and different competencies—many women and men bring to an engineering workplace. Gender Competence, effective management of differences increases "fire prevention," customer focus, and innovation in research, development, and marketing of products; and advancement of both women and men. (2 units)

ENGR 304. Building Global Teams

Challenges of working virtually and globally. Building global teams. Working across cultures and distance; achieving goals while managing differences. Diverse approaches to managing task, time, and hierarchy. Social interactions and decision-making. Culture's impact on teamwork. Global leader dimensions. Trust building. Empowering self and others. Business practices in China, India, Russia, and other countries. (2 units)

ENGR 306. Engineering and the Law

Exploration of legal issues affecting project engineers, contractors, and owners. Topics include structure of project teams, contracts, standard of care, insurance, and dispute resolution. Evolving legal issues with Integrated Project Delivery (IPD) and Building Information Modeling (BIM). (2 units)

ENGR 330. Law, Technology, and Intellectual Property

Study of available legal provisions for establishing, receiving, preserving, and enforcing intellectual property rights in research, development, engineering, and marketing of products. Includes a study of patents, trade secrets, copyrights, mask works, trademarks, and employer-employee contracts regarding intellectual property. (2 units)

ENGR 332. How Engineers, Businesspeople and Lawyers Communicate with Each Other

It can be challenging to communicate and collaborate effectively with people from different disciplines. This course will help students from business, engineering, and law learn to understand each other's perspectives, speak each other's language, and work together effectively in a collaborative environment. Students from different schools will be organized into teams to work together on a simulated project involving a technological matter, such as privacy/security or IP. Also listed as LAW 371. (3 units)

ENGR 334. Energy, Climate Change, and Social Justice

The field of climate ethics has emerged recently to negotiate the serious and complex ethical choices facing human society as we balance energy, environmental, and economic development needs. Social science and ethical lenses are used to examine energy use and climate disruption in light of the moral principle of social justice. This course gives graduate engineering students the background and skills to communicate these issues in several different modes. It consists of three main thematic parts: energy choices; social vulnerabilities; and difficult policy dilemmas. (2 units)

ENGR 336. Engineering for the Developing World

How does one innovate products and services for developing countries? How can complex problems be tackled with simple technologies and low-cost business models? This course presents a framework of engineering design and management techniques that are appropriate for developing markets. Topics such as "ruggedization," cost control, and local resource use will be explored through a variety of examples and case studies, which range from alternative energy and low-cost diagnostics to mobile applications and micro entrepreneurship. This course examines the potential social benefits that design, manufacturing, and business innovation can provide to address various challenges in the developing world. (2 units)

ENGR 338. Mobile Applications for Emerging Markets

The mobile revolution is changing the lives of people across the globe, from Wall Street to Main Street to rural villages. This course will provide an overview of the technological innovation, including applications and instrumentation, which the mobile revolution is spawning, particularly in underserved communities globally. It will feature guest speakers from technology companies involved in Mobile R&D, look at market and beneficiary needs, and discuss how to innovate products and services for these customers and how to tackle complex "life" problems with simple technologies, applications, and business models, using real-life case studies. (2 units)

ENGR 339. Energy Storage Systems*

Energy storage systems play an essential role in the utilization of renewable energy. They are used to provide reserve power under different circumstances and needs such as peak shaving, load leveling, and ancillary services. Power electronics equipment converts the battery power into usable grid power. The course will survey batteries, pumped storage, flywheels, ultracapacitors, etc., with an analysis of the advantages and disadvantages, and uses of each. Also listed as ELEN 287. (2 units)

ENGR 340. Distributed & Renewable Energy

This course surveys energy engineering and entrepreneurship in emerging market countries, with an emphasis on strategies for coping with the absence of a grid. It analyzes strategies for energy generation, transmission, and storage at household, community and regional scales drawing from sector and case studies in the developing world. (2 units)

ENGR 341. Innovation, Design, and Spirituality

IDS provides opportunity for the SCU graduate engineering student to begin to integrate knowledge gained in other engineering coursework with innovation management, design thinking and spiritual development, particularly in entrepreneurial and intrapreneurial contexts, whether for commercial and/or social benefit. The 2-credit course assumes engineers play significant roles in innovation efforts in their future employments and deployments. As a result, IDS aims to deepen the engineering student's leadership character, competences and capacity, especially for these contexts and deployments. (2 units)

ENGR 342. 3D Print Technology and Society

This class is designed to introduce students to 3D print technology, which offers a range of exciting possibilities for product design, delivery, and democratization of entrepreneurship. Along with hands-on experience of the technology, students will be exposed to the ecosystem engaged by the technology. Implications for life sciences, career opportunities, entrepreneurship, and restructuring of global markets and society will be examined. (2 units)

ENGR 350. Success in Global Emerging Markets

Strategies and tactics for moving new products and technologies into global emerging markets, comprehending cultural impact, and creating new markets. Understanding your company's objective, determining what is possible, and developing practical go-to-market strategies. Topics include new ventures, sustainability, social responsibility, risk assessment and mitigation. (2 units)

ENGR 351. New Paradigm for Technology-Global Mindfulness Leadership

The main purpose of this course is to examine the role that leadership and strategic vision play in a globalized interconnected business environment. Emphasis will be placed on developing critical thinking and collaborative skills through research projects and case studies. (2 units)

ENGR 371. Space Systems Design and Engineering I *

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to orbital mechanics, power, command and data handling, and attitude determination and control. Note: ENGR 371 and 372 may be taken in any order. Also listed as MECH 371. (4 units)

ENGR 372. Space Systems Design and Engineering II*

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to mechanical, thermal, software, and sensing elements. Note: ENGR 371 and 372 may be taken in any order. Also listed as MECH 372. (4 units)

****Eligible for Technical Stem in Engineering Management***

Chapter 13: Department of Engineering Management and Leadership

Dean's Executive Professor: Paul Semenza (Department Chair)
Adjunct Faculty: Michele Ellie Ahi, Octave Baker, Marlene Cole, Theresa Conefrey, Don Danielson, John Giddings, Pravin Jain, Ronald Lesniak, Eric Monsef, Mohammad Musa, Usha Parimi, Kern Peng, Bruce Pittman, Dennis Segers, Nataliya Starostina, Dave Trindade

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. In addition, the GRE is required for all students who do not have at least two years of working experience in the United States.

Requirements

Students are required to complete a minimum of 46 quarter units to complete the master's degree, following these guidelines:

- **Engineering Management Core (20 units)**
  - Required Courses (10 units): EMGT 255, 322, 330, 352, and 380
  - Leadership (2 units): select from EMGT 269, 285, 324, 349, 373, or 395
  - Project, Program, and Product Management (2 units): select from EMGT 296, 307, 308, 333, 335, 338, 339, 345, 358, or 378
  - Operations/Innovation Management (2 units): select from EMGT 253, 289, 292, 323, or 357
  - Electives (4 units): choose any 2 EMGT courses
- **Technical Stem (18 units)**
  - A focused set of courses from Graduate Engineering departments; see guidelines and restrictions below
- **Enrichment Experience (minimum 8 units)**
  - Graduate Core: A minimum of 4 units. One from each topic
    - Emerging Topics in Engineering
    - Engineering and Society
  - The additional 4 units can be satisfied by any combination of
    - a) one or more technical electives
    - b) additional classes from Graduate Core List
    - c) Cooperative Education courses (ENGR 288/289)
    - d) combination of a, b and c

Please see Chapter 6 for additional information regarding the Enrichment Experience.

Technical Stem Courses

Engineering Management and Leadership students are required to create a focused, coherent program of studies within a field of engineering. The following list areas of focus by department, which can be used as guidelines for developing the Technical Stem program.

- **Bioengineering**: Biomolecular Engineering/Biotechnology; Biomaterials and Tissue Engineering; Microfluidics/Biosensors and Imaging; Computational or Translational Bioengineering
- **Civil, Environmental, and Sustainable Engineering**: Structural Engineering; General Civil Engineering; Construction Engineering and Management
- **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; RF and Applied Electromagnetics; Signal Processing; Digital Systems; Communications
- **Mechanical Engineering**: Aerospace Engineering; Dynamics and Controls; Materials Engineering; Mechanical Design; Robotics and Mechatronic Systems; Thermofluids
- **Power Systems and Sustainable Energy** Interdisciplinary Technical Stem programs can be created to pursue areas of interest within engineering management. For example, the following program would be applicable to Industrial Engineering and/or Operations Research.
- **Probabilistic Modeling/Optimization:** 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 option: substitute COEN 240 or 281 for 1 or 2 of the above; or ELEN 520, 521

Courses for the Technical Stem of Engineering Management and Leadership are selected from the graduate course listings in the Graduate Bulletin. However, not all graduate classes listed in the bulletin are considered technical in terms of fulfilling the technical stem requirements. This is especially the case of ENGR courses. In addition, there are other limitations, some of which are listed below. Therefore, it is important that students complete a program of studies in their first term, to make sure all of the courses they select will fulfill the degree requirements.

- All courses applied to the Engineering Management and Leadership degree must be graded courses—no P/NP courses are allowed.
- Undergraduate courses cross-listed with graduate course numbers do not apply unless the student registers with the graduate course number.
- Graduate seminars in other departments such as ELEN 200, COEN 400, MECH 261, MECH 297 are not applicable.
- COEN 485 Software Engineering Capstone is not applicable to the technical stem unless students complete three one-quarter consecutive sessions beginning in the fall quarter.
- The following courses do not count toward the technical stem: BIOE 210; CENG 208 and 292; COEN 287 and 288; ELEN 217; ENGR 245, 261, 271, 272, 273, 288, 289, 293, 302, 303, 304, 306, 330, 332, 334, 336, 338, 340, 341, 342, 343, 344, 349, 350, and 351.
- Engineering Management and Leadership students are allowed to enroll in one unit of Independent Study or Directed Research under the direction of a full-time faculty member in the respective engineering department. Any additional units will not be counted toward graduation.
- New courses are often developed and offered during the academic year that are not listed in this bulletin. It is important that students check with their advisor prior to enrolling in those courses to make sure they will count toward their degree.

All of the requirements for the engineering management and leadership degree must be completed within a six-year timeframe. In addition to the overall 3.0 GPA graduation requirement, engineering management and leadership degree candidates must earn a 3.0 GPA in those courses applied to their technical stem and a 3.0 GPA in their engineering management course stem. All courses in which a student is enrolled at Santa Clara are included in these calculations.

A completed program of studies for Engineering Management and Leadership degree candidates must be submitted to the chair of the Department of Engineering Management and Leadership during the first term of enrollment to ensure that all courses undertaken are applicable to the degree. Students who take courses that have not been approved for their program of studies by both the department chair and the Graduate Programs Office do so at their own risk, as they may not be counted toward completion of the degree.

A maximum of nine quarter units (six semester units) of graduate-level coursework may be transferred from other accredited institutions at the discretion of the student's advisor provided they have not been applied to a previous degree. However, in no case will the minimum units taken in the Department of Engineering Management and Leadership be fewer than 16. Extension classes, continuing education classes, professional development courses, or classes from international universities are not accepted for transfer credits.

Note: International students or students not fluent in the English language should enroll in one or more of the following courses prior to enrolling in advanced courses in engineering management:

- *EMGT 270 Effective Oral Technical Presentations*
- *EMGT 272 Effective Written Technical Communications II*
- *EMGT 318 Strategies for Career and Academic Success (for foreign-born technical professionals)*

Engineering Management and Leadership Five-Year Program

The School of Engineering offers qualified Santa Clara University undergraduates the opportunity to earn both a Bachelor of Science degree in their technical discipline and a Master of Science degree in Engineering Management and Leadership in five years. This is an excellent path to continue technical education while learning the essential skills required to manage technical projects and people. The degree program is open to students in engineering and engineering physics.

The application fee and GRE General Test requirement are waived for students completing their undergraduate B.S. degree in the technical disciplines listed above who have a minimum GPA of 3.0 in their technical major. Students are required to apply no later than the end of their junior year. Upon notification of acceptance into the Engineering Management and Leadership Five-Year Program, students may begin taking graduate-level courses in the fall quarter of their senior year. The maximum number of graduate units allowed to transfer as an undergraduate in this program is 20.

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. *B.S. degrees (for those who are graduating seniors) must be posted by September 1 to allow the student progression in their graduate career.*
2. *Undergraduate students must submit "Permission to Take Graduate Course" form to be correctly registered for graduate courses.*
3. *All coursework applied to the M.S. degree must be at the 200 level or above and not applied to any other degree.*
4. *Course numbers below 200 indicate undergraduate courses, numbers of 200 and above indicate graduate courses. Students may take courses assigned both undergraduate and graduate numbers (same title used for both numbers) only once as an undergraduate or graduate student.*
5. *Students must register with the graduate course number in cross-listed courses to apply the course to an M.S. degree.*
6. *Students who are entering this program should meet with their Engineering Management and Leadership advisor at the end of their junior year 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 253. Operations and Production Systems

Provides the knowledge and techniques required to properly manage operations and production systems. Topics include operations strategies, process management, forecasting, location and layout decisions, capacity and resource planning, technology management, computer-integrated manufacturing. TQM, statistical process control, Lean, Just-in-Time, simulation, and supply-chain and inventory management. (2 units)

EMGT 255. Managerial Accounting for Operating Managers

This course provides an introductory survey to the underlying principles and applications of managerial accounting and financial analysis. Taken from the perspective of the recipient of accounting data, rather than the generator of reports, this course will equip operating managers with the skills to interpret the story behind the numbers to gain a more accurate understanding of the status of their business and to make more informed decisions. (2 units)

EMGT 269. Human Resource Development and the Engineering Manager

Provides concepts of human resource management in tech companies, including staffing, performance management, people development, compensation and benefit strategies. Also explores the meaning of work, the individual and organization behaviors, growth and learning, the manager’s role in career/life management, corporate cultures, as well as the development of major management theories. (2 units)

EMGT 270. Effective Oral Technical Presentations

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

EMGT 271. Effective Written Technical Communication I

Cluster writing; pyramid technique; audience analysis; opening, body, and end of text; technical correspondence; abstracts and summaries; presentation patterns for reports and proposals; proposal presentation. (2 units)

EMGT 272. Effective Written Technical Communication II

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

EMGT 285. Managing Business Relationships

Leadership skills taught to develop and leverage key relationships in one’s own organization, including person-to-person (manager), group-to-group (director), and company-wide (executive) relationship management strategies. Learn to develop and manage interaction models, dependency analyses, and team structures. Develop people skills and techniques to manage outsourcing, partnerships, joint development strategies, and change management. Calibration and driving key metrics as part of ability to influence across one's network. High class participation using group exercise, combined with practical training methods. (2 units)

EMGT 289. Managing, Controlling, and Improving Quality

Management structure and statistical and analytical tools for quality success: total quality management, six-sigma and beyond, statistical inference (made simple), control charts (SPC), sampling procedures, designed experiments (DOE), and reliability. (2 units)

EMGT 292. Managing Capital Assets in the Smart Machine Era

Provides effective tactics in managing capital assets in technical firms. With Industry 4.0 and the development of a new generation of smart machines, the complexity and cost of capital equipment are increasing substantially. Prepares students to manage the new generation of machines with the applications of robotics, IoT, AI and ML.

Covers approaches and practices in managing the lifespan of capital assets: development, introduction, sustaining, decommission. (2 units)

EMGT 295. Project Planning Under Conditions of Uncertainty

Managerial decision making in project management under conditions of varying knowledge about the future. Decisions relying on certainty and decisions based on probabilities and made under risk. Situations in which there is no basis for probabilities; decisions made under conditions of uncertainty. Use of applications of decision theory to help develop strategies for project selection and evaluation. (2 units)

EMGT 296. Project Risk Management

There are three fundamental steps: risk analysis, risk evaluation, and risk migration and management. The acceptable risk threshold is defined by the customer and management, and identifies the level above which risk reduction strategies will be implemented. (2 units)

EMGT 299. Directed Research

By arrangement. Limited to a single enrollment. (1 unit)

EMGT 307. Medical Device Product Development

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

EMGT 308. Solutions Architecture and the Cloud

System design foundation blocks, design considerations and best practices for cloud services; micro services to build sample systems. Hands-on labs to deploy applications on cloud platforms such as AWS, Azure and GCP. Review of cloud certification paths relevant to solutions architect roles at cloud infrastructure and platform companies. (2 units)

EMGT 318. Strategies for Career and Academic Success (for Foreign-born Technical Professionals)

Designed to help foreign-born engineers and technical professionals develop the knowledge and skills needed to be more effective in the American academic and corporate environments and to achieve career success. Focuses on key skills in career development, effective communication, interpersonal effectiveness, and building relationships with co-workers. Uses participatory, experiential training methods including role plays, simulations, and small group exercises. (2 units)

EMGT 319. Human Interaction I

Individuals interacting in groups to solve problems. Discusses a mix of electronic and personal elements to achieve goals. (2 units)

EMGT 320. Human Interaction II

A close look at communications. Personal limits. Electronic interfacing. The role of communication skills, attitudes, knowledge level, and culture in the communication process. (2 units)

EMGT 322. Organizational Behavior

This course will cover the skills required in transitioning from a technical contributor to a technical manager or team leader. This transition requires a new set of skills and knowledge in which engineers and scientists are typically not trained. These new skills will include “soft skills” from the areas of psychology, ethics, and interpersonal relationships, as well as the management processes essential to becoming an effective manager. This class blends the technical dialog with a more personal and social dialogue. Students will think introspectively about managerial roles and responsibilities through lectures and discussions. (2 units)

EMGT 323. Management of Technological Innovation: Opportunities and Challenges

Understanding innovation as the process of commercializing new technologies or applying them in new ways, at the levels of industries, markets, and the firm, including startups and incumbents. Sources, types and models of innovation, s-curves and disruptive innovation, dominant designs and standards, first-mover and other timing issues, network effects and platforms, intellectual property and markets for technology, and tools for selecting innovation projects. Focus will be on strategies and processes for capitalizing on innovations. (2 units)

EMGT 324. Engineering Leadership

This course is designed to facilitate successful transitions by individuals with technical backgrounds from team management to corporate leadership positions. Students will learn the attitudes and social approaches necessary for serving as an effective corporate leader. This will be accomplished through lectures and discussions with classroom participation exercises and topical essay homework. Prerequisite: EMGT 322. (2 units)

EMGT 329. Parallel Thinking

This workshop-style program will provide the tools and coaching engineering leaders need to be effective in harnessing the brainpower of groups. Draws heavily on the application of the research done at Stanford University on precision questioning, the work of Edward DeBono, and group processing work on high-performance systems. (2 units)

EMGT 330. Project Management Basics

Designed to provide the basic knowledge and techniques required to properly manage projects. Covers the fundamental concepts and approaches in project management, such as the triple constraints, project life cycle and processes, project organizations, project scheduling, budgeting, resource loading, project monitoring and controls, and project information systems. (2 units)

EMGT 331. Strategic Technology Management

Translating strategic plans into action plans and ensuring their implementation. Integration of a process that crosses all organizational boundaries. Performance objectives and priorities, change and discontinuities, managed growth, accelerated technology transfer. Analyzing competitive technical positions, collecting and utilizing user/customer information, and changing leadership. (2 units)

EMGT 333. Computer-Aided Project Management Scheduling and Control

This course is designed to teach students real world project management using modern project management software. We consider customers, competition, technology, and financial realities in order to develop project requirements. We then go on to project planning, resource allocation, and strategies for dealing with multiple projects. Finally, we focus on 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 380. (4 units)

EMGT 345. Program Management

Fundamentals of program and portfolio management and how they are applied to improve business results on programs of varying size, within all types of businesses, from small companies to large enterprises. Prerequisite: EMGT 330 (Project Management Basics) or equivalent experience. (2 units)

EMGT 346. Engineering Economics

Valuating and selecting engineering projects based on their characteristics of risk, available information, time horizon, and goals. Utilization of classical capital budgeting techniques, qualitative criteria, and financial option theory. Exploration of the value of individual projects on the company's total portfolio of projects. Introduction to decision theory as it applies to project evaluation. Prerequisite: Finance or familiarity with time value of money concepts such as net present value. (2 units)

EMGT 349. Ethical Decision Making for Technology Leaders

Designed to create a holistic understanding of leadership. Through readings, discussions, and case studies, students will learn to integrate key leadership concepts from psychology, ethics, political science, philosophy, and sociology. Students will be able to characterize their individual approaches to leadership and learn to adapt it to changes resulting from globalization and advancing technology. (2 units)

EMGT 352. Marketing of High-Tech Products and Innovations

This course is designed to give engineers and managers a working understanding of the strategic role marketing plays in the development and promotion of high-technology products and systems. This course provides insights into the particular challenges of marketing high-tech products. Students will learn marketing frameworks and apply them to case studies as well as by creating a marketing plan for an emerging technology or business. (2 units)

EMGT 353. Introduction to Total Quality Management

The basic tenets of TQM: customer focus, continuous improvement, and total participation. Particular emphasis on using TQM to enhance new product development. (2 units)

EMGT 354. Innovation, Creativity, and Engineering Design

Research, development, the process of discovery, recognizing a need, encouraging change, assuming risks, technological feasibility, marketability, and the environment for innovation. (2 units)

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

Root cause analysis of problems is one of the main functions of engineering and is a critical component of organizational governance for engineering managers. This course will help problem solvers differentiate among the generic steps involved in (1) identifying a problem, (2) performing a diagnosis, (3) selecting and implementing solutions, and (4) leveraging and sustaining results. The major emphasis is placed on diagnosis, which at its core is logical, deductive analysis carried out using critical thinking. Cross-listed with Bioe 357 (2 units)

EMGT 358. Global Technology Development

Global markets present growth opportunities for both business and professionals. Approaches the development of global technology from the perspective of the engineering manager engaged as either part of a large corporate team or as an entrepreneur in a small business. Skills for characterizing, developing, and leveraging trending technology and risk management tools, as well as diversified cultures and global resources. Approaches include formal methodologies and practical lessons learned from industry. (2 units)

EMGT 360. Current Papers in Engineering Management and Leadership

Individual topics to be selected in concurrence with the instructor. (2 units)

EMGT 362. Topics in Engineering Management

Topics of current interest in engineering management and leadership. May be taken more than once as the topics change. (2 units)

EMGT 370. International (Global) Technology Operations

Examines methods and important issues in managing operations when customers, facilities, and suppliers are located across the globe. Topics include the global technology environment, international operations strategy and process formulation, and issues on the location and coordination of overseas facilities. These and other course topics are examined through a combination of lectures, text material, and integrated case studies. (2 units)

EMGT 373. Technology Entrepreneurship

Designed for students who are interested in starting their own venture as well as those working for a start-up company. Students will discover the process of moving from an idea to making a profit. Topics will include idea development, intellectual property, forming a team, obtaining funding, start-up logistics, executing your plan, and finding customers. Understanding the steps, risks, and pitfalls to avoid in starting a high-tech business can help in being better prepared for launching a successful technology venture. (2 units)

EMGT 378. New Product Planning and Development

This course blends the perspectives of marketing, engineering, and manufacturing into a single approach to new product development - and consequentially product management - at various stages of the product life cycle. Students gain an appreciation for the realities of industrial practice, and the complex and essential roles played by team members led by product managers. For industrial practitioners in particular, the product planning and implementation methods can be put into immediate practice on development projects. (2 units)

EMGT 380. Introduction to Systems Engineering Management

Introduces the fundamental principles and methods of systems engineering and their application to complex systems. For the engineer, and project manager, it provides a basic framework for planning and assessing system development. For the non-engineer, it provides an overview of how a system is developed. (2 units)

EMGT 381. Managing System Conceptual Design

A continuation of EMGT 380 addressing in detail the system engineer's responsibilities and activities in the concept development stage of the system life cycle. Topics include needs and requirements analysis, system concept exploration and definition, and risk assessment. It concludes with a discussion of advanced development and the system engineer's role in planning and preparing for full-scale engineering development. Prerequisite: EMGT 380. (2 units)

EMGT 382. Managing System Design, Integration, Test and Evaluation

A continuation of EMGT 381 with a focus on the system engineer's responsibilities and activities in the engineering development and post-development stages of the system life cycle. Topics include engineering design, system integration and evaluation, and the systems engineer's role in preparing for full-scale manufacturing and subsequent deployment and support. Prerequisite: EMGT 380. (2 units)

EMGT 388. System Supportability and Logistics

The supportability of a system can be defined as the ability of a system to be supported in a cost-effective and timely manner, with a minimum of logistics support resources. The required resources might include test and support equipment, trained maintenance personnel, spare and repair parts, technical documentation, and special facilities. For large complex systems, supportability considerations may be significant and often have a major impact upon life cycle cost. It is therefore particularly important that these considerations be included early during the system design trade studies and design decision-making. (2 units)

EMGT 389. Design for Reliability, Maintainability, and Supportability

Provides the tools and techniques that can be used early in the design phase to effectively influence the design from the perspective of system reliability, maintainability, and supportability. Students will be introduced to various requirements, definition and analysis tools and techniques to include Quality Function Deployment, Input-Output Matrices, and Parameter Taxonomy. (2 units)

EMGT 390. System Architecture and Design

Fundamentals of system architecting and the architecting process, along with practical heuristics. The course has a strong "how-to" orientation, and numerous case studies are used to convey and discuss good architectural concepts as well as lessons learned. Adaptation of the architectural process to ensure the effective application of COTS will be addressed. (2 units)

EMGT 395. Intrapreneurship – Innovation from Within

Intrapreneurship is about creating an innovative business opportunity within the existing structure of an organization. Innovation and creativity, mixed with limited marketing and financial views that will create profitable new products, are critical components of intrapreneurship. Using small independent development teams, the concept incorporates product launch with an overview of marketing and customer views. The methods from this class are widely used by the most successful innovators in start-ups as well as established companies. (2 units)

Chapter 14: Department of Mechanical Engineering

Professor Emeritus: Terry E. Shoup
Associate Professor Emeritus: Timothy K. Hight
Professors: Christopher Kitts, M. Godfrey Mungal
Associate Professors: Mohammad Ayoubi, Drazen Fabris, Hohyun Lee (Chair), On Shun Pak, Panthea Sepehrband, Michael Taylor
Lecturers: Robert Marks, Gaetano (Tony) Restivo, Calvin Tszeng

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 seven technical areas: (1) design and analysis of thermo-fluid systems; (2) analysis and control of dynamic systems; (3) robotics and mechatronic systems; (4) mechanical design; (5) materials engineering; (6) theoretical and computational mechanics; and (7) space systems. Educational efforts are channeled to expand the skills of prospective and practicing engineers, not only in understanding fundamentals but also in developing competence in analyzing engineering systems. The department offers graduate degrees at the master, engineer, and doctorate levels, as well as certificates.

Master Of Science Programs

An M.S. degree requires a minimum 46 units of study with an overall GPA of 3.0 or higher. The student must select one of the five concentration areas and develop a program of studies with an advisor. Courses taken to satisfy any particular requirement may be used to simultaneously satisfy additional requirements for which they are appropriate. Master of Science degrees must include the following:

- Engineering Core- Enrichment experience requirement as described in Chapter 6 (minimum of 8 units). Students must take a minimum of 4 units from at least two of the three areas:
    - Emerging Topics in Engineering,
    - Engineering and Business/Entrepreneurship
    - Engineering and Society
- The remaining 4 units can be accumulated by,
    - a) taking one or more major technical stem electives,
    - b) additional classes from the Graduate Core list,
    - c) cooperative education courses and
    - d) combining a, b, and c.
- Math requirement: 8 units composed of MECH 200 and 201, or MECH 202, and an approved two-course sequence or equivalent four-unit course in applied math
- Topic Requirement: 8 or more units depending on concentration area
- Concentration Electives: depending on the area (approximately 12 units)
- Culminating experience: 4–9 units toward a thesis, capstone project, or project course sequence

Culminating experience options depend on the concentration area. A thesis requires a faculty advisor and must be approved by an additional reader and the department chair. Thesis topics are to be determined by the student and faculty advisor, who need not be the concentration advisor. The additional reader need not be a Mechanical Engineering faculty member, but must be a full-time faculty member in the School of Engineering.

The student may take any additional graduate courses offered by the School of Engineering to meet the minimum 46-unit requirement.

Master Of Science In Mechanical Engineering Concentrations

Theoretical and Computational Mechanics

Advisors: Dr. On Shun Pak, Dr. Michael Taylor

Math Requirements (8 units): MECH/AMTH 200 and 201, or 202; and 4 units chosen from the following

- AMTH 374: Partial Differential Equations I (2 units)
- AMTH 375: Partial Differential Equations II (2 units)
- AMTH 220: Numerical Analysis I (2 units)
- AMTH 221: Numerical Analysis II (2 units)

Required Courses

- MECH 266: Fundamentals of Fluid Mechanics (2 units)
- MECH 270: Viscous Flows I (2 units)
- MECH 294: Continuum Mechanics (2 units)
- MECH 334: Elasticity I (2 units)Electives (8 units)
- MECH 214: Advanced Dynamics I (2 units)
- MECH 215: Advanced Dynamics II (2 units)
- MECH 250: Finite Elements Methods I (2 units)
- MECH 251: Finite Elements Methods II (2 units)
- MECH 252: Finite Elements Methods III (2 units)
- MECH 268: Computational Fluid Dynamics I (2 units)
- MECH 269: Computational Fluid Dynamics II (2 units)
- MECH 271: Viscous Flows II (2 units)
- MECH 281: Fracture Mechanics and Fatigue (2 units)
- MECH 330: Atomic Arrangements, Defects, and Mechanical Behavior (2 units)

Culminating Experience: Thesis or Approved Course Sequence (4-9 units).

Dynamics and Controls

Advisors: Dr. Mohammad Ayoubi, Dr. Christopher Kitts

Math requirement (8 units): MECH 200 and 201, or MECH 202 and approved two-course sequence or equivalent four-unit course in Applied Math. Optimization techniques, numerical methods, probability, or linear algebra are recommended.

Required Courses

- MECH 214, 215 Advanced Dynamics I, II (4 units)
- MECH 305, 306 Advanced Vibrations I, II (4 units)
- MECH 323, 324 Modern Control Systems I, II (4 units)

Elective Courses (8 units required)

- MECH 205, 206 Aircraft Flight Dynamics I, II (4 units)
- MECH 221, 222 Orbital Mechanics I, II (4 units)
- MECH 232, 233 Multi-body Dynamics I, II (4 units)
- MECH 329 Introduction to Intelligent Control (2 units)
- MECH 337, 338 Robotics I, II (4 units)
- MECH 355, 356 Adaptive Control I, II (4 units)
- MECH 423 and 424 Nonlinear Systems and Control I, II (4 units)
- MECH 429 and 430 Optimal Control I and II (4 units)
- MECH 431 and 432 Spacecraft Dynamics and Control I, II (4 units)

Culminating experience: Thesis optional, counts towards concentration electives (4–9 units).

Materials Engineering

Advisor: Dr. Panthea Sepehrband

Math requirement (8 units): MECH 200 and 201, or MECH 202 and approved two-course sequence or equivalent four-unit course in Applied Math.

Required Courses

- MECH 256 Introduction to Biomaterials (2 units)
- MECH 281 Fracture Mechanics and Fatigue (2 units)
- MECH 330 Atomic Arrangement, Defects, and Mechanical Behavior (2 units)
- MECH 331 Phase Equilibria and Transformations (2 units)
- MECH 332 Electronic Structure and Properties (2 units)
- MECH 333 Experiments in Materials Science (2 units)
- MECH 334 Elasticity (2 units)
- MECH 345 Modern Instrumentation and Experimentation (2 units)

Recommended Courses

- AMTH 210 Introduction to Probability I and AMTH 211 Continuous Probability (2 units each)
- AMTH 217 Design of Scientific Experiments and AMTH 219 Analysis of Scientific Experiments (2 units each)
- AMTH 218 Process Troubleshooting and Control (2 units)
- CENG 205, 206, and 207 Finite Element Methods I, II, and III (2 units each)
- CENG 211 Advanced Strength of Materials (4 units)
- ELEN 271 Microsensors: Components and Systems (2 units)
- ELEN 274 and 275 Integrated Circuit Fabrication Processes I and II (2 units each)
- ELEN 276 Integrated Circuits Devices and Technology (2 units)
- ELEN 277 IC Assembly and Packaging Technology (2 units)
- ELEN 390 Semiconductor Device Technology Reliability (2 units)
- MECH 273 Designing with Plastic Materials (2 units)
- MECH 274 Processing Plastic Materials (2 units)
- MECH 277 Injection Mold Tool Design (2 units)
- MECH 350 and 351 Composite Materials I and II (2 units each)

Culminating experience: Thesis (4–9 units), or MECH 333B, or MECH 346.

Mechanical Design

Advisors: Dr. Gaetano (Tony) Restivo

Math requirement (8 units): MECH 200 and 201, or MECH 202 and approved two-course sequence or equivalent four-unit course in Applied Math.

Required Courses

- CENG 205, 206, and 207 Finite Element Methods I, II, and III (2 units each)
- MECH 275 Design for Competitiveness (2 units)
- MECH 285 Computer-Aided Design of Mechanisms (2 units)
- MECH 325 Computational Geometry for Computer-Aided Design and Manufacture (2 units)
- MECH 334 Elasticity (2 units)
- MECH 415 Optimization in Mechanical Design (2 units)

Recommended Courses

- MECH 207, 208, and 209 Advanced Mechatronics I, II, and III (3 units each)
- MECH 273 and 274 Designing with Plastic Materials and Processing Plastic Materials (2 units each)
- MECH 281 Fracture Mechanics and Fatigue I (2 units)

- MECH 330 Atomic Arrangement, Defects, and Mechanical Behavior (2 units)
- MECH 331 Phase Equilibria and Transformations (2 units)
- MECH 332 Electronic Structure and Properties (2 units)
- MECH 371 and 372 Space Systems Design and Engineering I and II (4 units each)

Culminating experience: Thesis (4–9 units) or MECH 275B.

Robotics and Mechatronic Systems

Advisor: Dr. Christopher Kitts

Math requirement (8 units): MECH 200 and 201, or MECH 202 and approved two-course sequence or equivalent four-unit course in Applied Math.

Required Courses

- MECH 207 and 208 Advanced Mechatronics I, II (3 units each)
- MECH 337 and 338 Robotics I, II (2 units each)

The student must also choose one of the following two-course sequences:

- MECH 218 and 219 Guidance and Control I, II (2 units each)
- MECH 323 and 324 Modern Control System I, II (2 units each)

Elective Courses (8 units required)

- MECH 209 Advanced Mechatronics III (2 units)
- MECH 218 Guidance and Control I (2 units)
- MECH 219 Guidance and Control II (2 units)
- MECH 275 Design for Competitiveness (2 units)
- MECH 311 Modeling and Control of Telerobotic Systems (4 units)
- MECH 315 Advanced Digital Control Systems I (2 units)
- MECH 316 Advanced Digital Control Systems II (2 units)
- MECH 323 Modern Control System Design I (2 units)
- MECH 324 Modern Control System Design II (2 units)
- MECH 329 Introduction to Intelligent Control (2 units)
- MECH 339 Robotics III (2 units)
- MECH 345 Modern Instrumentation and Experimentation (2 units)

Culminating experience: Thesis (4–9 units) or Capstone (4–6 units).

Space Systems

Advisor: Dr. Christopher Kitts

Math requirement (8 units): MECH 200 and 201, or MECH 202 and approved two-course sequence or equivalent four-unit course in Applied Math, approved by the student’s advisor.

In addition, the student must enroll in courses to fulfill both systems-oriented and technical engineering requirements.

Required Systems-Oriented courses:

- EMGT 380 Introduction to Systems Engineering (2 units)
- EMGT 381 System Conceptual Design (2 units)
- EMGT 330 Project Management Basics (2 units)
- EMGT 265 Advanced Project Management and Project Leadership (2 units)

Required Technical Depth Area courses:

- MECH 371 Space Systems Design and Engineering I (4 units)

- MECH 372 Space Systems Design and Engineering II (4 units)
- MECH 207 Advanced Mechatronics I (3 units)
- MECH 208 Advanced Mechatronics II (3 units)
- MECH 337 Robotics I (2 units)
- MECH 338 Robotics II (2 units)

The student must also choose one of the following 2-course sequences on control systems:

- MECH 218 and 219 Guidance and Control I, II (2 units each)
- MECH 323 and 324 Modern Control Systems I, II (2 units each)

Culminating experience: Thesis (4-9 units) or Capstone (4-6 units) or the MECH 211/212 Capstone Course sequence (4 units)

Thermofluids

Advisors: Dr. Drazen Fabris, Dr. Hohyun Lee, Dr. Godfrey Mungal, Dr. On Shun Pak

Math requirement (8 units): MECH 200 and 201, or MECH 202 and approved two-course sequence or equivalent four-unit course in Applied Math.

Required Courses

- MECH 228 Equilibrium Thermodynamics (2 units)
- MECH 236 Conduction Heat Transfer (2 units)
- MECH 238 Convective Heat and Mass Transfer I (2 units)
- MECH 240 Radiation Heat Transfer I (2 units)
- MECH 266 Fundamentals of Fluid Mechanics (2 units)
- MECH 270 Viscous Flow I (2 units)

Elective Courses (8 units required)

- MECH 225 Gas Dynamics I (2 units)
- MECH 226 Gas Dynamics II (2 units)
- MECH 230 Statistical Thermodynamics (2 units)
- MECH 239 Convective Heat and Mass Transfer II (2 units)
- MECH 241 Radiation Heat Transfer II (2 units)
- MECH 242 Nanoscale Heat Transfer (2 units)
- MECH 268 Computational Fluid Dynamics I (2 units)
- MECH 269 Computational Fluid Dynamics II (2 units)
- MECH 271 Viscous Flow II (2 units)
- MECH 288 Energy Conversion I (2 units)
- MECH 345 Modern Instrumentation and Control (2 units)

Culminating experience: Thesis (4–9 units), or MECH 345 and MECH 346.

Master of Science in Aerospace Engineering

Advisors: Dr. Mohammad Ayoubi, Dr. Christopher Kitts

Required Core Courses (minimum 8 units)

- MECH 214, 215 Advanced Dynamics I, II (4 units)
- MECH 323, 324 Modern Control Systems I, II (4 units)
- MECH 250, 251, 252 Finite Element Methods I, II, III (6 units)
- MECH 266 Fundamentals of Fluid Mechanics (2 units)
- MECH 268, 269 Computational Fluid Mechanics I, II (4 units)
- MECH 270 Viscous Flow I (2 units)

- MECH 225, 226 Gas Dynamics I, II (4 units)
- MECH 209 Continuum Mechanics (2 units)
- MECH 334 Elasticity (2 units)

Required Aerospace Engineering Courses (minimum 12 units)

- MECH 220, 221 Orbital Mechanics I, II (4 units)
- MECH 205, 206 Aircraft Flight Dynamics and Control I, II (4 units)
- MECH 313 Aerospace Structures (4 units)
- MECH 371, 372 Space Systems Design and Engineering I (8 units)
- MECH 431, 432 Spacecraft Dynamics and Control I, II (4 units)

Elective Courses (recommended)

- MECH 232, 233 Multibody Dynamics I, II (4 units)
- MECH 299 Thesis (4–9 units)
- MECH 315, 316 Digital Control Systems I, II (4 units)
- MECH 329 Introduction to Intelligent Control (2 units)
- MECH 355, 356 Adaptive Control I, II (4 units)
- MECH 371, 372 Space Systems Design and Engineering II (8 units)
- MECH 420/ELEN 238 Model Predictive Control (2 units)
- MECH 423, 424 Nonlinear Systems and Control I, II (4 units)
- MECH 429, 430 Optimal Control I and II (4 units)

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 Chapter 2 for details on admission and general degree requirements. The following departmental information augments the general School requirements.

Academic Advisor

A temporary academic advisor will be provided to the student upon admission. The student and advisor must meet prior to registration for the second quarter to complete a preliminary program of studies, which will be determined largely by the coursework needed for the preliminary exam.

Preliminary Exam

A preliminary written exam is offered at least once per year by the School of Engineering as needed. The purpose is to ascertain the depth and breadth of the student's preparation and suitability for Ph.D. work. Each student in mechanical engineering must take and pass an exam in mathematics as well as in four 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 Graduate Program Leadership Council. (GPLC)

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

Controls

Objective

The Controls Certificate is intended for working engineers in mechanical and closely related fields of engineering. The certificate will provide a foundation in contemporary control theory and methods. The Controls Certificate covers classical and modern control systems and analysis. Specialization in digital control, mechatronics, robotics, or aerospace applications is possible with a suitable choice of electives. Completion of the certificate will allow the student to design and analyze modern control systems.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a closely related field of engineering. They are expected to have prior coursework in undergraduate mathematics. No prior control courses are required.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (8 units)

- MECH 217 Introduction to Control (2 units)
- MECH 218 Guidance and Control I (2 units)
- MECH 323 Modern Control Systems I (2 units)
- MECH 324 Modern Control Systems II (2 units)

Elective Courses (8 units)

- AMTH 245 Linear Algebra I (2 units)
- AMTH 246 Linear Algebra II (2 units)
- CENG 211 Advanced Strength of Materials (4 units)
- MECH 207 Advanced Mechatronics I (2 units)
- MECH 208 Advanced Mechatronics II (2 units)
- MECH 209 Advanced Mechatronics III (2 units)
- MECH 219 Guidance and Control II (2 units)
- MECH 329 Introduction to Intelligent Control (2 units)
- MECH 429, 430 Optimal Control I, II (2 units each)
- MECH 355, 356 Adaptive Control I, II (2 units each)

Dynamics and Vibrations

Objective

The Dynamics and Vibrations Certificate is intended for working engineers in mechanical and related fields of engineering. The certificate will provide a fundamental and broad background in engineering dynamics. The Dynamics and Vibrations Certificate includes a strong foundational base in dynamics and applications in optimization, robotics, mechatronics, or dynamics of aircraft or spacecraft (depending on the chosen elective courses). Completion of the certificate will allow the student to formulate and solve the complex dynamics problems that arise in such fields as robotics and space flight.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a closely related field of engineering. They are expected to have prior coursework in undergraduate dynamics and mathematics.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (8 units)

- MECH 214, 215 Advanced Dynamics I, II (2 units each)
- MECH 305, 306 Advanced Vibrations I, II (2 units each)

Elective Courses (8 units)

- MECH 205, 206 Aircraft Flight Dynamics I, II (2 units each)
- MECH 431, 432 Spacecraft Dynamics and Control I, II (2 units each)

Materials Engineering

Objective

The Materials Engineering Certificate is intended for working engineers in mechanical, materials or manufacturing engineering. The certificate will provide either an upgrade in materials understanding, or advanced study in a particular aspect of the subject. Completion of the certificate will allow the student to develop a deeper understanding of materials and their applications in design and manufacturing.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a related engineering discipline. They are expected to have prior coursework in basic materials science and strength of materials.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (12 units)

- MECH 281 Fracture Mechanics and Fatigue (2 units)
- MECH 330 Atomic Arrangements, Defects, and Mechanical Behavior (2 units)
- MECH 331 Phase Equilibria and Transformations (2 units)
- MECH 332 Electronic Structure and Properties (2 units)
- MECH 333 Experiments in Materials Science (2 units)
- MECH 345 Modern Instrumentation and Control (2 units)

Elective Courses (4 units)

AMTH 210 Introduction to Probability I and AMTH 211 Continuous Probability (2 units each)

AMTH 217 Design of Scientific Experiments and AMTH 219 Analysis of Scientific Experiments (2 units each)

- CENG 211 Advanced Strength of Materials (4 units)
- ENGR 260 Nanoscale Science and Technology (2 units)
- ENGR 262 Nanomaterials (2 units)
- MECH 273 Designing with Plastic Materials (2 units)
- MECH 274 Processing Plastic Materials (2 units)
- MECH 277 Injection Mold Tool Design (2 units)
- MECH 334 Elasticity (2 units)
- MECH 350 and 351 Composite Materials I and II (2 units each)

Mechanical Design Analysis

Objective

The Mechanical Design Analysis Certificate is intended for working engineers in mechanical or structural engineering. The certificate will provide a succinct upgrade in knowledge and skills that will allow the student to gain a deeper understanding of CAD and FEA principles and practices. Completion of the certificate will allow the student to pursue more advanced design and analysis tasks.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical, civil, aerospace, or a related field. They are expected to have prior coursework in strength of materials, thermodynamics, fluid mechanics, and mathematics through differential equations.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (12 units)

- CENG 205 Finite Element Methods I (2 units)
- CENG 206 Finite Element Methods II (2 units)
- CENG 207 Finite Element Methods III (2 units)
- MECH 325 Computational Geometry for Computer-Aided (2 units)

Design and Manufacture (2 units)

- MECH 334 Elasticity (2 units)
- MECH 415 Optimization in Mechanical Design (2 units)

Elective Courses (4 units)

- AMTH 220 Numerical Analysis I (2 units)
- AMTH 221 Numerical Analysis II (2 units)
- AMTH 308 Mathematical Modeling I (2 units)
- AMTH 309 Mathematical Modeling II (2 units)
- AMTH 370 Optimization Techniques I (2 units)
- AMTH 371 Optimization Techniques II (2 units)
- CENG 211 Advanced Strength of Materials (4 units)
- CENG 214 Theory of Elasticity (4 units)
- CENG 222 Advanced Structural Analysis (4 units)
- MECH 268 Computational Fluid Mechanics I (2 units)
- MECH 269 Computational Fluid Mechanics II (2 units)

Mechatronics Systems Engineering

Objective

The Mechatronics Systems Engineering Certificate is intended for working engineers in mechanical engineering and related fields. The certificate program introduces students to the primary technologies, analysis techniques, and implementation methodologies relevant to the detailed design of electro-mechanical devices. Completion of the certificate will allow the student to develop systems that involve the sensing, actuation, and control of the physical world. Knowledge such as this is vital to engineers in the modern aerospace, robotics, and motion control industries.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical, aerospace, electrical, engineering physics, or a related field. They are expected to have prior coursework in mathematics through differential equations, introductory linear control theory, and introductory electronics and programming.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (8 units)

- MECH 207 Advanced Mechatronics I (3 units)
- MECH 208 Advanced Mechatronics II (3 units)
- MECH 217 Introduction to Control (2 units)

Elective Courses (8 units)

- MECH 209 Advanced Mechatronics III (2 units)
- MECH 218 Guidance and Control I (2 units)
- MECH 219 Guidance and Control II (2 units)
- MECH 275 Design for Competitiveness (2 units)
- MECH 310 Advanced Mechatronics IV (2 units)
- MECH 311 Modeling and Control of Telerobotic Systems (4 units)
- MECH 316 Digital Control Systems II (2 units)
- MECH 323 Modern Control Systems I (2 units)
- MECH 324 Modern Control Systems II (2 units)
- MECH 329 Intelligent Control (2 units)
- MECH 337 Robotics I (2 units)
- MECH 338 Robotics II (2 units)
- MECH 339 Robotics III (2 units)
- MECH 345 Modern Instrumentation (2 units)

An independent study or Capstone project would be suitable as one of the electives. In addition, other courses may serve as electives at the discretion of the program advisor.

Thermofluids

Objective

The Thermofluids Certificate is intended for working engineers in mechanical, chemical, or a closely related field of engineering. The certificate will provide fundamental theoretical and analytic background, as well as exposure to modern topics and applications. Specialization in fluid mechanics, thermodynamics, or heat transfer is possible with a suitable choice of electives. Completion of the certificate will allow the student to design heat transfer and fluid solutions for a range of modern applications.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a closely related field of engineering. They are expected to have prior undergraduate coursework in fluid mechanics, thermodynamics, and heat transfer.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (12 units)

- MECH 228 Equilibrium Thermodynamics (2 units)
- MECH 236 Conduction Heat Transfer (2 units)
- MECH 238 Convective Heat Transfer I (2 units)
- MECH 240 Radiation Heat Transfer I (2 units)
- MECH 266 Fundamentals of Fluid Mechanics (2 units)
- MECH 270 Viscous Flow I (2 units)

Elective Courses (4 units)

- MECH 202 Mathematical Methods in Mechanical Engineering (4 units)
- MECH 225 Gas Dynamics I (2 units)
- MECH 226 Gas Dynamics II (2 units)
- MECH 230 Statistical Thermodynamics (2 units)
- MECH 239 Convective Heat Transfer II (2 units)
- MECH 241 Radiation Heat Transfer II (2 units)
- MECH 242 Nanoscale Heat Transfer (2 units)
- MECH 268 Computational Fluid Mechanics I (2 units)
- MECH 269 Computational Fluid Mechanics II (2 units)
- MECH 271 Viscous Flow II (2 units)
- MECH 288 Energy Conversion I (2 units)
- MECH 289 Energy Conversion II (2 units)
- MECH 345 Modern Instrumentation (2 units)

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 ***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 ***2013 Solar Decathlon House*** is a highly instrumented testbed for study of photovoltaic and solar thermal systems, as well as general home control systems. Projects include development of a carbon meter, investigation of the impact of micro-inverters on performance, and control of a solar thermal-driven vapor absorption chiller.

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 both a three-axis CNC vertical milling center (VMC) and a CNC lathe. Commercial CAM software is available to aid programming of the computer controlled equipment. The prototyping area is equipped with a rapid prototyping system that utilizes fused deposition modeling (FDM) to create plastic prototypes from CAD-generated models. Also featured in this area is a Laser CAMM CNC laser cutting system for nonmetallic materials.

The ***Fluid Dynamics/Thermal Science Laboratory*** contains equipment to illustrate the principles of fluid flow and heat transfer and to familiarize students with hydraulic machines, refrigeration cycles, and their instrumentation. The lab also contains a subsonic wind tunnel equipped with an axial flow fan with adjustable pitch blades to study aerodynamics. Research tools include modern, non intrusive flow measurement systems.

The ***Heat Transfer Laboratory*** contains equipment to describe three modes of heat transfer. The temperature measurement of the extended surface system allows students to learn steady state conduction, and the pyrometer enables measurement of emitted power by radiation. The training systems for heat exchanger and refrigeration system are also placed in the lab.

The ***Instrumentation Laboratory*** contains seven computer stations equipped with state-of-the-art, PC-based data acquisition hardware and software systems. A variety of transducers and test experiments for making mechanical, thermal, and fluid measurements are part of this lab.

The ***Materials Laboratory*** contains equipment for metallography and optical examination of the microstructure of materials as well as instruments for mechanical properties characterization including tension, compression, hardness, and impact testing. The Materials Laboratory also has a tube furnace for heat treating and a specialized bell-jar furnace for pour casting and suction casting of metallic glasses and novel alloy compositions.

The ***Vibrations and Control Systems Laboratory*** is equipped with two flexible test systems. One is capable of single or multi-degree of freedom modes, free or forced motion, and adjustable damping. The other is an inverted pendulum. Both systems can be controlled by a wide variety of control algorithms and are fully computer connected for data acquisition and control.

Undergraduate Course Descriptions

Lower-Division Undergraduate Courses

MECH 10. Graphical Communication in Design

Introduction to the design process and graphical communications tools used by engineers. Documentation of design through freehand sketching and engineering drawings. Basic descriptive geometry. Computer-aided design as a design tool. Conceptual design projects presented in poster format. Co-requisite: MECH 10L. (4 units)

MECH 10L. Graphical Communication in Design Laboratory

Laboratory for MECH 10. Co-requisite: MECH 10. (1 unit)

MECH 11. Materials and Manufacturing Processes

The principles of manufacturing processes as related to materials properties, design, and production. A review of structures, properties, and manufacturing processes for main groups of engineering materials including metals and metallic alloys, polymers, and ceramics. Prerequisite: MECH 15. (4 units)

MECH 15. Introduction to Materials Science

Physical basis of the electrical, mechanical, optical, and thermal behavior of solids. Relations between atomic structure and physical properties. Prerequisite: CHEM 11. Co-requisite: MECH 15L. (4 units)

MECH 15L. Introduction to Materials Science Laboratory

Laboratory for MECH 15. Co-requisite: MECH 15. (1 unit)

MECH 45: Applied Programming in MATLAB

Computer programming in MATLAB, including: use of the development environment, m-files, and debugging; data structures; flow control, including loops, vectorization, and conditional statements; functions and variable scope; file input and output; plotting and visualization; selected topics in object-oriented programming. Applications to engineering problems including linear algebra and differential equations. Prerequisite: MATH 13. Co-requisite: MECH 45L. (4 units)

MECH 45L: Applied Programming in MATLAB Lab

Laboratory for MECH 45. Co-requisite: MECH 45 (1 unit)

Upper-Division Undergraduate Courses

MECH 101L. Machining Lab

Practical experience with machine tools such as mills, lathes, band saws, etc. Basic training in the safe and proper use of the equipment associated with simple mechanical projects. Laboratory. P/NP grading. Prerequisite: Senior standing. Co-requisite: MECH 194. (1 unit)

MECH 102. Introduction to Mathematical Methods in Mechanical Engineering

The application of mathematical methods to the solution of practical engineering problems. A review of fundamental mathematical methods and calculus of a single variable, multivariable calculus, ordinary differential equations, numerical methods, and basics of linear algebra. (4 units)

MECH 114. Machine Design I

Analysis and design of mechanical systems for safe operation. Stress and deflection analysis. Failure theories for static loading and fatigue failure criteria. Team design projects started. Formal, conceptual design reports required. Prerequisites: MECH 15, CENG 41, and CENG 43. (4 units)

MECH 115. Machine Design II

Continuation of MECH 114. Treatment of basic machine elements (e.g., bolts, springs, gears, bearings). Design and analysis of machine elements for static and fatigue loading. Team design projects completed. Design prototypes and formal final report required. Prerequisite: MECH 114. (4 units)

MECH 120. Engineering Mathematics

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

MECH 121. Thermodynamics I

Definitions of work, heat, and energy. First and second laws of thermodynamics. Properties of pure substances. Application to fixed mass systems and control volumes. Irreversibility and availability. Prerequisite: PHYS 32. (4 units)

MECH 122. Fluid Mechanics

Fluid properties and definitions. Fluid statics, forces on submerged surfaces,
manometry. Streamlines and the description of flow fields. Euler's and Bernoulli's equations. Mass, momentum, and energy analysis with a control volume. Laminar and turbulent flows. Losses in pipes and ducts. Dimensional analysis

and similitude.
Prerequisite: MECH 121 (can be taken concurrently) and CENG 42 or MECH 140 (can be taken concurrently). Co-requisite: MECH 122L. (4 units)

MECH 122L. Fluid Mechanics Laboratory

Laboratory for MECH 122. Co-requisite: MECH 122 Co-requisite: MECH 122. (1 unit)

MECH 123. Heat Transfer

Introduction to the concepts of conduction, convection, and radiation heat transfer. Application of these concepts to engineering problems. Prerequisites: MECH 121 and 122, AMTH 118 or MATH 166. Co-requisite: MECH 123L. (4 units)

MECH 123L. Heat Transfer Laboratory

Laboratory work to understand the concept of heat transfer. Practical experience with temperature and heat flux measurement. Co-requisite: MECH 123. (1 unit)

MECH 125. Thermal Systems Design

Analysis, design, and simulation of fluids and thermal engineering systems. Application of optimization techniques, life cycle and sustainability concepts in these systems. Prerequisite: MECH 123. (4 units)

MECH 131. Thermodynamics II

Thermodynamic potential and availability, advanced power and refrigeration cycles, chemical equilibrium, advanced power and refrigeration cycles with non-reacting or reacting air/vapor mixture. Prerequisite: MECH 121. (4 units)

MECH 132. Aerodynamics

Introduction to gas dynamics. Concepts of lift and drag. Mechanics of laminar and turbulent flow. Introduction to boundary-layer theory. Application to selected topics in lubrication theory, aerodynamics, turbo-machinery, and pipe networks. Offered every other year. Prerequisites: MECH 121 and 122. (4 units)

MECH 140. Dynamics

Kinematics of particles in rectilinear and curvilinear motion. Kinetics of particles, Newton’s second law, energy and momentum methods. Systems of particles. Kinematics and plane motion of rigid bodies, forces and accelerations, energy and momentum methods. Introduction to three-dimensional dynamics of rigid bodies. Prerequisites: PHYS 31, CENG 41, AMTH 106, and MECH 10. (4 units)

MECH 141. Mechanical Vibrations

Fundamentals of vibration, free and forced vibration of (undamped/damped) single degree of freedom systems. Vibration under general forcing conditions. Free and forced vibration of (undamped/damped) two degree of freedom systems. Free and forced vibration of (undamped/damped) multidegree of freedom systems. Determination of natural frequencies and mode shapes. Prerequisites: MECH 140 and AMTH 106. Co-requisite: MECH 141L. (4 units)

MECH 141L. Mechanical Vibration Laboratory

Laboratory for MECH 141. Co-requisite: MECH 141. (1 unit)

MECH 142. Control Systems, Analysis, and Design

Introduction to system theory, transfer functions, and state space modeling of physical systems. Course topics include stability, analysis and design of PID, lead/lag, other forms of controllers in time and frequency domains, root locus Bode diagrams, gain and phase margins. Prerequisite: MECH 141. Co-requisite: MECH 142L. (4 units)

MECH 142L. Control Systems, Analysis, and Design Laboratory

Employs the use of simulation and experimental exercises that allow the student to explore the design and performance of feedback control systems. Exercises include the modeling and analysis of physical systems, the design of feedback controllers, and the quantitative characterization of the performance of the resulting closed-loop systems. Co-requisite: MECH 142. (1 unit)

MECH 143. Mechatronics

Introduction to behavior, design, and integration of electro-mechanical components and systems. Review of appropriate electronic components/circuitry, mechanism configurations, and programming constructs. Use and integration of transducers, microcontrollers, and actuators. Also listed as COEN 123 and ELEN 123. Prerequisite: ELEN 50. Co-requisite: MECH 143L. (4 units)

MECH 143L. Mechatronics Laboratory

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

MECH 144. Smart Product Design

Design of innovative smart electromechanical devices and products. Topics include a review of the basics of mechanical, electrical, and software design and prototyping, and will emphasize the synthesis of functional systems that solve a customer need, that are developed in a team-based environment, and that are informed by the use of methodologies from the fields of systems engineering, concurrent design, and project/business management. Designs will be developed in the context of a cost-constrained business environment, and principles of accounting, marketing, and supply chain are addressed. Societal impacts of technical products and services are reviewed. Enrollment is controlled in order to have a class with students from diverse majors. Offered every other year. Prerequisites: Core Foundation-level natural science and mathematics, or equivalent and instructor approval. (4 units)

MECH 144L. Smart Product Design Laboratory

Laboratory for MECH 144. Co-requisite: MECH 144. (1 unit)

MECH 145. Introduction to Aerospace Engineering

Basic design and analysis of atmospheric flight vehicles. Principles of aerodynamics, propulsion, structures and materials, flight dynamics, stability and control, mission analysis, and performance estimation. Introduction to orbital dynamics. Offered every other year. Prerequisites: MECH 122 and 140. Co-requisite: MECH 121. (4 units)

MECH 146. Mechanism Design

Kinematic analysis and synthesis of planar mechanisms. Graphical synthesis of linkages and cams. Graphical and analytical techniques for the displacement, velocity, and acceleration analysis of mechanisms. Computer-aided design of mechanisms. Three or four individual mechanism design projects. Offered every other year. Prerequisite: MECH 114. (4 units)

MECH 151. Finite Element Theory and Applications

Basic introduction to finite elements; direct and variational basis for the governing equations; elements and interpolating functions. Applications to general field problems—elasticity, fluid mechanics, and heat transfer. Extensive use of software packages. Prerequisites: MECH 45 and AMTH 106. (4 units)

MECH 151L. Finite Element Theory and Applications Laboratory

Laboratory for MECH 151. Co-requisite: MECH 151. (1 unit)

MECH 152. Composite Materials

Analysis of composite materials and structures. Calculation of properties and failure of composite laminates. Manufacturing considerations and design of simple composite structures. Knowledge of MATLAB or an equivalent programming environment is required. Prerequisites: MECH 15, CENG 43, and MECH 45. (4 units)

MECH 153. Aerospace Structures

This introductory course presents the application of fundamental theories of elasticity and stress analysis to aerospace structures. Course topics include fundamentals of elasticity, virtual work and matrix methods, bending and buckling of thin plates, component load analysis, and airframe loads, torsion, shear, and bending of thin-walled sections. Prerequisites: CENG 43 and 43L. (4 units)

MECH 155. Astrodynamics

This course provides the foundations of basic gravitation and orbital theory. Topics include gravitation and the two-body problem, position and time, orbit determination, Laplace and Gibbs methods, basic orbital maneuvers, lunar trajectories, and rocket dynamics. Prerequisite: MECH 140. (4 units)

MECH 156. Introduction to Nanotechnology

Introduction to the field of nanoscience and nanotechnology. Properties of nanomaterials and devices. Nanoelectronics: from silicon and beyond. Measurements of nanosystems. Applications and implications. Laboratory experience is an integral part of the course. This course is part of the Mechanical Engineering Program and should be suitable for juniors and seniors in engineering and first-year graduate students. Also listed as ELEN 156. Prerequisites: PHYS 33 and either PHYS 34 or MECH 15. Co-requisite: MECH 156L.
(4 units)

MECH 156L. Introduction to Nanotechnology Laboratory

This laboratory practicum is co-requisite to MECH/ELEN 156. This will give students an opportunity to gain hands-on experience operating main nanotechnology tools such as SEM and AFM. Complimentary equipment located at CNS (center for nanostructures) may be utilized as well. Projects are samples/materials based and involve nanostructure visualization along with image analysis. Results of the projects are presented in scientific format. Co-requisite: MECH 156. (1 unit)

MECH 158. Aerospace Propulsion Systems

Fundamentals of air breathing and rocket jet propulsion. Gas dynamics fundamentals, review of thermodynamic relation. Basic theory of aircraft gas turbine engines, propulsive efficiency, and application of Brayton cycle to gas turbine engine analysis. Rocket engine nozzle configuration and design. Thrust Equation. Chemical rocket engine fundamentals. Solid vs. liquid propellant rockets. Prerequisites: MECH 121, and 122. (4 units)

MECH 160. Modern Instrumentation for Engineers

Introduction to engineering instrumentation, computer data acquisition hardware and software, sampling theory, statistics, and error analysis. Laboratory work spans the disciplines of mechanical engineering: dynamics, fluids, heat transfer, controls, with an emphasis on report writing and experimental design. Prerequisites: MECH 123 and 141. Co-requisite: MECH 160L. (4 units)

MECH 160L. Modern Instrumentation for Engineers Laboratory

Laboratory work spans the disciplines of mechanical engineering: dynamics, controls, fluids, heat transfer, and thermodynamics, with emphasis on report writing. Students will design their own experiment and learn how to set up instrumentation using computer data acquisition hardware and software. Co-requisite: MECH 160. (1 unit)

MECH 163. Materials Selection and Design

Design considerations in the use of materials; materials selection for optimizing multiple properties; materials failure modes and failure mechanism; materials selection to prevent failure; case studies and discussions on process economics, life-cycle thinking, and eco-design. CES EduPack will be introduced as a materials and processes database and a tool for students to compare, analyze, and select materials and processes. Prerequisites: MECH 11 and CENG 43. (4 units)

MECH 179. Satellite Operations Laboratory

This laboratory course reviews the physical principles and control techniques appropriate to communicating with, commanding, and monitoring spacecraft. Students learn to operate real satellite tracking, commanding, and telemetry systems and to perform spacecraft-specific operations using approved procedures. Given the operational status of the system, students may conduct these operations on orbiting NASA spacecraft and interact with NASA scientists and engineers as part of the operations process. Prerequisite: Instructor approval. (1 unit)

MECH 188. Co-op Education

Practical experience in a planned program designed to give students work experience related to their academic field of study and career objectives. Satisfactory completion of the assignment includes preparation of a summary report on co-op activities. P/NP grading. May be taken for graduate credit. (2 units)

MECH 189. Co-op Technical Report

Credit is given for a technical report on a specific activity such as a design or research project, etc., after completing the co-op assignment. Approval of department co-op advisor required. Letter grades based on content and presentation quality of the report. May be taken twice. May be taken for graduate credit. Prerequisite: MECH 188.(2 units)

MECH 191. Mechanical Engineering Project Manufacturing

Laboratory course that provides supervised evening access to the machine shop and/or light fabrication area for qualified mechanical engineering students to work on their University-directed projects. Students wishing to utilize the machine shop or light fabrication area during the evening lab/shop hours are required to enroll. Enrollment in any section allows students to attend any/all evening shop hours on a drop-in basis. Staff or faculty will be present during each scheduled meeting to supervise as well as be available for consultation and manufacturing advising. Prerequisites: Students must be qualified for machine shop use through successful completion of MECH 101L and a passing grade on the Mechanical Engineering Lab Safety Test. Qualifications for light fabrication area use: successful completion of the Light Fabrication Training Seminar and a passing grade on the Mechanical Engineering Lab Safety Test. P/NP. (1 unit)

MECH 194. Advanced Design I: Tools

Design tools essential to all aspects of mechanical engineering, including design methodology, computer-design tools, CAD, finite element method, simulation, engineering economics, and decision making. Senior design projects have begun. Prerequisite: MECH 115. (3 units)

MECH 195. Advanced Design II: Implementation

Implementation of design strategy. Detail design and fabrication of senior design projects. Quality control, testing and evaluation, standards and specifications, and human factors. Prerequisite: MECH 194. (4 units)

MECH 196. Advanced Design III: Completion and Evaluation

Design projects completed, assembled, tested, evaluated, and judged with opportunities for detailed re-evaluation by the designers. Formal public presentation of results. Final written report required. Prerequisite: MECH 195. (3 units)

MECH 198. Independent Study

By arrangement with faculty. (1–5 units)

MECH 199. Directed Research/Reading

Investigation of an engineering problem and writing an acceptable report. Meetings with faculty advisor required. Prerequisite: Senior standing. (2–4 units)

Graduate Courses

MECH 200. Advanced Engineering Mathematics I

Method of solution of the first, second, and higher order differential equations (ODEs). Integral transforms including Laplace transforms, Fourier series and Fourier transforms. Cross-listed with AMTH 200. (2 units)

MECH 201. Advanced Engineering Mathematics II

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

MECH 202. Advanced Engineering Mathematics I and II

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

MECH 205. Aircraft Flight Dynamics I

Review of basic aerodynamics and propulsion. Aircraft performance, including equations of flight in vertical plane, gliding, level, and climbing flight, range and endurance, turning flight, takeoff and landing. Prerequisite: MECH 140. (2 units)

MECH 206. Aircraft Flight Dynamics II

Developing a nonlinear six-degrees-of-freedom aircraft model, longitudinal and lateral static stability and trim, linearized longitudinal dynamics including short period and phugoid modes. Linearized lateral-directional dynamics including roll, spiral, and Dutch roll modes. Aircraft handling qualities and introduction to flight control systems. Prerequisite: MECH 140 or MECH 205. (2 units)

MECH 207. Advanced Mechatronics I

Theory of operation, analysis, and implementation of fundamental physical and electrical device components: basic circuit elements, transistors, op-amps, sensors, electro-mechanical actuators. Application to the development of simple devices. Also listed as ELEN 460. Prerequisite: MECH 141 or ELEN 100. (3 units)

MECH 208. Advanced Mechatronics II

Theory of operation, analysis, and implementation of fundamental controller implementations: analog computers, digital state machines, microcontrollers. Application to the development of closed-loop control systems. Also listed as ELEN 461. Prerequisites: MECH 207 and 217. (3 units)

MECH 209. Advanced Mechatronics III

Electro-mechanical modeling and system development. Introduction to mechatronic support subsystems: power, communications. Fabrication techniques. Functional implementation of hybrid systems involving dynamic control and command logic. Also listed as ELEN 462. Prerequisite: MECH 208. (2 units)

MECH 214. Advanced Dynamics I

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. Prerequisites: MECH 140 and AMTH 106. (2 units)

MECH 215. Advanced Dynamics II

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. Prerequisite: MECH 214. (2 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, 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 I

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. Prerequisites: MECH 140 or equivalent and AMTH 118 or equivalent. (2 units)

MECH 221. Orbital Mechanics II

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

MECH 225. Gas Dynamics I

Flow of compressible fluids. One-dimensional isentropic flow, normal shock waves, frictional flow. Prerequisites: MECH 121 and 132. (2 units)

MECH 226. Gas Dynamics II

Continuation of MECH 225. Flow with heat interaction and generalized one-dimensional flow. Oblique shock waves and unsteady wave motion. Prerequisite: MECH 225. (2 units)

MECH 227. Aerospace Propulsion

Advanced topics in air breathing and rocket jet propulsion. Analysis and design of ideal and real turbojets, shock wave formation in ramjets, chemistry of combustion in liquid rocket engines, design of rocket engine thrust chambers, method of characteristics for computing shock waves in over and under expanded rocket nozzles, solid and hybrid rocket engines, and electric/ion spacecraft propulsion. Some review of gas dynamics fundamentals, chemical and thermodynamic theory applicable to jet propulsion.

Prerequisites: MECH 121, MECH 122, MECH 145, and MECH 158. (2 units)

MECH 228. Equilibrium Thermodynamics

Principles of thermodynamic equilibrium. Equations of state, thermodynamic potentials, phase transitions, and thermodynamic stability. Prerequisite: MECH 131 or equivalent. (2 units)

MECH 230. Statistical Thermodynamics

Kinetic theory of gases. 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 I

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. Prerequisite: MECH 140 or equivalent. (2 units)

MECH 233. Multibody Dynamics II

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 232. (2 units)

MECH 234. Combustion Technology

Theory of combustion processes. Reaction kinetics, flame propagation theories. Emphasis on factors influencing pollution. Prerequisites: AMTH 106 and MECH 131. (2 units)

MECH 236. Conduction Heat Transfer

Flow of heat through solid and porous media for steady and transient conditions. Consideration of stationary and moving heat sources. Prerequisites: AMTH 106 and MECH 123. (2 units)

MECH 238. Convective Heat and Mass Transfer I

Solutions of basic problems in convective heat and mass transfer, including boundary layers and flow in pipes. Prerequisites: MECH 123 and 266. (2 units)

MECH 239. Convective Heat and Mass Transfer II

Application of transfer theory to reacting boundary layers, ablating and reacting surfaces, multicomponent diffusion. Introduction of modern turbulence theory to predict fluctuations and other flow properties. Prerequisite: MECH 238. (2 units)

MECH 240. Radiation Heat Transfer I

Introduction to concepts of quantum mechanics, black body behavior, and radiant heat exchange between bodies. Prerequisite: MECH 123. (2 units)

MECH 241. Radiation Heat Transfer II

Treatment of gaseous radiation in enclosures. Solutions of transfer equations in various limits and for different molecular radiation models. Gray and nongray applications. Mathematical techniques of solutions. Prerequisite: MECH 240. (2 units)

MECH 242. Nanoscale Heat Transfer

Understand fundamental heat transfer mechanisms at nanoscale. Students will learn how thermal transport properties are defined at atomic level, and how properties can be engineered with nanotechnology. Both classical size effect and quantum size effect will be discussed. Topics include introduction to statistical thermodynamics, solid state physics, scattering of charge/energy carriers, Boltzamann Transport Equation with Relaxation Time Approximation, heat conduction in thin film structure. Prerequisite: MECH 123 or Undergraduate Heat Transfer. (2 units)

MECH 250. 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. Also listed as CENG 205. (2 units).

MECH 251. 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. Also listed as CENG 206. Prerequisite: MECH 250. (2 units)

MECH 252. 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 application to solid mechanics. Transient nonlinear problems in thermal and fluid mechanics. Application of commercial FF codes to nonlinear analysis. Also listed as CENG 207. Prerequisite: MECH 251. (2 units)

MECH 254. Introduction to Biomechanics

Overview of basic human anatomy, physiology, and anthropometry. Applications of mechanical engineering to the analysis of human motion, function, and injury.
Review of issues related to designing devices for use in, or around, the human body including safety, biocompatibility, ethics, and FDA regulations. Offered every other year. (4 units)

MECH 256. Clinical Biomaterials

The objective of this course is to convey the state-of-the-art of biomaterials currently used in medical devices. The course is taught as a series of semi-independent modules on each class of biomaterials, each with examples of medical applications. Students will explore the research, commercial and regulatory literature. In teams of 2 to 4, students will prepare and orally present a design study for a solution to a medical problem requiring one or more biomaterials, covering alternatives and selection criteria, manufacture and use of the proposed medical device, and economic, regulatory, legal and ethical aspects. Students should be familiar with or prepared to learn medical, anatomical and physiological terminology. Written assignments are an annotated bibliography on the topic of the design study and an individual-written section of the team’s report. Material from lectures and student presentations will be covered on a midterm quiz and a final examination. Also listed as BIOE 178/BIOE 278. (2 units)

MECH 266. Fundamentals of Fluid Mechanics

Mathematical formulation of the conservation laws and theorems applied to flow fields. Analytical solutions. The viscous boundary layer. Prerequisite: MECH 122. (2 units)

MECH 268. Computational Fluid Mechanics I

Introduction to numerical solution of fluid flow. Application to general and simplified forms of the fluid dynamics equations. Discretization methods, numerical grid generation, and numerical algorithms based on finite difference techniques. Prerequisite: MECH 266. (2 units)

MECH 269. Computational Fluid Mechanics II

Continuation of MECH 268. Generalized coordinate systems. Multidimensional compressible flow problems, turbulence modeling. Prerequisite: MECH 268. (2 units)

MECH 270. Viscous Flow I

Derivation of the Navier-Stokes equations. The boundary layer approximations for high Reynolds number flow. Exact and approximate solutions of laminar flows. Prerequisite: MECH 266. (2 units)

MECH 271. Viscous Flow II

Continuation of MECH 270. Similarity solutions of laminar flows. Separated flows. Fundamentals of turbulence. Introduction to numerical methods in fluid mechanics. Prerequisite: MECH 270. (2 units)

MECH 275A. 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 275B. Project Design Development

This course is a follow-up to MECH 275A and is focused on further developing product ideas from MECH 275A into physical prototypes, performing market analysis, honing business plans, and presenting these ideas to a panel of venture capitalists.
Prerequisite: MECH 275A. (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 279. Introduction to CNC I

Introduction to Computer Numeric Control (CNC) machining. Principles of conventional and CNC machining. Process identification and practical application using conventional machine tools. Job planning logic and program development for CNC. Set-up and basic operation of a CNC machine through “hands-on” exercises. Introduction to Computer Aided Manufacturing (CAM) software, conversational programming, verification software, and file transfers. The class is lab intensive; the topics will be presented primarily by demonstration or student use of the equipment. (3 units)

MECH 280. Introduction to CNC II

Builds on foundation provided by MECH 279. Emphasis on CNC programming. Overview of controllers, features of CNC machines, manual and computer-aided programming, G-code basics, advanced cycles and codes. Lab projects will consist of “hands-on” operation of CNC milling machines, programming tools, and verification software. Lab component. Prerequisite: MECH 279 or instructor approval. (3 units)

MECH 281. Fracture Mechanics and Fatigue

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. (2 units)

MECH 282. Failure Analysis

This course will examine how and why engineering structures fail, and will provide the student with the tools to identify failure mechanisms and perform a failure analysis. Students will review several case studies, and will conduct independent failure
analysis investigations of actual engineering systems and parts using state-of-the-art-tools. (2 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 ELEN 286. (2 units)

MECH 287. Introduction to Alternative Energy Systems

Assessment of current and potential future energy systems; covering resources, extraction, conversion, and end-use. Emphasis on meeting regional and global energy needs in a sustainable manner. Different renewable and conventional energy technologies will be presented and their attributes described to evaluate and analyze energy technology systems. Also listed as ELEN 280. (2 units)

MECH 288. Energy Conversion I

Introduction to nonconventional methods of power generation using solar energy, thermoelectric effect, and fuel cells. Description of the physical phenomena involved, analysis of device performance, and assessment of potential for future use. Prerequisite: MECH 121. (2 units)

MECH 289. Energy Conversion II

Discussion of magnetohydrodynamic power generation, thermionic converters, and thermonuclear fusion. Note: MECH 288 is NOT a prerequisite. (2 units)

MECH 290. Capstone Project

(2–6 units)

MECH 292. Theory and Design of Turbomachinery

Theory, operation, and elements of the design of turbomachinery that performs by the dynamic interaction of fluid stream with a bladed rotor. Emphasis on the design and

efficient energy transfer between fluid stream and mechanical elements of turbomachines, including compressors, pumps, and turbines. Prerequisites: MECH 121 and 122. (2 units)

MECH 293. Special Topics in Manufacturing and Materials

Topics vary each quarter. (2 units*)*

MECH 294. Special Topics in Mechanical Design

Topics vary each quarter. (2 units)

MECH 295. Special Topics in Thermofluid Sciences

Topics vary each quarter. (2 units)

MECH 296A. Special Topics in Dynamics and Control

Topics vary each quarter. (2 units)

MECH 296B. Special Topics in Dynamics and Control

Topics vary each quarter. (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 Research

By arrangement. (1–9 units)

MECH 300. Directed Research

Research into topics of mechanical engineering; topics and credit to be determined by the instructor, report required, cannot be converted into Master or Ph.D. research. By arrangement. Prerequisites: instructor and department chair approval. (1–6 units)

MECH 304. Design and Mechanics Problems in the Computer Industry

Design and mechanics problems related to computer peripherals. Dynamics of disk interface, stresses, and vibrations in rotating disks and flexible disks. Actuator design, impact, and non impact printing, materials and design for manufacturability, the role of CAD/CAM in design. Prerequisite: Instructor approval. (2 units)

MECH 305. Advanced Vibrations I

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. Prerequisite: MECH 141. (2 units)

MECH 306. Advanced Vibrations II

Vector-tensor-matrix formulation with practical applications to computer simulation. Dynamic response of continuous elastic systems. Strings, membranes, beams, and plates exposed to various dynamic loading. Applications to aero-elastic systems and mechanical systems. Modal analysis and finite element methods applied to vibrating systems. Prerequisite: MECH 305. (2 units)

MECH 308. Thermal Control of Electronic Equipment

Heat transfer methods to cool electronic equipment. Contact resistance, cooling fins, immersion cooling, boiling, and direct air cooling. Use of heat exchangers, cold plates, and heat pipes. Applications involving transistor cooling, printed circuit boards, and microelectronics. Prerequisites: MECH 122 and 123. (2 units)

MECH 310. 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 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. Aerospace Structures

Presents the fundamental theories of elasticity and stress analysis pertaining to aircraft and spacecraft structures. Course topics include aircraft/spacecraft structural elements, material selection, elasticity, torsion, shear, bending, thin-walled sections, failure criteria, buckling, fatigue, and an introduction to mechanics of composites. (4 units)

MECH 315. Digital Control Systems I

Introduction to digital control systems design. Mini- and microcomputer application in industrial control. Analog-to-digital and digital-to-analog converters. Discrete time systems, state-space representation, stability. Digital control algorithms, optimal tuning of controller gains. Finite-time settling control. Controllability and observability of discrete-time systems. Prerequisite: MECH 142 or 217. (2 units)

MECH 316. Digital Control Systems II

Continuation of MECH 315. Linear state vector feedback control, linear quadratic optimal control. State variable estimators, observers. System identification, model reference adaptive systems, pole-placement control. Minimum variance control, tracking, and regulation problems. Adaptive control. Prerequisite: MECH 315. (2 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 ELEN 236. Prerequisite: MECH 142 or 217. (2 units)

MECH 324. Modern Control Systems II

Shaping the dynamic response, pole placement, reduced-order observers, LQG/LTR, introduction to random process and Kalman filters. Prerequisite: MECH 323. (2 units)

MECH 325. Computational Geometry for Computer-Aided Design and Manufacture

Analytic basis for description of points, curves, and surfaces in three-dimensional space. Generation of surfaces for numerically driven machine tools. Plane coordinate geometry, three-dimensional geometry and vector algebra, coordinate transformations, three-dimensional curve and surface geometry, and curve and surface design. (2 units)

MECH 329. Introduction to Intelligent Control

Intelligent control, AI, and system science. Adaptive control and learning systems. Artificial neural networks and the Hopfield model. Supervised and unsupervised learning in neural networks. Fuzzy sets and fuzzy control. Also listed as ELEN 329. Prerequisite: MECH 324. (2 units)

MECH 330. Atomic Arrangements, Defects, and Mechanical Behavior

Structure of crystalline and non-crystalline materials and the relationship between structure, defects, and mechanical properties. For all engineering disciplines. (2 units)

MECH 331. Phase Equilibria and Transformations

Thermodynamics of multi-component systems and phase diagrams. Diffusion and phase transformations. For all engineering disciplines. (2 units)

MECH 332. Electronic Structure and Properties

Band structure and electrical conductivity of metals, semiconductors, and insulators with applications to electronic devices such as the p-n junction and materials characterization techniques utilizing electron-solid interactions. For all engineering disciplines. (2 units)

MECH 333A. Experiments in Materials Science

This course is an introduction into experimental methods in materials science with the focus on the evaluation of structural and physical properties, especially at the nanoscale. A review of the fundamentals of X-ray, SEM, EDS, and TEM microanalysis represents the core of the course. The main AFM imaging modes and their applications are covered. Practical implementation concepts of Optical, Electron and Atomic Force Microscopes are given along with sample preparation techniques, calibration methods, image analysis, and AFM artifacts. (2 units)

MECH 333B. Experimental Analysis in Materials Science

This course consists of research-oriented assignments involving heavy use of scientific instrumentation mainly at CNS (center for nanostructures). The projects are samples/materials based. The assignments may involve hands-on sample preparation, instrumentation calibration verification on the reference samples, imaging and measurements followed by the data analysis. The research may include hands-on examination of surface morphology/roughness, elemental composition and mechanical properties. Students are expected to correlate obtained data of structural and compositional changes on micro /nano scale to changes in materials properties. The results of the assignments are written up in a scientific paper format and presented thereafter. An off-campus field trip may be organized if arrangements are possible. Prerequisite: MECH 333A or equivalent. (2 units)

MECH 334. Elasticity

Fundamentals of the theory of linear elasticity, formulation of boundary value problems, applications to torsion, plane strain, flexture, and bending of plates. Introduction to three-dimensional solutions. Prerequisite: MECH 330 or CENG 205. (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, ELEN 237, and knowledge of Matlab/Simulink. (2 units)

MECH 336. Adaptive Control II

Stability and robustness of adaptive controller, robust modification, bounded linear stability analysis, metrics-driven adaptive control, constraint-based optimal adaptive control, and advanced topics in adaptive control. Prerequisite: MECH 335 or instructor approval, ELEN 237. (2 units)

MECH 337. Robotics I

Overview of robotic systems and applications. Components. Homogeneous transforms.

Denavit-Hartenberg representation. Forward and inverse kinematics. Manipulator Jacobian. Singular configurations. Also listed as ELEN 337. Prerequisites: AMTH 245 and MECH 217. (2 units)

MECH 338. Robotics II

Newton-Euler Dynamics. Trajectory planning. Linear manipulator control. Nonlinear manipulator control. Joint space control. Cartesian space control. Hybrid force/position control. Obstacle avoidance. Robotic simulation. Also listed as ELEN 338. Prerequisite: MECH 337. (2 units)

MECH 339. Robotics III

Advanced topics: parallel manipulators, redundant manipulators, underactuated manipulators, coupled manipulator/platform dynamics and control, hardware experimentation and control, dextrous manipulation, multi-robot manipulation, current research in robotic manipulation. Also listed as ELEN 339. Prerequisite: MECH 338. (2 units)

MECH 340. Introduction to Direct Access Storage Devices

Introduction to direct access storage devices, including flexible and rigid disk drives. Overview of magnetic and optical recording technology emphasizing their similarity and differences and basic principles of operation. Device components technology, including head, disk, positioning actuator, drive mechanism, drive interface, and controller. Prerequisite: Instructor approval. (2 units)

MECH 345. Modern Instrumentation and Experimentation

Overview of sensors and experimental techniques. Fundamentals of computer-based data acquisition and control, principles of operation of components in a data acquisitions system. Design and analysis of engineering experiments with emphasis on practical applications. Characterization of experimental accuracy, error analysis, and statistical analysis. Experiments involving measurements and control of equipment. (2 units)

MECH 346. Design of Experiments in Mechanical Engineering

Design, planning, and implementation of an experiment. Students will work in a group to define a project, conduct background research, provide analysis, and record data. A formal report is required. Prerequisite: MECH 345 or equivalent. (2 units)

MECH 350. Composite Materials I

Design, analysis, and manufacturing of composite materials. Characterization of composites at the materials and substructural levels. Hyperselection. Manufacturing technology and its impact on design. (2 units)

MECH 351. Composite Materials II

Composite material design at the structural level. Fabrication methods. Design for damage tolerance, durability, and safety. Transfer of loads. Prerequisite: MECH 350. (2 units)

MECH 371. Space Systems Design and Engineering I

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to orbital mechanics, power, command and data handling, and attitude determination and control. Also listed as ENGR 371. Note: MECH 371 and 372 may be taken in any order. (4 units)

MECH 372. Space Systems Design and Engineering II

A review of the engineering principles, technical subsystems, and design processes that serve as the foundation of developing and operating spacecraft systems. This course focuses on subsystems and analyses relating to mechanical, thermal, software, and sensing elements. Also listed as ENGR 372. Note: MECH 371 and 372 may be taken in any order. (4 units)

MECH 378. New Product Planning and Development

This course blends the perspectives of marketing, design, and manufacturing into a single approach to product development. Students are provided with an appreciation for the realities of industrial practice and for the complex and essential roles played by the members of the product development teams. For industrial practitioners, in particular, the product development methods described can be put into immediate practice on development projects. Also listed as EMGT 378. Pre-requisites: MECH 275A and MECH 275B or equivalent. (2 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 413. Vehicle Design I

Automotive vehicle design overview addressing the major subsystems that comprise a typical on-road vehicle application, including frame/cab, powertrain, suspension/ steering, and auxiliary automotive. The class will cover the vehicle development constraints, requirement, and technology assessments, design drivers, benchmarking, and subsystem synergies within the overall vehicle system context. (2 units)

MECH 414. Vehicle Design II

Building on Vehicle Design I instruction and material, system level automotive vehicle design that addresses off-road vehicle applications. Major subsystems reviewed include frame/cab, powertrain, suspension/ steering (including track laying), and supporting subsystems. Unique off-road duty cycle/load cases and supportability issues are addressed. (2 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 245. (2 units)

MECH 416. System Design and Project Operation

An overview of the tools and processes of systems design as it applies to complex projects involving mechanical engineering and multidisciplinary engineering. Traditional lectures by the faculty coordinator, as well as special presentations by selected industry speakers. (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 ELEN 238. Prerequisite: MECH 323 or ELEN 236. (2 units)

MECH 423. Nonlinear Control 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 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 Elen 237. Prerequisite: MECH 323 or an equivalent course in linear system theory. Students are expected to be proficient in MATLAB/Simulink or MECH 142 or equivalent. (2 units)

MECH 430. Optimal Control II

Continuation of Optimal Control I, control with state constraints, minimum-time and minimum-fuel problems, singular arcs, Bellman's principle of optimality, dynamic programming, the Hamilton-Jacobi-Bellman (H-J-B) equation, and introduction to differential game theory including zero-sum game and linear quadratic differential game problem. Prerequisite: MECH 429 or an equivalent course. Students are expected to be proficient in MATLAB/Simulink. (2 units)

MECH 431. Spacecraft Dynamics and Control I

Kinematics and Attitude dynamics, gravity-gradient stabilization, single and dual-spin stabilization, control laws with momentum exchange devices, momentum wheels. Prerequisites: MECH 140 and AMTH 106. (2 units)

MECH 432. Spacecraft Dynamics and Control II

Continuation of MECH 431. Time-optimal slew maneuvers, momentum-biased attitude stabilization, reaction thruster attitude control, introduction to dynamics of flexible spacecraft and liquid sloshing problem. Prerequisite: MECH 431. (2 units)

Chapter 15: Power Systems andSustainable Energy Program

Program Advisor: Dr. Maryam Khanbaghi

Overview

Twenty-first century problems demand holistic thinking to effectively address the social, environmental, and economic impact of emerging energy technologies. We offer a graduate certificate in Renewable Energy and a multi-disciplinary master's degree in Power Systems and Sustainable Energy. Both offerings balance deep technical expertise with practical application experience, while also promoting understanding of the economics, public policy, and ethics that shape the industry. A broad and ever-increasing range of courses—power systems, smart grid, energy management, security, and infrastructure, to name a few—are complemented by lectures, workshops, and field trips offered quarterly by our energetic Energy Club. Fuel your passion for energy engineering as you train alongside Silicon Valley professionals to meet the changing demands in energy and fulfill a pressing need in the rapidly growing renewable energy market in our Valley and the world.

Master's Degree Program And Requirements

Students interested in this major must satisfy the standard admissions criteria used by the School of Engineering, which include an undergraduate degree in a field of engineering (physics degrees will also be considered), appropriate GRE scores and (for international students) demonstrated proficiency in English. Both TOEFL and IELTS scores are acceptable for this purpose. All students are expected to maintain a minimum grade point average of 3.0 while enrolled in the program. They must also develop a PS&SE Program of Studies with the program advisor and file this document with the Graduate Programs Office by the end of their first quarter at SCU.

Required Courses

Foundational Courses

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

Graduate Core Courses

- ENGR 272 Energy Public Policy (2 units)
- ENGR 273 Sustainable Energy and Ethics (2 units) or ENGR 344 Artificial Intelligence and Ethics (2 units)
- EMGT 255 Managerial Accounting for Operating Managers (2 units)
- EMGT 380 Introduction to Systems Engineering Management (2 units)

Applied Mathematics Courses

- AMTH 245 Linear Algebra I (2 units)
- AMTH 246 Linear Algebra II (2 units)
- 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

- ELEN 231 Power System Stability and Control (4 units)
- ELEN 287/ENGR 339 Energy Storage Systems (2 units)

- MECH 228 Equilibrium Thermodynamics (2 units) or MECH 230 Statistical Thermodynamics (2 units)
- MECH 288 Energy Conversion I (2 units)

Electrical Engineering

- ELEN 231 Power System Stability and Control (4 units)
- ELEN 287/ENGR 339 Energy Storage Systems (2 units)
- ELEN 288 Energy Management Systems or ELEN 236 Linear Control Systems (2 units)
- ELEN 353 DC to DC Power Conversion (2 units)

Computer Engineering

- COEN 242 Big Data (4 units) or Coen 240 Machine Learning (4 units)
- COEN 243 Internet of Things (4 units)
- COEN 266 Artificial Intelligence (4 units)

Civil Engineering

- CENG 217 Sustainable Infrastructure for Developing Countries (4 units) or CENG 288 Engineering Decision and Risk Analysis (4 units)
- CENG 219 Designing for Sustainable Construction (4 units)
- CENG 249 Civil Systems Engineering (4 units)

Additional elective courses to complete the 46-unit requirement must be approved by the academic advisor. These elective courses may include a thesis, up to nine units.

Renewable Energy Certificate Program

The main goal of this certificate is to introduce students to the field of renewable energy. The intent is to help equip professionals in Silicon Valley with the knowledge that will help them advance in their present career or enter the renewable energy field. To enroll in this certificate, an applicant should have a B.S. in Engineering from an accredited school and maintain a grade point average of 3.0. As with most certificates in the Graduate School of Engineering, the requirement is 16 quarter units. Eight of these units are in Power Systems and eight units are in Renewable Energy.

Continuation For A Master's Degree

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 3.5 or better.

Required Courses (16 units total)

Power Systems

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

Renewable Energy

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

Chapter 16: Robotics and Automation Program

Program Advisor: Dr. Christopher Kitts

OVERVIEW

Robotics and the automation sciences relating to intelligent machines and smart systems is a burgeoning field that is fueling the economy, driving employment in Silicon Valley and beyond, and transforming the nature of work in a wide range of applications. We offer a multi-disciplinary master's degree in Robotics and Automation, which balances deep technical expertise with practical application-oriented experience and with insight into the societal impacts, ethical challenges and entrepreneurial opportunities relevant to this field. A technical core ensures competence in the areas of design, controls and perception. Elective-based focus areas within the degree provide opportunities for students to build knowledge and expertise in application areas such as industrial internet-of-things and manufacturing, field robotics, etc. Furthermore, partnerships with local companies and agencies provide highly applicable project experiences, ensure a relevant curriculum, and contribute to a strong student recruitment pipeline. Finally, a novel co-curricular option certifies student competencies in modern skills and tools relevant to the robotics and automation industry.

MASTER'S DEGREE PROGRAM AND REQUIREMENTS

Students interested in this major must satisfy the standard admissions criteria used by the School of Engineering, which include an undergraduate degree in a field of engineering or related area, appropriate GRE scores, and demonstrated proficiency in English. Students must also have an academic background or be able to demonstrate proficiency in computer programming, electrical circuit design, and mechanical design; students deficient in one or more of these areas may be required to take additional courses in these areas at either the graduate or undergraduate level prior to entering or early in their degree program. Students are expected to maintain a minimum grade point average of 3.0 while enrolled in the program. They must also develop a Robotics and Automation Program of Studies with an academic advisor and file this document with the Graduate Services Office by the end of their first quarter at SCU.

The degree requires completion of a minimum of 46 graduate units, to include:

- **Enrichment Experience (minimum 8 units)**
    - Graduate Core: one course each from "Engineering and Business/Entrepreneurship" and "Engineering and Society" (a minimum of 4 units)
    - The additional 4 units can be satisfied by any combination of a) one or more technical electives, b) additional classes from Graduate Core List, c) Cooperative Education courses (ENGR 288/289) and d) combination of a, b and c.

Mathematics (8 units): Students must complete at least one Applied Math 4-unit sequence in either linear algebra or probability. The additional 4 units may be completed by taking another Applied Math course or by completing 4 units of technical elective courses that have significant mathematical components (a list of applicable elective courses is maintained in the program office).

- AMTH 245 Linear Algebra I (2) and AMTH 246 Linear Algebra II (2) [or AMTH 247 Linear Algebra I & II (4)]
- AMTH 210 Probability I (2) and AMTH 211 Probability II (2) [or AMTH 212 Probability I & II (4)]

Technical Core (13 units): Students must complete 13 or more units of core courses covering basic mechatronic device design, mechatronic control systems, robotic kinematics/dynamics/control, and advanced sensing/perception techniques:

- ELEN 460 / MECH 207 Advanced Mechatronics I (3)
- ELEN 461 / MECH 208 Advanced Mechatronics II (3)
- ELEN 337 / MECH 337 Robotics I (2)

- ELEN 338 / MECH 338 Robotics II (2)
- 3 or 4 units of course content in advanced sensing/perception, which may be satisfied by either:
  - COEN 240 Machine Learning (4), or
  - COEN 340 / ELEN 640 Digital Image Processing I (2) and COEN 341 / ELEN 643 Digital Image Processing II (2)
  - Other possible courses as approved by the program advisor

Technical Electives (8 units): Students must complete a minimum of 8 units of technical electives based on the following list or by a course approved by the student's advisor via the Program of Studies prior to enrolling in the course. Students are encouraged to select technical electives to build expertise in one or more application areas; a list of these application areas and their associated electives is maintained in the program office.

- AMTH 377 / COEN 279 Design and Analysis of Algorithms (4)
- BIOE 252 Computational Neuroscience (2)
- BIOE 277 Biosensors (2)
- BIOE 281 Introduction to Pattern Recognition (2)
- COEN 201 / Elen 233 Digital Signal Processing I (2) & COEN 202 / Elen 234 Digital Signal Processing II (2) [or COEN 201e / Elen 233e Digital Signal Processing I & II (4)]
- COEN 240 Machine Learning (4)
- COEN 242 Big Data (4)
- COEN 243 Internet of Things (4)
- COEN 266 Artificial Intelligence (4)
- COEN 277 User Experience Research & Design (2)
- COEN 281 Pattern Recognition and Data Mining (4)
- COEN 317 Distributed Systems (4)
- COEN 319 Parallel Programming (4)
- COEN 340 / ELEN 640 Digital Image Processing I (2) & COEN 341 / ELEN 643 Digital Image Processing II (2)
- COEN 342 Deep Learning
- COEN 344 / ELEN 644 Computer Vision I (2) & COEN 345 / ELEN 645 Computer Vision II (2)
- COEN 376 Expert Systems (4)
- ELEN 235 Estimation (2)
- ELEN 236 Linear Control Systems (2)
- ELEN 237 Optimal Control (2)
- ELEN 238 / MECH 420 Model Predictive Control (2)
- ELEN 239 Introduction to Self-Driving Car Technology (4)
- ELEN 271 Microsensors (2)
- ELEN 329 / MECH 329 Introduction to Intelligent Control (2)
- ELEN 331(L) Autonomous Driving Systems (and Lab)
- ELEN 333 Digital Control Systems (2)
- ELEN 335 Estimation II (2)
- ELEN 501 Embedded Systems (2)
- ELEN 501L Embedded Systems Lab (1)
- ELEN 502 Real-Time Systems (2)
- ELEN 503 Hardware-Software Codesign (2)
- ELEN 520 Introduction to Machine Learning (2)
- ELEN 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 web site lists current themes with affiliated industry partners and capstone/thesis opportunities. Examples include topics such as advanced manufacturing, field robotics, bio-robotics/mechatronics, aerospace robotics, automation sciences, and so on.

Culminating Experience (6-12 units): Students must complete 6-9 units of either a Capstone Design Project or a 9-12 unit Thesis research project through an existing Capstone or Masters Thesis course in a relevant engineering department.

Additional Units (as necessary): Additional units as required to reach a minimum of 46 units must be completed; these must be approved by the student’s advisor via the Program of Studies prior to enrolling in the courses. Typically, any extra units would be completed by enrolling in additional technical elective courses; however, in some cases, it may be of interest to take courses such as the project management or systems engineering course sequences offered by the Engineering Management program. Students may not apply the completion of one course to two different requirement categories, with the exception of the mathematics requirement.

Modern Tools/Skills Competency Badging (Optional): Students may participate in this competency certification system to develop verified capabilities, acknowledged through the awarding of a “badge,” in a variety of areas that are in great demand by employers. Some of these badges will be obtained through completion of courses within the program. Others may be incorporated into the required “culminating experience.” There may also be opportunities to participate in co-curricular non-credit workshops in some topics. Management of these competency badges are managed through an online design portfolio system available to all students.

Chapter 17: Graduate Minor in Science, Technology, and Society (STS)

Program Advisor: Dr. Aleksandar Zecevic

Program Description

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

The need to develop such skills has been widely recognized in universities around the country, as witnessed by the growing emphasis on interdisciplinary studies in undergraduate engineering curricula. It is unusual, however, to encounter programs of this kind on the graduate level. Most traditional master's programs still focus on specialized technical topics and offer little insight into how practicing engineers might engage global challenges such as climate change, sustainability, or economic disparity (to name just a few).

The primary purpose of the STS minor is to offer graduate students an opportunity to examine some of these key social issues on an advanced level. The scope of the minor is broad and includes topics that range from the social impact of new technologies, to applied ethics, sustainability, and religion. As such, it reflects an educational philosophy that goes well beyond narrow specialization and promotes a global and societal orientation. All the courses in this program have a distinctly interdisciplinary flavor, and are designed to develop creativity, innovation, and leadership.

The minor consists of a Core and a set of electives and entails a minimum of 12 units of coursework. It is open to all students who are pursuing a master's degree in engineering, regardless of the specific program in which they are enrolled.

Program Requirements

The STS minor consists of a Core and a set of electives and entails a minimum of 12 units of coursework. The Core courses cover four distinct thematic areas:

• Social and Philosophical Issues in Science and Engineering

• Engineering and Ethics

• Science and Religion

• Sustainability and Engineering

Students will be required to take courses in at least three of the 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.

The courses and the different thematic areas to which they belong are listed 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 261 Nanotechnology and Society
- ENGR 272 Energy Public Policy
- ENGR 302 Managing in the Multicultural Environment

- ENGR 303 Gender and Engineering
- ENGR 304 Building Global Teams
- ENGR 336 Engineering for the Developing World
- ENGR 338 Mobile Applications for Emerging Markets
- ENGR 341 Innovation, Design and Spirituality
- ENGR 342 3D Print Technology and Society

Engineering and Ethics

- COEN 288 Software Ethics
- ENGR 273 Sustainable Energy and Ethics
- ENGR 310 Engineering Ethics
- ENGR 334 Energy, Climate Change, and Social Justice

Science and Religion

- ELEN 217 Chaos Theory, Metamathematics and the Limits of Knowledge: A Scientific Perspective on Religion
- ENGR 334 Energy, Climate Change, and Social Justice
- ENGR 341 Innovation, Design and Spirituality

Sustainability and Engineering

- ENGR 271 Energy Conservation
- ENGR 272 Energy Public Policy
- ENGR 273 Sustainable Energy and Ethics
- ELEN 280/MECH 287 Introduction to Alternative Energy Systems
- ELEN 288/COEN 282 Energy Management Systems
- ENGR 334 Energy, Climate Change, and Social Justice
- ENGR 337 Sustainability and Green Information Technology
- ENGR 340 Distributed and Renewable Energy for the Developing World
- ENGR 349 Topics in Frugal Engineering

Admission Procedures

The STS minor option is open to all master's students in the School of Engineering. Those who wish to pursue this minor must submit an application form to the Graduate Services Office by the end of their third quarter at SCU (at the latest), and must have their program of studies approved by the academic advisor for this program (Dr. Aleksander Zecevic). Links to the application form and the program of studies form can be found at the website: www.scu.edu/engineering/graduate

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 45 units that are required for a master's degree.

In order to become eligible for this benefit, students must check the appropriate box that pertains to financial aid on the application form. In addition, their program of studies must be approved by the academic advisor for the program (Dr. Aleksandar Zecevic). Financial aid comes into effect once a student completes 46 units of course work, at which point he or she should follow the procedure outlined below:

1. The quarterly tuition must be paid in full, and in the timeframe specified by the Bursar’s Office.
2. In the second week of each quarter, students must provide the program academic advisor with a list of courses in which they are currently enrolled (this will require official proof of registration).
3. Once the academic advisor establishes that the courses conform to the approved programs of studies (both in the technical and in the STS area), students will receive financial aid in the amount of 75% of their tuition expenses for that quarter (excluding fees).

Chapter 18: Certificate Programs

General Information

Certificate programs are designed to provide intensive background in a narrow area at the graduate level. At approximately one-third of the units required for a master's degree, the certificate is designed to be completed in a much shorter period of time. These certificate programs are appropriate for students working in industry who wish to update their skills or for those interested in changing their career path.

Interdisciplinary

Certificate in Frugal Innovation

Advisor: Dr. Aleksandar Zecevic

Over the past two decades, global trends have been forcing businesses to adapt to growing consumer bases in Africa, Asia, and Latin America, which are in desperate need of low-cost and high-quality solutions to the challenges that they face. The importance of these new "economic realities" is underscored by the fact that emerging markets are expected to exceed 50% of the world's GDP in 2017 (according to IMF estimates). In order to excel professionally in such an environment, engineers will have to be equipped with the knowledge and skill sets to appropriately define, design, and implement solutions that are not merely a "stripping down" of Western products to meet the rising demand. Industry, particularly in Silicon Valley, is becoming increasingly aware of this fact and has begun to move toward a 'Triple Bottom Line' approach to business, which integrates environmental, societal, and financial considerations. The Certificate in Frugal Innovation is designed to give students the ability and the tools to adapt to this new model, and to expand their understanding of the impact that engineering has on society.

This program is suitable for working professionals in a wide variety of engineering disciplines. To enroll, students must have a B.S in Engineering from an accredited institution, and should maintain a GPA of at least 3.0 in order to receive the certificate.

Program Requirements

The Certificate in Frugal Innovation entails a minimum of 16 units of course work. It consists of an eight-unit Core, and a set of electives that are organized into two groups. Students are required to take four units from Group A and another four from Group B, as described below.

Required Core Classes (8 units)

- ENGR 336 Engineering for the Developing World (2 units)
- ENGR 338 Mobile Applications and Instrumentation for Emerging Markets (2 units)
- ENGR 340 Distributed and Renewable Energy for the Developing World (2 units)
- ENGR 341 Innovation, Design and Spirituality (2 units)

Elective Group A (4 units)

- ENGR 273 Sustainable Energy and Ethics (2 units)
- ENGR 304 Building Global Teams (2 units)
- ENGR 342 3D Print Technology and Society (2 units)
- ENGR 349 Special Topics in Frugal Engineering (2 units)

Elective Group B (4 units)

- CENG 219 Designing for Sustainable Construction (4 units)
- COEN 389 Energy Efficient Computing (2 units)
- ELEN 280/MECH 287 Introduction to Alternative Energy Systems (2 units)

- ELEN 288/COEN 282 Energy Management Systems (2 units)
- ENGR 302 Managing in the Multicultural Environment (2 units)
- ENGR 334 Energy, Climate Change, and Social Justice (2 units)

Renewable Energy Certificate

Advisor: Dr. Maryam Khanbaghi

Renewable energy is the fastest-growing sector in California and brings together principles and practices from engineering, environmental science, and economics. Silicon Valley, the home of the world's largest cluster of renewable energy companies and green investors, offers fertile ground to recruit career changers who wish to move into renewable energy and students who want to take advantage of the tremendous career opportunities.

The main goal of this certificate is to introduce students to the field of renewable energy. The intent is to help equip professionals in Silicon Valley with the knowledge that will help them advance in their present career or enter the renewable energy field. To enroll in this certificate, an applicant should have a B.S. in Engineering from an accredited school and should maintain a grade point average of 3.0. As with most certificates in the Graduate School of Engineering, the requirement is 16 quarter units. Eight of these units are in Power Systems, eight units are in Renewable Energy.

Required Courses (16 units total)

Power Systems (8 units)

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

Renewable Energy (8 units)

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

Electrical Engineering Certificates

Digital System Design

Advisor: Dr. Sara Tehranipoor

This certificate program has a triple purpose: (a) to increase design skills in digital system development, (b) to strengthen fundamental knowledge of computer architecture, digital design and embedded systems; and (c) to introduce the digital system designer to state-of-the-art tools and techniques. The program consists of the courses listed below, totaling 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (6 units)

- ELEN 501 Embedded Systems (2 units)
- ELEN 511 Advanced Computer Architecture (2 units)
- ELEN 603 Logic Design using HDL (2 units)

Elective Courses (10 units)

- ELEN 387 VLSI Design I (2 units)
- ELEN 388 VLSI Design II (2 units)
- ELEN 500 Logic Analysis and Synthesis (2 units)

- ELEN 502 Real Time Systems (2 units)
- ELEN 503 Hardware-Software Co-design (2 units)
- ELEN 512 Advanced Computer Architecture II (2 units)
- ELEN 513 Parallel System Architectures (2 units)
- ELEN 530 Hardware Security and Trust (2 units)
- ELEN 608 Design for Testability (2 units)
- ELEN 613 SoC (System-on-Chip) Verification (2 units)

Integrated Circuit Design and Technology

Advisors: Dr. Shoba Krishnan, Dr. Cary Yang, Dr. Mahmudur Rahman

The study of integrated circuits consists of three interconnected areas: Design, Devices and Process Technology. This certificate provides the necessary fundamentals in these areas and advanced concepts and application 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 take a total of 16 units. Any change in the requirements must be approved by the academic advisor.

Required Courses (8 units)

- ELEN 252 Analog Integrated Circuits I (2 units)
- ELEN 261 Fundamentals of Semiconductor Physics (2 units)
- ELEN 270 Introduction to IC Materials (2 units)
- ELEN 387 VLSI Design I (2 units)

Elective Courses (8 units)

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

Digital Signal Processing and Machine Learning

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a basic understanding of digital signal processing theory, machine learning and modern implementation methods, as well as advanced knowledge of at least one specific application area. Digital signal processing and machine learning have become important across many areas of engineering, and this certificate prepares students for traditional or novel applications.

Required Courses (11 units minimum)

- ELEN 233 Digital Signal Processing I (2 units)
- ELEN 520 and ELEN 520L Introduction to Machine Learning (3 units)
- At least one course from: AMTH 210 Probability I or AMTH 245 Linear Algebra I or AMTH 370 Optimization Techniques (2 units)

- At least one course from: ELEN 233 Digital Signal Processing System Development (4 units) or ELEN 226 Machine Learning and Signal Processing Using FPGAs (2 units) or ELEN 234 Digital Signal Processing II (2 units)
- At least one course from: ELEN 421 Speech Processing I or ELEN 640 Digital Image Processing I (2 units)

Note: ELEN 233E Digital Signal Processing I, II (4 units) is equivalent to both ELEN 233 and ELEN 234.

Elective Courses (Additional courses to make a total of 16 units) selected from the list below:

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ELEN 241 Introduction to Communications (2 units)
- ELEN 243 Digital Communications Systems (2 units)
- ELEN 244 Information Theory (2 units)
- ELEN 247 Communication Systems Modeling Using Simulink I (2 units)
- ELEN 334 Introduction to Statistical Signal Processing (2 units)
- ELEN 422 Speech Coding II (2 units)
- ELEN 431 Adaptive Signal Processing I (2 units)
- ELEN 521 and 521L Deep Learning (3 units)
- ELEN 643 Digital Image Processing II (2 units)
- ELEN 644 Computer Vision I (2 units) or ELEN 645 Computer Vision II (2 units)

Digital Signal Processing Theory

Advisors: Dr. Tokunbo Ogunfunmi, Dr. Sally Wood

This certificate program provides a firm theoretical grounding in fundamentals of digital signal processing (DSP) technology and its applications. It is appropriate for engineers involved with any application of DSP who want a better working knowledge of DSP theory and its applications. A novel feature of the program is a hands-on DSP hardware/software development laboratory course in which students design and build systems for various applications using contemporary DSP hardware and development software.

Required Courses (8 units)

- AMTH 308 Theory of Wavelets (2 units) or AMTH 358 Fourier Transforms (2 units)
- ELEN 233E or ELEN 233 and 234 Digital Signal Processing I, II (4 units)
- ELEN 334 Introduction to Statistical Signal Processing (2 units)

Elective Courses (8 units)

- ELEN 223 Digital Signal Processing System Development (4 units)
- ELEN 226 Machine Learning and Signal Processing Using FPGAs (2 units)
- ELEN 235 Estimation I (2 units)
- ELEN 241 Introduction to Communications (2 units)
- ELEN 244 Information Theory (2 units)
- ELEN 336 Detection (2 units)
- ELEN 431 Adaptive Signal Processing I (2 units)
- ELEN 640 Digital Image Processing I (2 units)
- ELEN 641 Image and Video Compression (2 units)
- ELEN 643 Digital Image Processing II (2 units)

Fundamentals of Electrical and Computer Engineering

Advisor: Dr. Shoba Krishnan

This certificate has been designed for those individuals who have significant work experience in some area of electrical and computer engineering and wish to take graduate-level courses but may lack some prerequisite knowledge because they have not earned a BS degree in electrical and/or computer engineering. This one-year program consists of 16 to 28 units, depending on the background of the individual student, and covers electrical and computer engineering core areas. Units from courses at or above the 200 level may be credited toward the Master of Science Degree in Electrical and Computer Engineering after successful completion of the certificate.

The specific required courses for a certificate are selected with the help of the program advisor according to the student's background.

- ELEN 21 Introduction to Logic Design (5 units)
- ELEN 50 Electric Circuits I (5 units)
- ELEN 100 Electric Circuits II (5 units)
- ELEN 104 Electromagnetics I (5 units)
- ELEN 110 Linear Systems (5 units) or ELEN 210 (2 units)
- ELEN 115 Electronic Circuits I (5 units) or ELEN 250 (2 units)
- ELEN 120 Microprocessor System Design (5 units)

RF and Applied Electromagnetics

Advisors: Dr. Timothy Healy, Dr. Kurt Schab

The purpose of this certificate is to meet the increasing need for the knowledge in microwave, antenna and RF integrated circuits in existing electronic products. This program is offered for students who have a B.S. in Electrical Engineering. Students are expected to have knowledge of multivariate calculus and preferably partial differential equations and they must ensure that they have prerequisites for the courses in their program.

The curriculum consists of 16 units: two required courses (4 units) and 12 units of elective courses listed below:

Required Courses (4 units)

- ELEN 201 Electromagnetic Field Theory I (2 units)
- ELEN 701 Microwave System Architecture (2 units)

Elective Courses (12 units)

- ELEN 202 Computational Electromagnetics (2 units)
- ELEN 203 Bio-Electromagnetics (2 units)
- ELEN 204 Magnetic Circuits for Electric and Autonomous Vehicles (2 units)
- ELEN 351 RF Integrated Circuit Design or ELEN 354 Advanced RFIC Design (2 units each)
- ELEN 624 Signal Integrity in IC and PCB Systems (2 units)
- ELEN 706 Microwave Circuit Analysis and Design (2 units) (Passive Component)
- ELEN 711 Active Microwave Devices I or ELEN 712 Active Microwave Devices II (2 units each) (Active Components)
- ELEN 715 Antennas I or ELEN 716 Antennas II (2 units each)
- ELEN 726 Microwave Measurements, Theory and Tech (3 units) (Laboratory Oriented)

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

Mechanical Engineering Certificates

Department Chair-Dr. Hohyun Lee

Controls

Objective

The Controls Certificate is intended for working engineers in mechanical and closely related fields of engineering. The certificate will provide a foundation in contemporary control theory and methods. The Controls Certificate covers classical and modern control systems and analysis. Specialization in digital control, mechatronics, robotics, or aerospace applications is possible with a suitable choice of electives. Completion of the certificate will allow the student to design and analyze modern control systems.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a closely related field of engineering. They are expected to have prior coursework in undergraduate mathematics. No prior control courses are required.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (8 units)

- MECH 217 Introduction to Control (2 units)
- MECH 218 Guidance and Control I (2 units)
- MECH 323 Modern Control Systems I (2 units)
- MECH 324 Modern Control Systems II (2 units)

Elective Courses (8 units)

- AMTH 245 Linear Algebra I (2 units)
- AMTH 246 Linear Algebra II (2 units)
- CENG 211 Advanced Strength of Materials (4 units)
- MECH 207 Advanced Mechatronics I (2 units)
- MECH 208 Advanced Mechatronics II (2 units)
- MECH 209 Advanced Mechatronics III (2 units)
- MECH 219 Guidance and Control II (2 units)
- MECH 329 Introduction to Intelligent Control (2 units)
- MECH 355, 356 Adaptive Control I, II (2 units each)
- MECH 429, 430 Optimal Control I, II (2 units each)

Dynamics and Vibrations

Objective

The Dynamics and Vibrations Certificate is intended for working engineers in mechanical and related fields of engineering. The certificate will provide a fundamental and broad background in engineering dynamics. The Dynamics and Vibrations Certificate includes a strong foundational base in dynamics and applications in optimization, robotics, mechatronics, or dynamics of aircraft or spacecraft (depending on the chosen elective courses). Completion of the certificate will allow the student to formulate and solve the complex dynamics problems that arise in such fields as robotics and space flight.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a closely related field of engineering. They are expected to have prior coursework in undergraduate dynamics and mathematics.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (8 units)

- MECH 214, 215 Advanced Dynamics I, II (2 units each)
- MECH 305, 306 Advanced Vibrations I, II (2 units each)

Elective Courses (8 units)

- MECH 205, 206 Aircraft Flight Dynamics I, II (2 units each)
- MECH 431, 432 Spacecraft Dynamics and Control I, II (2 units each)

Materials Engineering

Objective

The Materials Engineering Certificate is intended for working engineers in mechanical, materials, or manufacturing engineering. The certificate will provide either an upgrade in materials understanding, or advanced study in a particular aspect of the subject. Completion of the certificate will allow the student to develop a deeper understanding of materials and their applications in design and manufacturing.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a related engineering discipline. They are expected to have prior coursework in basic materials science and strength of materials.

Program Requirements

Students must complete 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (12 units)

- MECH 281 Fracture Mechanics and Fatigue (2 units)
- MECH 330 Atomic Arrangements, Defects, and Mechanical Behavior (2 units)
- MECH 331 Phase Equilibria and Transformations (2 units)
- MECH 332 Electronic Structure and Properties (2 units)
- MECH 333 Experiments in Materials Science (2 units)
- MECH 345 Modern Instrumentation and Control (2 units)

Elective Courses (4 units)

- AMTH 210 Introduction to Probability I and AMTH 211 Continuous Probability (2 units each)
- AMTH 217 Design of Scientific Experiments and AMTH 219 Analysis of Scientific Experiments (2 units each)
- CENG 211 Advanced Strength of Materials (4 units)
- ENGR 260 Nanoscale Science and Technology (2 units)
- ENGR 262 Nanomaterials (2 units)
- MECH 273 Designing with Plastic Materials (2 units)
- MECH 274 Processing Plastic Materials (2 units)
- MECH 277 Injection Mold Tool Design (2 units)
- MECH 334 Elasticity (2 units)
- MECH 350 and 351 Composite Materials I and II (2 units each)

Mechanical Design Analysis

Objective

The Mechanical Design Analysis Certificate is intended for working engineers in mechanical or structural engineering. The certificate will provide a succinct upgrade in knowledge and skills that will allow the student to gain a deeper understanding of CAD and FEA principles and practices. Completion of the certificate will allow the student to pursue more advanced design and analysis tasks.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical, civil, aerospace, or a related field. They are expected to have prior coursework in strength of materials, thermodynamics, fluid mechanics, and mathematics through differential equations.

Program Requirements

Students must complete 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (12 units)

- CENG 205 Finite Element Methods I (2 units)
- CENG 206 Finite Element Methods II (2 units)
- CENG 207 Finite Element Methods III (2 units)
- MECH 325 Computational Geometry for Computer-Aided (2 units)

Design and Manufacture (2 units)

- *MECH 334 Elasticity (2 units)*
- *MECH 415 Optimization in Mechanical Design (2 units)*

Elective Courses (4 units)

- AMTH 220 Numerical Analysis I (2 units)
- AMTH 221 Numerical Analysis II (2 units)
- AMTH 308 Mathematical Modeling I (2 units)
- AMTH 309 Mathematical Modeling II (2 units)
- AMTH 370 Optimization Techniques I (2 units)
- AMTH 371 Optimization Techniques II (2 units)
- CENG 211 Advanced Strength of Materials (4 units)
- CENG 214 Theory of Elasticity (4 units)
- CENG 222 Advanced Structural Analysis (4 units)
- MECH 268 Computational Fluid Mechanics I (2 units)
- MECH 269 Computational Fluid Mechanics II (2 units)

Mechatronics Systems Engineering

Objective

The Mechatronics Systems Engineering Certificate is intended for working engineers in mechanical engineering and related fields. The certificate program introduces students to the primary technologies, analysis techniques, and implementation methodologies relevant to the detailed design of electro-mechanical devices. Completion of the certificate will allow the student to develop systems that involve the sensing, actuation and control of the physical world. Knowledge such as this is vital to engineers in the modern aerospace, robotics and motion control industries.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical, aerospace, electrical, engineering physics, or a related field. They are expected to have prior coursework in mathematics through differential equations, introductory linear control theory, and introductory electronics and programming.

Program Requirements

Students must complete a total of 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (8 units)

- MECH 207 Advanced Mechatronics I (3 units)

- MECH 208 Advanced Mechatronics II (3 units)
- MECH 217 Introduction to Control (2 units)

Elective Courses (8 units)

- MECH 209 Advanced Mechatronics III (2 units)
- MECH 218 Guidance and Control I (2 units)
- MECH 219 Guidance and Control II (2 units)
- MECH 275 Design for Competitiveness (2 units)
- MECH 310 Advanced Mechatronics IV (2 units)
- MECH 311 Modeling and Control of Telerobotic Systems (4 units)
- MECH 315 Digital Control Systems I (2 units)
- MECH 316 Digital Control Systems II (2 units)
- MECH 323 Modern Control Systems I (2 units)
- MECH 324 Modern Control Systems II (2 units)
- MECH 329 Intelligent Control (2 units)
- MECH 337 Robotics I (2 units)
- MECH 338 Robotics II (2 units)
- MECH 339 Robotics III (2 units)
- MECH 345 Modern Instrumentation (2 units)

An independent study or Capstone project would be suitable as one of the electives. In addition, other courses may serve as electives at the discretion of the program advisor.

Thermofluids

Objective

The Thermofluids Certificate is intended for working engineers in mechanical,
chemical, or a closely related field of engineering. The certificate will provide fundamental theoretical and analytic background, as well as exposure to modern topics and applications. Specialization in fluid mechanics, thermodynamics, or heat transfer is possible with a suitable choice of electives. Completion of the certificate will allow the student to design heat transfer and fluid solutions for a range of modern applications.

Admission

Applicants must have completed an accredited bachelor's degree program in mechanical or a closely related field of engineering. They are expected to have prior undergraduate coursework in fluid mechanics, thermodynamics and heat transfer.

Program Requirements

Students must complete 16 units as described below, with a minimum GPA of 3.0 and a grade of C or better in each course.

Required Courses (12 units)

- MECH 228 Equilibrium Thermodynamics (2 units)
- MECH 236 Conduction Heat Transfer (2 units)
- MECH 238 Convective Heat Transfer I (2 units)
- MECH 240 Radiation Heat Transfer (2 units)
- MECH 266 Fundamentals of Fluid Mechanics (2 units)
- MECH 270 Viscous Flow I (2 units)

Elective Courses (4 units)

- MECH 202 Mathematical Methods in Mechanical Engineering (4 units)
- MECH 225 Gas Dynamics I (2 units)

- MECH 226 Gas Dynamics II (2 units)
- MECH 230 Statistical Thermodynamics (2 units)
- MECH 239 Convective Heat Transfer II (2 units)
- MECH 241 Radiation Heat Transfer II (2 units)
- MECH 242 Nanoscale Heat Transfer (2 units)
- MECH 268 Computational Fluid Mechanics I (2 units)
- MECH 269 Computational Fluid Mechanics II (2 units)
- MECH 271 Viscous Flow II (2 units)
- MECH 288 Energy Conversion I (2 units)
- MECH 289 Energy Conversion II (2 units)
- MECH 345 Modern Instrumentation and Control (2 units)

Chapter 19: Campus Life

Santa Clara students are encouraged to participate in extracurricular activities as part of their total development. The primary educational objective in supporting student activities and organizations is to foster a community that is enriched by men and women of diverse backgrounds, wherein freedom of inquiry and expression enjoys high priority.

The following sections describe various aspects of student life and services.

Campus Ministry

Campus Ministry is comprised of people who are committed to spiritual and personal growth. Its mission is to foster the spiritual life of our students and Campus Ministry values Gathering across difference, Discerning what is needed, and Transforming our hearts & communities.

- In support of the University's mission to the "development of the whole person," Campus Ministry offers a variety of programs as well as pastoral presence to support that development, particularly the spiritual and personal aspects.
- Campus Ministry provides a welcoming environment where faith may be explored, discovered, and developed through worship, retreats, small groups, and conversation.
- In addition to eight full-time campus ministers, there are also spirituality facilitators who are associated with campus ministry and who live in the university's residence halls.

What does Campus Ministry have to offer?

- **Worship:** Three Sunday liturgies in the Mission Church, daily noon Mass in the Mission, weekday Misas en español, weekly confession, University celebrations, prayer services, ecumenical (Christian) and interfaith services throughout the year.
- **Intercultural Ministry:** Campus Ministry sponsors three faith-based, student-led organizations dedicated to the spiritual wellness of BIPOC students: Beloved Community for Black students, SLC en español for Latinx students, and the API SLC for Asian Pacific Islander students. 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.
- **Retreats:** Santa Clara students are offered a number of retreat experiences over the course of the academic year. Offerings include Search retreats, an Ignatian retreat, and a retreat for first-year students. Retreats are offered to persons of all faiths.
- **Prayer and reflection groups:** The Spiritual Life Community program places students in small groups for weekly prayer and reflection. In addition, there are Interfaith Dinner Discussions, weekly Breaking Open the Word (reflection on the lectionary readings), RLC small groups, and outreach to student athletes.
- **Leadership opportunities:** Students explore the values of "servant leadership" by serving and leading in all program areas, as volunteers, or in one of a number of paid internships.
- **Faith formation:** Campus Ministry offers several opportunities for students to learn, reflect, and grow in regard to their faith through Scripture reflection, forums, and presentations. This includes preparation for the sacraments of baptism, first Eucharist, and confirmation in the Catholic Church.
- **Social justice awareness and action:** Campus Ministry provides students with a variety of opportunities to live out a faith that does justice. Some key focus areas include participation in the annual Ignatian Family Teach-in for Justice, and community service at a local school.
- **Faith-based clubs:** In partnership with the Center for Student Involvement, Campus Ministry aids in the mentoring and support of all faith-based registered student organizations.
- **Sacred spaces:** Throughout campus, there are spaces that can be conducive for prayer, meditation, and reflection, such as the Mission Church, the Multifaith Sanctuary in St. Joseph's Hall, or the Meditation Room in Benson.

Is Campus Ministry for everyone?

Yes! We welcome the participation of anyone interested in spiritual and personal growth, regardless of faith tradition. This is a time for learning about yourself and our world, and we hope we can accompany you in that exploration and deepening of faith and spirituality.

Student Media

KSCU: KSCU is a student-run, non-commercial radio station at 103.3 FM. The program format features primarily independent music, including indie rock, punk, ska, jazz, blues, electronic, reggae, and more. Students may get involved with the radio station as a staff member or as a volunteer disc jockey, office assistant, fundraiser, or sound technical staff. The staff of KSCU operates all aspects of an FM radio station in accordance with SCU's mission and goals, and Federal Communications Commission regulations.

Santa Clara Review: The *Santa Clara Review (SCR)* is the University's biannual literary magazine and draws submissions from students, faculty, staff, and artists outside the University community. The *Review* is committed to the development of student literary talent in editorial knowledge and creative writing skills. Students may get involved with the magazine in several staff positions and with opportunities to volunteer in the areas of poetry, fiction, nonfiction, art, and management.

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 psychologists who 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. Individual counseling, couples counseling, group counseling, and psychoeducational programs are available. In counseling, students work on a wide range of psychosocial and developmental issues such as depression, anxiety, interpersonal problems, disturbed sleep, eating behaviors, acculturation, academic motivation, homesickness, family concerns, intimacy, and sexuality. All students are eligible for up to 10 counseling sessions per academic year; the first six (6) sessions are free, with a nominal fee assessed for sessions seven (7) through ten (10).

When CAPS is closed, an after-hours emergency and suicide crisis hotline (408-279-3312) is available to students along with Santa Clara's unique crisis webpage featured on the Ulifeline website.

Student Health Services

Student Health Services (SHS) is staffed with a physician, physician assistant, nurse practitioners, registered nurses, and medical assistants. A psychiatrist, registered dietitian, and physical therapy assistant are available on a part-time basis. SHS provides high-quality services, such as primary medical care, physicals, diagnosis and treatment of illness and injuries, immunizations, gynecological examinations, a limited in-house pharmacy, 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. Visits to Cowell Center's Counseling and Psychological Services range in cost from no charge to $100 per visit for all students. For further information, see the Cowell Center website. When SHS is closed, an advice nurse is available by phone for students both on campus (**extension 4880**) and off campus (**408-554-4880**). A volunteer student emergency medical group, SCU Emergency Medical Services (EMS), is also available to take care of medical emergencies on campus. The health center is closed from mid-June to mid-August.

Chapter 20: Student Conduct Code

Statement Of Responsibilities And Standards Of Conduct

All members of the University community have a strong responsibility to protect and maintain an academic climate in which the fundamental freedom to learn can be enjoyed by all and where the rights and well-being of all members of the community are protected. To this end, certain basic regulations and policies have been developed to govern the conduct of all students as members of the University community. The Student Handbook is available online at http://www.scu.edu/osl/policies-and-protocols/

Academic Integrity

The University is committed to academic excellence and integrity. Santa Clara University Students affirm the following commitment to academic integrity:

- *I am committed to being a person of integrity. I pledge, as a member of the Santa Clara University community, to abide by and uphold the standards of academic integrity contained in the Student Conduct Code.*

Students are expected to do their own work and to cite any sources they use. Academic dishonesty may include but is not limited to plagiarism (i.e., representing the work or ideas of others as one's own without giving proper acknowledgment), cheating (e.g., copying the work of another person, falsifying laboratory data, sabotaging the work of others), and other acts generally understood to be dishonest by faculty or students in an academic context.

A student who is guilty of a dishonest act in an examination, paper, or other work required for a course, or who assists others in such an act, may, at the discretion of the instructor, receive a grade of "F" for the course. In addition, a student found guilty of a dishonest act may be subject to sanctions, up to and including dismissal from the University, as a result of the student judicial process as described in the Student Handbook and the Academic Integrity Protocol. A student who violates copyright laws, including those covering the copying of software programs, or who knowingly alters official academic records from this or any other institution is subject to similar disciplinary action.

Academic Integrity Protocol

Allegations within the Context of a Course

These procedures are intended to protect the integrity of the instructional program and of student academic achievement. Any member of the Santa Clara University community with a suspicion or evidence of academic dishonesty of some kind as described in the Student Conduct Code (e.g., plagiarism, falsification of data, misrepresentation of research, or the use of prohibited materials during an examination, and other acts generally understood to be dishonest by faculty or students in an academic context) may initiate an allegation of student academic dishonesty. The following describes procedures for resolution by due process.

If the allegation arises within the context of a course or academic assignment, its resolution begins with the instructor responsible for that course or assignment, who informs the student of the suspicion. If the instructor judges on the basis of available evidence that an academic violation has occurred, the instructor applies an academic sanction and notifies the student of the reason for the academic sanction. The instructor decides on the severity of the academic sanction (e.g., refusal to accept an assignment, "F" on the particular assignment, or "F" for the entire course). The instructor will report in writing to the department chair and the Office of Student Life what violation of academic integrity has occurred and what academic sanction has been applied. The Office of Student Life will pursue the matter as a violation of the Student Conduct Code through the University judicial process. This process is not intended to limit academic freedom.

Appeal Process for Academic Sanctions

If, after discussion with the instructor concerning the academic sanction applied, the student wants to challenge the instructor's decision, the student will contact the chair of the department in which the course is offered. If the instructor is the department chair, then the appeal is made to the dean of the school or college in which the course is offered or designated, and the dean or designate refers the case to the chair of a closely related department.

The department chair hearing the appeal has the option to convene an ad hoc panel if the complexity of the case warrants doing so. The student suspected of committing academic dishonesty has the right to bring a support person whose only role is to accompany the student to the hearing. The panel will include two full-time faculty members from the department in which the course was offered, one full-time faculty member from a closely related department, and two students who are trained student judicial board members. Staff in the Office of Student Life will arrange for the participation of the student panel members. The charge of the panel is to study all previously considered and newly developed evidence, review statements of all parties concerned, interview all parties concerned, and make a recommendation to the department chair.

The parties involved have the right to file an objection to the appointment of a particular faculty member or student to the ad hoc panel. This objection must be based upon a belief that the named faculty member or student is unable to conduct an impartial evaluation and therefore will not review the case in an impartial manner. The objection is filed with the chair hearing the appeal who will make a ruling on this objection. If necessary, the chair will then appoint a different faculty member or student.

After reviewing all relevant materials and information, including the recommendation of the ad hoc panel when one is convened, the department chair will consider all evidence available, confer with all parties concerned, inform all parties of the recommendation regarding the alleged violation, and report the recommendation to the student and the Office of Student Life. However, final responsibility for assigning grades remains with the instructor of the course.

Decisions may only be appealed to one level above the instructor. All proceedings are intended to be confidential.

If the student wishes to withdraw from the course, the instructor's approval is required for the withdrawal process. The instructor may refuse to approve of the withdrawal and may assign an appropriate grade.

University Judicial Records Policy

When the Office of Student Life receives the report, the assistant dean will meet with the student to discuss the relevance of the violation to the Student Conduct Code. Whether further judicial sanctions are applied or not, the report of academic dishonesty will remain on file in the Office of Student Life for the remainder of the student's enrollment at Santa Clara University. The student involved has the right to include a statement as part of these files.

If it is ruled that the student committed an academic integrity violation, the Office of Student Life will administer a judicial sanction that would range from a letter of warning to expulsion from the University. The severity of the judicial sanction depends on the severity of the circumstances, including the student's judicial history and previous academic integrity violations.

Allegations Outside a Course

If the allegation involves a situation outside the context of a course, resolution begins with the Office of Student Life. The assistant dean will confer with all parties concerned. After hearing all evidence and conducting further investigation as needed, the assistant dean will either hear the case or refer it to a judicial board in accordance with the University Judicial Process. The outcome of the hearing will be communicated to those involved.

Chapter 21: University Policies

Equal Opportunity, Nondiscrimination and Sexual Harassment Policies

Gender-Based Discrimination and Sexual Misconduct Policy

Santa Clara University is committed to providing an environment free of gender-based discrimination, including sexual harassment, sexual misconduct, sexual violence and assault, relationship (dating and domestic) violence, and stalking. The University provides resources and reporting options to students, faculty, and staff to address concerns related to gender-based discrimination and sexual misconduct prohibited by Title IX and University policy, and, through training and education, works to prevent its occurrence. The University seeks to provide a consistent, caring, and timely response when sexual and gender-based misconduct occurs within the University community. When the University becomes aware of allegations of sexual misconduct, it will take prompt and effective action. This action may include an initial assessment of safety and well-being, implementing interim remedies at no cost to the complainant for protection and support, discussing how the complainant wishes to proceed, initiating an investigation, and identifying appropriate avenues for resolution. The University's response will be overseen by the Director of Equal Opportunity and Title IX.

The University's Gender-Based Discrimination and Sexual Misconduct Policy applies to all students, faculty, and staff, and includes any individual regularly or temporarily employed, studying, living, visiting, or serving in an official capacity at Santa Clara University (including volunteers and contractors). The policy applies to both on-campus and off-campus conduct and to online actions that have a potential or actual adverse impact on any member of the University community, or which substantially interferes with a person's ability to participate in University activities, or which could affect a substantial University interest or its educational mission. For more information about reporting, response, and adjudication, please see the University's Gender-Based Discrimination and Sexual Misconduct Policy or contact the Director of Equal Opportunity and Title IX, www.scu.edu/title-ix.

NOTE: The Department of Education issued new Title IX regulations to be effective August 14, 2020. The University will update relevant policies and procedures including the Gender-Based Discrimination and Sexual Misconduct Policy to ensure compliance and will post revisions online at www.scu.edu/title-ix.

What Constitutes Consent

The University adheres to California's definition of affirmative consent for sexual activity. Affirmative consent means affirmative, conscious, and voluntary agreement to engage in sexual activity. Since individuals may experience the same interaction in different ways, it is the responsibility of each party to determine that the other has consented before engaging in the activity.

For consent to be valid, there must be a clear expression in *words* or *actions* that the other individual consented to that specific sexual conduct. Reasonable reciprocation can be implied. For example, if someone kisses you, you can kiss them back (if you want to) without the need to explicitly obtain their consent to being kissed back.

Consent can also be withdrawn once given, as long as the withdrawal is reasonably and clearly communicated. If consent is withdrawn, that sexual activity should cease. Consent to some sexual contact (such as kissing or fondling) cannot be presumed to be consent for other sexual activity (such as intercourse). A current or previous intimate relationship is not sufficient to constitute consent.

Consent is based on the totality of the circumstances evaluated from the perspective of a reasonable person in the same or similar circumstances, including the context in which the alleged incident occurred and any similar previous patterns that may be evidenced. The question of whether the responding party should have known of the reporting party's incapacity is an objective inquiry as to what a reasonable person, exercising sober judgment, would have known, in the same or similar circumstances.

Consent is not voluntary if forced or coerced. Force is the use of physical violence or physical imposition to gain sexual access. Force also includes threats, intimidation (implied threats), and coercion that is intended to overcome resistance or produce consent Coercion is *unreasonable* pressure for sexual activity. Sexual activity that is forced is, by definition, non-consensual, but non-consensual sexual activity is not necessarily forced. Silence or the absence of resistance alone is not consent. Consent is not demonstrated by the absence of resistance. While resistance is not required or necessary, it is a clear demonstration of non-consent.

A person cannot consent if they are unable to understand what is happening, asleep, or unconscious for any reason. A person violates this policy if they engage in sexual activity with someone they know to be, or should know to be, physically or mentally incapacitated. This policy also covers a person whose incapacity results from a temporary or permanent physical or mental health condition, involuntary physical restraint, or the consumption of incapacitating drugs or alcohol. Incapacitation occurs when someone cannot make rational, reasonable decisions because they lack the capacity to give knowing/informed consent (e.g. to understand the "who, what, when, where, why, or how" of their sexual interaction).

Incapacitation is determined through consideration of all relevant indicators of an individual's state and is not synonymous with (under the) influence, impairment, intoxication, inebriation, blackout, or being drunk. It is not an excuse that the responding party was intoxicated and, therefore, did not realize the incapacity of the reporting party.

Reporting Options

There are confidential and non-confidential reporting options available. Confidential Resources include on and off campus mental counselors, health service providers, local rape crisis counselors, domestic violence resources, and members of the clergy and chaplains. **Confidential on-campus resources include CAPS, Cowell Center, 408-554-4501; Wellness Center, 862 Market Street, 408-554-4409; and members of the clergy or chaplains. Confidential means that what a reporting party shares will not be communicated with anyone else unless except in extreme cases of immediacy of threat or abuse of a minor.**

Reporting to Law Enforcement

For immediate, emergency assistance or to report a crime of sexual violence, including sexual assault, domestic/dating violence (intimate partner violence), and stalking students, **contact the Santa Clara Police Department, dial 911, or contact Campus Safety Services at 408-554-4444.**

Reporting to the University

To report an incident to the University, students may:

- Report directly to the Director of Equal Opportunity and Title IX
- Report online at https://www.scu.edu/title-ix/reporting/
- Report anonymously using EthicsPoint at www.scu.edu/hr/quick-links/ethicspoint/

Other campus non-confidential reporting options: Students may report incidents and seek support from other University officials, including:

- The Office of Student Life,
- The Office of Residence Life (including Community Facilitators, Resident Directors, Assistant Resident Directors, Neighborhood Representatives, and Assistant Area Coordinators),

- Spirituality Facilitators,
- The Office of Housing,
- Athletics and Recreation,
- The Center for Student Leadership,
- The Drahmann Center,
- Office of Accessible Education (OAE),
- The Career Center, and
- Campus Ministry.

These University resources are required to report incidents to the Director of Equal Opportunity and Title IX, who will oversee the investigation and resolution process. At the time a report is made, a complainant does not have to decide whether or not to request or participate in an investigation or University resolution process.

Notice of Nondiscrimination

Santa Clara University's fundamental principles of academic excellence through diversity and inclusion is central to the University's Jesuit, Catholic values, and requires us to provide a workplace and educational environment free from discrimination. In accordance with federal and state law, Santa Clara University does not discriminate and prohibits discrimination against any individual on the basis of race, ethnicity, nationality, religion, age, gender, gender expression, gender identity, sexual orientation, marital status, registered domestic partner status, veteran or military status, physical or mental disability (including perceived disability), medical condition (including cancer related or genetic characteristics), pregnancy (including childbirth, breastfeeding, and related medical conditions), or other protected classes under the law. This policy therefore affects employment policies and actions, as well as the delivery of educational services at all levels and facilities of the University including in admissions, scholarships and loan programs, athletics, hiring, promotion, job assignment, retention, and compensation. The University will promptly investigate all complaints of protected class discrimination, sexual harassment, sexual misconduct and related retaliation in accordance with University's Policy on Discrimination, Harassment and Sexual Misconduct and applicable federal and state laws.

Title IX of the Education Amendments of 1972

Title IX of the Education Amendments of 1972 ("Title IX"), 20 U.S.C. §1681 et seq., is a Federal civil rights law that prohibits discrimination on the basis of sex in education programs and activities. Santa Clara University is committed to providing an environment free from discrimination based on sex and provides a number of resources and services to assist students, faculty, and staff in addressing issues involving sex discrimination. Under Title IX, discrimination on the basis of sex can include sexual harassment or forms of sexual violence, such as rape, sexual assault, domestic violence, dating violence, sexual exploitation, and stalking also prohibited by University Policy.

Inquiries regarding the University's equal opportunity and nondiscrimination policies may be directed to the Director for the Office of Equal Opportunity and Title IX who serves as the University's designated Title IX Coordinator and ADA/504 Coordinator, and Affirmative Action Officer.

Belinda Guthrie, Director of Equal Opportunity and Title IX
Santa Clara University
Office of Equal Opportunity and Title IX
500 El Camino Real
Santa Clara, CA 95053

Office Location: Loyola Hall, Suite 140, 425 El Camino Real, Santa Clara, CA 95053
Main Office: 408-551-3043 | Direct Line: 408-554-4113
Email: bguthrie@scu.edu
Web: www.scu.edu/title-ix****

Sex discrimination claims or other inquiries concerning the application of Title IX of the Education Amendments of 1972 and its implementing regulations may also be directed to the Director of Equal Opportunity and Title IX, the Assistant Secretary, Office for Civil Rights or both, and to the Equal Employment Opportunity Commission (EEOC), and/or the California Department of Fair Employment and Housing (DFEH).

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

Santa Clara University, in compliance with state and federal laws and regulations including Section 504 of the Rehabilitation Act of 1973, the Americans with Disabilities Act (ADA), and the Americans with Disabilities Act Amendments Act (ADAAA) does not discriminate on the basis of disability in administration of its education-related programs and activities. The University is committed to providing individuals with disabilities including those with learning disabilities, ADHD, chronic health conditions, traumatic brain injuries, hearing impairments, physical disabilities, psychological disorders, visual impairments, and other health impairments equal access to academic courses, programs, activities, services and employment opportunities, and strives in its policies and practices to provide for the full participation of individuals with disabilities in all aspects of University life.

For information concerning policies and procedures for students with disabilities, see the Office of Accessible Education (OAE) website, https://www.scu.edu/oae/. Students with disabilities who are registered with the OAE office may be qualified to receive accommodations, auxiliary aids or services based on supporting documentation. To register with OAE, contact the Director at 408-554-4109 or by email at oae@scu.edu. Faculty and staff should contact Human Resources for information on how to request employee disability-related accommodations, auxiliary aids or services, https://www.scu.edu/hr/.

Students, faculty, and staff who believe they have been subjected to unlawful discrimination on the basis of disability, or have been denied access to services or accommodations required by law, should contact the Director of Equal Opportunity and Title IX, https://www.scu.edu/title-ix/.

Drug-free Policies

It is the goal of Santa Clara University to maintain a drug-free workplace and campus. The unlawful manufacture, distribution, dispensation, possession, and/or use of controlled substances or the unlawful possession, use, or distribution of alcohol is prohibited on the Santa Clara University campus, in the workplace, or as part of any of the University’s activities. This includes the unlawful use of controlled substances or alcohol in the workplace even if it does not result in impaired job performance or in unacceptable conduct.

The unlawful presence of any controlled substance or alcohol in the workplace and campus itself is prohibited. The workplace and campus are presumed to include all Santa Clara premises where the activities of the University are conducted.

Violations will result in disciplinary action up to and including termination of employment for faculty and staff or expulsion of students. A disciplinary action may also include the completion of an appropriate rehabilitation program. Violations may also be referred to the appropriate authorities for prosecution.

The program information is distributed on an annual basis to all faculty, staff, and students. New staff employees are given a copy at New Employee Orientation. New faculty employees are given a copy at New Faculty Orientation. The program is reviewed at least biennially by the Office of Student Life, Affirmative Action Office, and the Department of Human Resources.

Policy For Withdrawal For Health Reasons

Withdrawal for Health Reasons

Students may experience an illness, injury, or psychological condition that significantly impairs their ability to function successfully or safely in their role as students. In these instances, the Policy for Withdrawal for Health Reasons allows time away from the University for treatment and recovery until functioning is restored to a level that will enable the student to return to the University. The purpose of this policy is to set forth the procedures for student withdrawals from the University for reasons of health and/or safety. The University has designated four categories relating to withdrawal. They differ according to who initiates the action, whether it is voluntary or not, and the re-enrollment procedures.

The Vice Provost for Student Life or designee, in consultation with the appropriate mental and medical health professionals and other staff as deemed necessary, is responsible for the implementation of this policy as stated in the Student Handbook.

Academic Accreditations

University Accreditation

Western Association of Schools and Colleges (WASC)
Senior College and University Commission
985 Atlantic Avenue, Suite 100
Alameda, CA 94501
510-748-9001

Specialized Academic Accreditations

American Association of Museums

ABET Inc.

American Bar Association

American Chemical Society

Association of American Law Schools

Association of Theological Schools

Association to Advance Collegiate Schools of Business–Accounting

Association to Advance Collegiate Schools of Business

California Board of Behavioral Sciences Accredited Marriage and Family Therapists

California State Commission on Teacher Credentialing

State Bar of California

Engineering Advisory Board

Renee Niemi, Chair

Sam Bertram
CEO and Co-Founder
OnePointOne and Willo

Ivo Bolsens
Vice President, Chief Technology Officer
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Chuck Cantoni
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Elaine Scott
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