School of Engineering

Graduation requirements and regulations for every academic program are provided in this catalog; however, this catalog is for informational purposes only and does not constitute a contract. Degree and program requirements and course descriptions are subject to change.

In most cases, you will use the catalog of the year you entered KU (see your advisor (http://www.advising.ku.edu/) for details). Other years' catalogs *(*https://catalog.ku.edu/archives/*)*»

Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/)	Bachelor of Science in Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/bs/) Master of Engineering in Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/me/) Master of Science in Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/ms/) Doctor of Engineering in Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/de/) Doctor of Philosophy in Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/phd/) Graduate Certificate in Computational Fluid Dynamics (https://catalog.ku.edu/engineering/aerospace-engineering/certificate-computational-fluid-dynamics/)
Chemical and Petroleum Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/)	Bachelor of Science in Chemical Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/bs-chemical/) Bachelor of Science in Petroleum Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/bs-petroleum/) Master of Science in Chemical Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/ms/) Master of Science in Petroleum Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/petroleum-ms/) Doctor of Philosophy in Chemical and Petroleum Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/phd/) Graduate Certificate in Applied Machine Learning for Chemists and Engineers (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/applied-machine-learning-gradcert/) Graduate Certificate in Petroleum Management (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/gradcert/)

Civil, Environmental, and Architectural Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/)

Bachelor of Science in Architectural Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/bs-architectural-engineering/)
Bachelor of Science in Civil Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/bs-civil-engineering/)
Master of Science in Architectural Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms-architectural-engineering/)
Master of Science in Civil Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms/)
Master of Science in Environmental and Water Resources Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms-environmental-water-resource-engineering/)
Master of Civil Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/master-civil-engineering/)
Master of Construction Management (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/master-construction-management/)
Doctor of Philosophy in Civil Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/phd/)
Doctor of Philosophy in Environmental and Water Resources Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/phd-environmental-water-resources-engineering/)
Graduate Certificate in Construction Management (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-construction-management/)
Graduate Certificate in Structural Analysis (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-structural-analysis/)
Graduate Certificate in Structural Design (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-structural-design/)
Graduate Certificate in Structural Forensics (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-structural-forensics/)
Graduate Certificate in Water Resources (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-water-resources/)

Electrical Engineering and Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/)	Bachelor of Science in Applied Computing (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-applied-computing/) Bachelor of Science in Electrical Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-electrical-engineering/) Bachelor of Science in Computer Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-computer-engineering/) Bachelor of Science in Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-computer-science/) Bachelor of Science in Cybersecurity Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-cybersecurity-engineering/) Undergraduate Certificate in Artificial Intelligence (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ugcertificate-artificial-intelligence/) Undergraduate Certificate in Cybersecurity (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ugcertificate-cybersecurity/) Master of Engineering in Electrical Engineering and Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/me-electrical-engineering-computer-science/) Master of Science in Electrical Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-electrical-engineering/) Master of Science in Computer Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-computer-engineering/) Master of Science in Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-computer-science/) Doctor of Philosophy in Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/phd-computer-science/) Doctor of Philosophy in Electrical Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/phd-electrical-engineering/) Graduate Certificate in Data Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-data-science/)
Interdisciplinary Engineering Programs (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/)	Bachelor of Science in Engineering Physics (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/bs-engineering-physics/) Minor in Biomedical Engineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/minor-biomedical-engineering/) Master of Engineering in Bioengineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/me-bioengineering/) Master of Science in Bioengineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/ms-bioengineering/) Doctor of Philosophy in Bioengineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/phd-bioengineering/) Graduate Certificate in Biomedical Product Design (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/gcrt-biomedical-product-design/)
Mechanical Engineering (https://catalog.ku.edu/engineering/mechanical-engineering/)	Bachelor of Science in Mechanical Engineering (https://catalog.ku.edu/engineering/mechanical-engineering/bs/) Master of Science in Mechanical Engineering (https://catalog.ku.edu/engineering/mechanical-engineering/ms/) Doctor of Philosophy in Mechanical Engineering (https://catalog.ku.edu/engineering/mechanical-engineering/phd/)

Introduction

From communication systems to bridges, from satellites to manufacturing - society depend on engineers. A KU engineering education helps students understand technical principles and the background behind them and prepares them for the changes ahead. Most graduates assume responsible positions in business, industry, education, or government, and our engineering programs also provide an excellent background for other careers. Many graduates are CEOs of major companies or enter fields like medicine or law.

Mission

The mission of the school is to provide students a high-quality educational experience, to generate and apply knowledge through research, development, and scholarly activity, and to serve society, the state of Kansas, and the engineering profession. In accordance with this mission and with KU's mission, all undergraduate engineering programs and the computer science program must meet these objectives. Additional objectives are specified in program descriptions.

Undergraduate Programs

The school offers 12 undergraduate degree programs:

- Aerospace engineering (https://catalog.ku.edu/engineering/aerospace-engineering/)
- Applied computing (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-applied-computing/)
- Architectural engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/)
- Chemical engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/)
- Civil engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/)
- Computer engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/)
- Computer science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/)
- Cybersecurity engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-cybersecurity-engineering/)
- Electrical engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/)
- Engineering physics (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/bs-engineering-physics/)
- Mechanical engineering (https://catalog.ku.edu/engineering/mechanical-engineering/)
- Petroleum engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/)

High School Preparation

Preparation for an engineering career begins in high school with basic mathematics and science courses. Prospective engineering students should take mathematics through at least trigonometry (Calculus is preferred) and at least one year of both chemistry and physics. A strong college preparatory program provides a good background for the student who plans to major in engineering. A well-rounded background in English, history, economics, and social studies, preferably with some computer operations and programming and advanced mathematics, affords flexibility in choosing a major.

University Honors Program

The school encourages all qualified students to participate in the University Honors Program (http://www.honors.ku.edu/). Honors Program students meet with a dedicated honors program academic advisor every semester.

Curriculum Overview

Undergraduates usually enroll in engineering in their first year. The first few semesters of all the curricula contain a large proportion of common courses. Through proper planning with advisors, students may delay choosing specific fields for one or two semesters. Selecting the major by the beginning of the third semester is strongly encouraged so that the recommended schedule of classes can be followed.

Each engineering degree program includes courses in 5 general areas of study:

1. KU Core 34 (SGE),
2. Basic sciences,
3. Basic engineering sciences,
4. Specialized engineering sciences, and
5. Engineering design.

The computer science degree program has a similar structure, but computer science courses replace some engineering courses. Courses taken during the first 2 years are largely from the first 2 areas, with a few courses in the basic engineering sciences or computer science. The basic sciences include mathematics, chemistry, and physics and further course work in the earth and life sciences in some of the curricula. Appropriate laboratory experience that combines elements of theory and practice is included in each student's program, together with extensive computer-based experience. Completion of KU Core 34 is required in all majors. Each department recommends or requires certain courses be used to fulfill Core 34 within each major to allow students the greatest flexibility in degree completion.

Requirements for Graduation

In addition to completing each of the required and elective courses listed in the curriculum,

1. A student must attain a cumulative grade-point average of at least 2.0 in the courses applied toward the degree. A student must also have a KU cumulative grade-point average of 2.0 whether or not all courses are being applied to the degree.
2. A student must attain a cumulative grade-point average of at least 2.0 in all courses taken in the school, including courses not applied toward a degree.
3. A student entering with advanced standing must attain a cumulative grade-point average of at least 2.0 in the resident courses applied toward the degree and at least a 2.0 in all courses taken in the school.
4. A student must take the last 30 hours of credit toward the degree at KU and be officially enrolled in the School of Engineering during this time.

Dual Enrollment

KU permits dual enrollment in 2 academic divisions. The student must plan carefully with special advisors in each area. Students should expect the minimum time required for 2 degrees to be at least 1 year longer than the minimum for 1 degree. The academically well-qualified student who is seriously considering dual enrollment might consider studying for the second degree at the graduate level. If the program is properly planned, it may be possible to earn 1 B.S. and 1 M.S. degree in about the same time required for 2 undergraduate degrees.

Credit for ROTC Courses

A few credit hours from courses in aerospace studies, military science, or naval science may be applied toward graduation in lieu of certain required or elective courses. A student normally must complete the ROTC curriculum, whether or not it leads to a commission, to receive ROTC hours toward a bachelor's degree in engineering. The student should submit a petition for substitution of courses to the department. The ROTC policy for each engineering degree program is listed with the information on each program.

Minors and Undergraduate Certificates

The School of Engineering has a minor in Biomedical Engineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/minor-biomedical-engineering/), which requires five courses and a minimum of 18 credit hours. This minor is open to all engineering undergraduates. The Electrical Engineering and Computer Science department has an undergraduate certificate in Cybersecurity (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ugcertificate-cybersecurity/), open to current EECS undergraduate students who do not have Cybersecurity Engineering as a declared major.

Additionally, engineering students may minor in many liberal arts (https://catalog.ku.edu/liberal-arts-sciences/) areas or in the schools of Business (https://business.ku.edu/), Journalism and Mass Communications (http://www.journalism.ku.edu/), or Music (http://www.music.ku.edu). To earn a minor, a student must fulfill all requirements specified in the minor's catalog page. Interested students should see an advisor in the department offering the minor and complete a minor declaration form as early as possible.

Preparation for Graduate Study

Undergraduates in the School of Engineering receive excellent preparation for pursuing graduate degrees. The school offers M.S. degrees as well as professional degrees. Students may apply for admission to graduate studies during the senior year and may be co-enrolled during the final undergraduate semester. Admission to graduate studies requires a minimum 3.0 grade-point average and completion of an ABET-accredited undergraduate degree.

Graduate Programs

Master's Programs

The **Master of Science (M.S.)** degree is offered in 11 areas:

- Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/ms/)
- Architectural Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms-architectural-engineering/)
- Bioengineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/ms-bioengineering/)
- Chemical Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/ms/)
- Civil Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms/)
- Computer Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-computer-engineering/)
- Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-computer-science/)
- Electrical Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-electrical-engineering/)
- Environmental & Water Resources Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms-environmental-water-resource-engineering/)
- Mechanical Engineering (https://catalog.ku.edu/engineering/mechanical-engineering/)
- Petroleum Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/petroleum-ms/)

The **Master of Engineering (M.E.)** is offered in 3 areas:

- A (https://catalog.ku.edu/engineering/aerospace-engineering/me/)erospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/)
- Bioengineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/me-bioengineering/)
- Electrical Engineering and Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/me-electrical-engineering-computer-science/)

The **Master of Civil Engineering (M.C.E.) (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/master-civil-engineering/)** and the **Master of Construction Management (M.C.M.) (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/master-construction-management/)** are offered by the Department of Civil, Environmental, and Architectural Engineering.

Doctoral Programs

The **Doctor of Philosophy (Ph.D.)** degree is offered in 8 areas:

- Aerospace Engineering (https://catalog.ku.edu/engineering/aerospace-engineering/phd/)
- Bioengineering (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/phd-bioengineering/)
- Chemical and Petroleum Engineering (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/phd/)
- Civil Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/phd/)
- Computer Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/phd-computer-science/)
- Electrical Engineering (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/phd-electrical-engineering/)
- Environmental & Water Resources Engineering (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/phd-environmental-water-resources-engineering/)
- Mechanical Engineering (https://catalog.ku.edu/engineering/mechanical-engineering/phd/)

Doctoral students interested in careers in research or teaching or both should consider the Ph.D. degree. Exceptionally qualified undergraduates may be admitted directly to a Fast-Track Ph.D. program.

The **Doctor of Engineering (D.E.)** in Aerospace Engineering is for aerospace students interested in careers in engineering design or engineering project management.

Graduate Certificate Programs

The School of Engineering is offers graduate certificate programs in the following areas:

- Applied Machine Learning (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/applied-machine-learning-gradcert/)
- Biomedical Product Design (https://catalog.ku.edu/engineering/interdisciplinary-engineering-programs/gcrt-biomedical-product-design/)
- Computational Fluid Dynamics (https://catalog.ku.edu/engineering/aerospace-engineering/certificate-computational-fluid-dynamics/)
- Construction Management (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-construction-management/)
- Data Science (https://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-data-science/)
- Petroleum Management (https://catalog.ku.edu/engineering/chemical-petroleum-engineering/gradcert/)
- Structural Analysis (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-structural-analysis/)
- Structural Design (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-structural-design/)
- Structural Forensics (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-structural-forensics/#text)
- Water Resources (https://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/certificate-water-resources/)

For information on graduate studies in petroleum management, contact the Department of Chemical and Petroleum Engineering (http://www.cpe.engr.ku.edu/) or the School of Business (https://business.ku.edu/).

Graduate Grade-Point Average (GPA) Requirement

In addition to completing a Plan of Study (https://engrgradplan.ku.edu/) that is formally approved by the advisory committee and other requirements appropriate to the graduate degree, a student must:

1. Attain and maintain at least a 3.0 grade-point average in all graduate courses and
2. Attain and maintain at least a 3.0 grade-point average in all course work, including undergraduate courses taken to make up background deficiencies, except for courses taken at the Applied English Center.

Please note, once you begin enrolling in your graduate career **all courses 500 level and above will count towards your graduate GPA**, even if you are not counting those courses towards your degree or are taking them as pre-requisite courses. Students who obtain a GPA below 3.0 will be placed on academic probation or dismissed from the School of Engineering.

Plan of Study

All graduate students must have an approved Plan of Study on file by the end of their second semester of graduate study. Click here (https://engrgradplan.ku.edu/) to create or update a plan. All students must have an up to date and approved Plan of Study on record in order to graduate.

Undergraduate Advising

Engineering students are advised by engineering academic advisors in the Jayhawk Academic Advising (http://www.advising.ku.edu) pathways model. Engineering advisors are located in the engineering complex. Each incoming student attends KU Orientation (https://orientation.ku.edu/) during the summer. At orientation, students are advised on course enrollment for the upcoming fall semester based on any credit for prior learning on their KU student account. Students who do not attend summer orientation meet with their academic advisor and enroll during open enrollment.

Engineering Advising Holds (EAH) are placed on all engineering students' accounts each semester before enrollment. Students must see their academic advisor to plan their next semester schedule. Once a student has met with an academic advisor, the advising hold is released. **Consultation with an academic advisor is recommended before making schedule changes.**

Undecided engineering and pre-engineering students are assigned engineering academic advisors and should visit Jayhawk GPS (http://www.jayhawkgps.ku.edu) to schedule an appointment. For general advising inquiries, contact KU Engineering Info (kuengr@ku.edu) or Jayhawk Academic Advising (advising@ku.edu).

Graduate Advising

Graduate advising generally is done at the department and program level. Graduate students should contact the Director of Graduate Studies or Graduate Coordinator in their department or program if they have not yet chosen an advisor or have general questions. Students starting their graduate program should attend the New Graduate Student Orientation (http://engr.ku.edu/graduate-student-orientation/) (scheduled the week prior to the start of the fall and spring semester classes). More information is available here (https://graduate.ku.edu/information-new-students/).

Plan of Study

Graduate students should discuss their enrollment plans with their faculty advisor or Graduate Director to plan schedules and discuss academic and career interests. Once a student has met with an advisor, they should complete their Plan of Study online and submit the plan to their advisory committee for approval. Consultation with an advisor is recommended before making a Plan of Study.   All graduate students, including those enrolled in courses at KU Medical Center and the Edwards campus, must have an approved Plan of Study on file by the beginning of their second semester in the graduate program. Enrollment holds are placed on students' accounts after their first year of graduate study if they do not have an up to date and approved Plan of Study on file. Click here (https://engrgradplan.ku.edu/) to create or update a plan. All students must have an approved Plan of Study on record in order to graduate.

Undergraduate Scholarships and Financial Aid

The school has a scholarship program for entering freshmen students. Engineering scholarships are awarded competitively according to academic merit and without regard to financial need. Awards range from $1,000 to $4,000 per year, and scholarships are renewable for a total of four years of undergraduate study. All first-time freshmen who are admitted to the School of Engineering are considered for scholarships if they apply to the School of Engineering by the university's scholarship deadline (typically November 1).

Students with financial need should fill out the FAFSA (Free Application for Federal Student Aid) by March 1.

Graduate Funding and Assistantships

A variety of scholarships, fellowships, and assistantships are available to graduate students through the School of Engineering, KU, and outside sources. Many opportunities require that students be admitted to a graduate program before students are eligable to apply. Be sure to apply early, in order to meet eligability requirements for funding (both internal and external) by posted deadlines. Graduate students are nominated by their departmet or program for School of Engineering funding each fall and spring.

The KU Office of Financial Aid & Scholarships offers a helpful calculator to estimate costs and search for scholarships. Financial Aid & Scholarships (https://financialaid.ku.edu/apply-for-aid/) also administers grants, loans, and need-based financial aid. Students should contact the Graduate Director within their department or program or their advisor to inquire about research or teaching assistantships. Students must be admitted regularly or enrolling on regular status to be eligable for assistantships. Students admitted provisionally or placed on academic probation are ineligable for research or teaching assistantships. More information on graduate student funding is available here (https://graduate.ku.edu/funding/).

Undergraduate University Regulations

For information about university regulations, see Regulations (https://catalog.ku.edu/regulations/) or visit the University of Kansas Policy Library (http://www.policy.ku.edu/).

Absences

A student with excessive absences may be withdrawn from the course by the dean.

Academic Standing

Good Academic Standing

Undergraduates must maintain both university and engineering semester and cumulative grade-point averages of 2.0 or higher, and make progress towards an engineering degree, to remain in good standing. Students' academic standings are reviewed after each fall and spring semester.

Placed on Notice

A first-year, first semester student whose university overall or engineering grade-point average is between 1.75 and 1.99 will be placed on academic notice. Academic notice serves as the warning system to recognize and make improvements to academic performance. Students placed on academic notice are monitored by the school, engineering department, and student's academic advisor.

A first-year freshman student placed on academic notice after their first semester at KU will either return to good standing after the subsequent semester dependent on university and engineering semester and cumulative GPAs above 2.0.

If a student placed on academic notice does not return to good standing after the subsequent semester, the student will then be placed on probation.

Probation

If a student's university or engineering semester or cumulative grade-point average falls below 2.0, the student is placed on probation. The student will return to good standing if:

1. The following semester's cumulative and engineering grade-point average is 2.0 or higher,
2. The cumulative grade-point average is 2.0 or higher, and
3. All other requirements described in the probation letter are met.

Students also may be placed on probation for failing to make progress toward an engineering degree or failing to be continuously enrolled in Applied English Center (https://aec.ku.edu/) or English courses until all AEC and the KU Core Written Communications requirements are met.

Dismissal

A student on probation may be dismissed if any of the following occur:

1. Failure to make progress toward their engineering degree while earning a GPA lower than 2.0 in the next semester.
2. Failure to have a university overall and engineering overall GPA of 2.0 or greater for two consecutive semesters

A student within one semester of completing degree requirements who is recommended for dismissal is subject to review by the engineering department and school to instead continue on probation.

Readmission

A student does not automatically become eligible to re-enroll after a certain period of time. A student who is readmitted on probation must meet stringent academic requirements to be returned to good standing. Students are encouraged to meet with their engineering department or department of interest to discuss a potential path forward into the School of Engineering. A student who has been dismissed from the School of Engineering for poor scholarship may apply for readmission by submitting a Change of School form. A student who has been dismissed from the University of Kansas may apply for admission or readmission to the School of Engineering by contacting the Office of Admissions and Scholarships (http://www.ku.edu/admission/).

Change of School, Major, Minor, or Certificate

To change from one school to another as well as update a student's major in their current school, KU students must submit a Program & Plan Change form online (https://registrar.ku.edu/program-and-plan-changes/).

Current students at KU must have an overall college grade-point average of 2.5 or better, with grades of C or better in Calculus I (MATH 125 or its direct equivalent) and any courses in mathematics, science, and engineering taken. Applications are accepted on an ongoing basis.

Credit/No Credit

A Credit/No Credit option is available to degree-seeking undergraduates depending on their academic program. Where permitted, students may enroll in one course per semester under the option; specifically required courses (such as calculus or physics) may not be taken credit/no credit. For more information, visit the KU Policy Library. (http://policy.ku.edu/) Always check with your academic advisor before electing credit/no credit, as policies vary from department to department. **If an engineering department requires that certain course work be used to fulfill any of these degree requirements, those courses shall not be eligible for credit/no credit.**

Aerospace engineering, architectural engineering, chemical engineering, and civil engineering **do not** accept Credit/No Credit. This is not an option for any credits counting towards the degree.

In EECS majors, any mathematics, science, engineering, or Core 34: English course that is required for an EECS degree cannot be taken for Credit/No Credit. For EECS majors, courses used to fulfill the KU Core 34 in Communications, Social & Behavioral Sciences, Arts & Humanities, U.S. Culture, and Global Culture accept Credit/No Credit.

In engineering physics, mechanical engineering, and petroleum engineering, any mathematics, science, or engineering course that is required for the engineering degree cannot be taken for Credit/No Credit. For engineering physics, mechanical engineering, and petroleum engineering majors, courses used to fulfill the KU Core 34 in English, Communications, Social & Behavioral Sciences, Arts & Humanities, U.S. Culture, and Global Culture accept Credit/No Credit.

Warning: Certain undesirable consequences may result from exercising the option. Some schools, scholarship committees, and honorary societies do not accept this grading system and convert grades of No Credit to F when computing grade-point averages.

Dean's Honor Roll

Students with grade-point averages of 3.75 who have completed at least 12 graded, A-F credit hours are recognized on the honor roll or dean’s list in fall and spring. An Honor Roll notation appears on the transcript.

Enrollment Holds

An Engineering Advising Hold (EAH) is placed on all engineering undergraduate students' accounts prior to enrollment each term. Students **must meet** with their academic advisor to have the hold released.

A No Drop Hold (DRP) is placed on all engineering students' accounts early in the term preventing students from dropping classes without the permission of their academic advisor and the Engineering Dean's Office. The No Drop Hold prevents students from withdrawing from essential classes without speaking with an academic advisor about the possible negative ramifications of a withdrawal.

Students voluntarily leaving the engineering may have their Engineering Advising Hold or No Drop Hold released by submitting an official Change of School form to declare their updated major.

Graduation with a Bachelor's Degree

Grade Point Average

In addition to completing each of the required and elective courses listed in an undergraduate program curriculum,

1. A student must earn a KU overall or Engineering overall GPA of at least 2.00 in the courses applied to the degree.
2. A student must earn at least a 2.00 in all courses taken in the School of Engineering, including those courses not applied toward a degree.
3. A student entering with advanced standing must attain a University overall or Engineering cumulative grade-point average of at least 2.00 in courses taken at the University of Kansas and applied toward the degree.
4. In addition to the grade-point policies previously adopted, a student receiving a bachelor’s degree from the school must have an all-university (KU) GPA of 2.00.
5. A student must be officially enrolled in the School of Engineering while completing the last 30 hours of credit to be applied toward the degree. This regulation may be waived under the conditions found in Article IV, Section 5 of the University Faculty Rules and Regulations.

Graduation with Departmental Honors

For students who complete their department’s honors program, designation of honors appears on the transcript.

Graduation with Distinction and Highest Distinction

Students who fulfill the following requirements are eligible for graduation with distinction.

1. Students must rank in the upper 10 percent of the graduating class by KU grade-point average.
2. Students must have taken at least 64 hours in residence at KU.
3. Students with transfer credit must also have overall grade-point averages, including transfer credit, that fall into the upper 10 percent of the class.

The upper third of those awarded distinction graduate with highest distinction. The list is compiled each spring and includes July, December, and May graduates.

Enrollment

The normal course load is 15-17 hours a semester. A student may not enroll in more than 19 credit hours during any semester or more than 10 credit hours during the summer session except with approval of the School of Engineering.

Prerequisites and Corequisites

Students may be administratively dropped from courses for which they do not meet prerequisite or corequisite requirements.

Required Work in Residence

Students must be enrolled in the school for the last 30 hours of credit.

Transfer of Credit & Credit for Prior Learning

CredTran (https://credittransfer.ku.edu/) is a transfer course equivalency system that lists more than 2,200 colleges and universities from which KU has accepted transfer courses in the past. If your school or course is not listed, your evaluation will be completed when you are admitted to KU.

Credit for Prior Learning (https://registrar.ku.edu/credit-prior-learning/) is detailed by the Office of the University Registrar which includes, but is not limited to AP credit, ACT scores, CI, CLEP credit, IB credit, SAT scores, and Military Service credit.

The School of Engineering does not routinely accept credits from foreign institutions or from vocational-technical programs in the United States. Before such courses may be added to a student's official KU record as transfer credits, they must be validated:

1. By examination by the department or school offering the course on the KU campus,
2. By earning a grade of C or higher in a later course in the sequence of courses, or
3. By earning a grade of C or higher in a course.

Credits for English composition at a foreign institution of higher education are not accepted for the required English courses in any engineering curriculum.

Credits from courses completed at the secondary level (high school), whether from U.S. or from foreign schools, are not added to a student's official record unless the student obtains college credits through one of three examination programs:

1. The College Entrance Examination Board's Advanced Placement test,
2. KU's own credit by examination program, or
3. The College Level Examination Program.

A course from another college or university may apply toward the Bachelor of Science in Engineering degree as transfer or nonresident credit only if the grade received is at least C-. This policy is detailed in the Transfer Coursework, Minimum Grade and GPA Calculation policy (https://policy.ku.edu/admissions/transfer-coursework/).

Transfer credit in engineering science and engineering design from institutions accredited by the Accreditation Board for Engineering and Technology (http://www.abet.org/) and from institutions with which KU has approved articulation agreements may be applied toward the degree as appropriate in the particular engineering curriculum. Transfer credit in engineering from other institutions must be evaluated and validated on a case-by-case basis.

Graduate University Regulations

For information about university regulations, see the Graduate (https://catalog.ku.edu/regulations/) Regulations (https://catalog.ku.edu/regulations/) or visit the University of Kansas Policy Library (http://www.policy.ku.edu/).

Graduate Enrollment

The Graduate Studies policy for graduate enrollment is that **all graduate students must be continuously enrolled in the fall and spring semesters**. Note that this does not include the summer semester, unless you are a Ph.D. candidate (post-comprehensive enrollment) or have a GTA/GRA appointment. This includes part-time programs, but does not include non-degree seeking students. Review the general information in the Graduate Studies (https://catalog.ku.edu/graduate-studies/) section of the online catalog for more information.

If you do not plan to enroll for a given semester, you will need to do one of the following:

Request a Leave of Absence – Use this option when you plan to return to your graduate study after one or more semesters. A leave of absence may be granted upon request to the graduate program in advance of leave. Leaves may be granted in cases of illness, emergency, to pursue family responsibilities, or to pursue full-time activities related to long-range professional goals. The time taken for a leave of absence does not count against the time limit for earning the degree. However, if the total time for the leave extends more than three semesters, you may lose your place in the program and have to re-apply for admission. To request a leave of absence, you must contact your department graduate coordinatort, who will submit a Progress-to-Degree (PtD) form. You need to provide the graduate coordinator with the following information: non-ku email address, mailing address, first term of leave and the semester you plan to return, as well as a statement on the reason for the leave of absence.

Request to Voluntarily Discontinue – Use this option if you do not plan to return to your graduate program in the School of Engineering. This means that you voluntarily resign from a program by requesting a discontinuance. If you choose to return at a later date, you must **re-apply** for admission. Discontinuance is requested through your department or program via email to the department graduate director or assistant.

Please note, students who do not request a leave of absence are discontinued in the system and will be required to apply for re-admission (application fee required). To prevent having to re-apply and pay additional fees, students are strongly encouraged to request a leave of absence and contact their departmental staff when they are ready to return.

Academic Status

Good Academic Standing

Graduate students must be admitted regularly and maintain cumulative grade-point averages (GPA) of 3.0 or higher to be considered in good standing. Students admitted provisionally must complete departmental / program requirements before they are considered in good standing. Students on academic probation can regain their good standing once they have a cumulative GPA of 3.0 or higher. Students' academic standings are reviewed after each semester. All courses 500-level and above will count towards the graduate GPA, if enrolled in a graduate program.

Provisional Admittance / Academic Probation

Students who are admitted provisionally are given a set of requirements that must be completed, generally within the first year, before they will be moved to regular status. Students placed on academic probation due to their graduate GPA must obtain a cumulative GPA of 3.0 or higher within a given time frame, generally one semester, before they are moved to regular status. If you receive a cumulative grade point average below a 3.0 during your graduate career, you are considered ineligible for teaching and research assistantship positions or will need to petition the school and Graduate Studies office for approval.

Dismissal

Graduate students who are unable to meet their provisional or probationary requirements within the given time frame may be dismissed from the School of Engineering. When the particular circumstances are deemed to justify continuation, and upon the recommendation of the department or program, such a student may be continued on probation by the Graduate Division for one additional semester equivalent of full-time study. If a student decides to pursue another graduate degree within the School of Engineering, they are required to re-apply.

Change of Degree

A student who wants to change from one engineering degree program to another within the same department should see their department graduate coordinator to complete a progress-to-degree (PtD) form. Students who wish to change to a program outside of their home department must submit an application for admission. If a student changes or is accepted into another program and wishes to pursue only the new degree, the student should notify the department graduate coordinator, so that the old plan may be removed from the student's record. Students are allowed to pursue multiple degrees, but should discuss these plans with both program advisors.

Credit/No Credit

Graduate students may select the Credit/No Credit option for certain courses. Students should follow the policy outlined in the University Senate Rules and Regulations (http://policy.ku.edu/governance/USRR/), Section 2, article 2.27.

Honors

Graduate student can obtain honors only at the time of the final defense or final exam (and comprehensive exam for Ph.D. students). Students enrolling in coursework only degree programs do not have the opportunity to receive honors at the graduate level. Students who complete a project, thesis or dissertation will have the opportunity to receive honors at the time of the final exam or defense. Students should discuss the requirements for graduation with their program advisor if seeking honors. Only 10-15% of graduate students receive this high distinction.

Entry and Employment in the Profession

Initial Licensing

Formal study in an accredited engineering program is the principal means of becoming licensed to practice engineering in Kansas and other states. During the junior or senior year, a student may take the national Fundamentals of Engineering examination. After 4 or more years (licensing regulations vary among states) of practice satisfactory to the board, the student may take the examination to become a registered professional engineer.

Job Search Assistance

The Engineering Career Center (http://ecc.ku.edu/) offers a comprehensive array of services to students seeking permanent employment and career-related summer or co-op employment. These include on-campus interviewing; 2 career fairs each year; individual advising and group workshops on résumés; interviewing, and job search strategies; online interviewing sign-up; online job postings from many employers not interviewing on campus; a library of employer and career literature; and an online résumé book searchable by employers.

The Engineering Career Center offers services to all engineering students. Students are encouraged to visit the Engineering Career Center early in their undergraduate or graduate studies. Many employers actively seek KU engineering and computer science students. Some prefer to hire students as early as the first-year level for internships. The Career Center is in 1410 LEEP2; additional information is available from 785-864-3891.

Aerospace Engineering Courses

AE 201. Statics. 2 Credits.
The principles of statics, with particular attention to engineering applications. (Same as CE 201.) Prerequisite: MATH 125 or MATH 145 or MATH 116. Corequisite: EPHX 210 or PHSX 211 or PHSX 213.

AE 211. Computing for Engineers. 3 Credits.
Introduction to computing concepts. Introduction to the MATLAB computing language using a suite of simulations in science and engineering in a progression which adds new MATLAB constructs - as well as logical and mathematical constructs - with each simulation. Simulations include numerical integration, coordinate transformations and primitive reinforcement learning constructs. Prerequisite: MATH 125 or MATH 145 with a grade of C- or higher.

AE 245. Introduction to Aerospace Engineering. 3 Credits.
Basic systems of an aerospace vehicle, meteorology, vehicle performance, navigation and safety. Specific examples emphasize general aviation. Open to students with less than 60 hours completed. Other students need permission of instructor. Prerequisite: Corequisite: MATH 125 or MATH 145.

AE 250. Dynamics. 3 Credits.
The principles of kinematics and kinetics, with particular attention to engineering applications. (Same as CE 250.) Prerequisite: CE 201 or AE 201 or ME 201 or ME 211, and MATH 126 or MATH 146, and EPHX 210 or PHSX 211 or PHSX 213.

AE 260. Statics and Dynamics. 5 Credits.
A combination of statics and dynamics covered in CE 201 and CE 250. This course must be taken as a five-hour unit. (Same as CE 260.) Prerequisite: EPHX 210 or PHSX 211 or PHSX 213, and MATH 126 or MATH 146.

AE 290. Aerospace Colloquium. 0.25 Credits.
This is a required course for all aerospace engineering majors. Topics of importance such as social responsibility, ethics, communication, and new technical developments are discussed by aerospace industry representatives and representatives of F.A.A., D.O.T., D.O.D., N.A.S.A., related sciences, and engineering disciplines. A forum for student activities at all levels. Open enrollment.

AE 310. Strength of Materials. 3 Credits.
Principles of stress and deformation in solid objects. (Same as CE 310.) Prerequisite: CE 201 or AE 201 or CE 260 or AE 260 or ME 201 or ME 211, and EPHX 210 or PHSX 211 or PHSX 213. Corequisite: MATH 220 or MATH 221 or MATH 320; or consent of instructor.

AE 312. Strength of Materials, Honors. 3 Credits.
Principles of stress and strain in solid objects with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, and presentations. (Same as CE 312.) Prerequisite: CE 201 or AE 201 or CE 260 or AE 260 or ME 201 or ME 211, and EPHX 210 or PHSX 211 or PHSX 213. Corequisite: MATH 220 or MATH 221 or MATH 320; or consent of instructor.

AE 345. Fluid Mechanics. 3 Credits.

Study of fundamental aspects of fluid motions and basic principles of gas dynamics with application to the design and analysis of aircraft. Prerequisite: C- or higher in MATH 126 or MATH 146, and CE 201 or AE 201. Corequisite: AE 245, CE 250 or AE 250 or CE 260 or AE 260, and MATH 220 or MATH 221 or MATH 320; or permission of instructor.

AE 360. Introduction to Astronautics. 3 Credits.
Introduction to astronautical engineering. The history of astronautics, including rocketry and space flight. Fundamentals of astronautics, including space environment, astrodynamics and the analysis and design of spacecraft systems. Design, construction and launch of a prototype earth-satellite using a high-altitude balloon. Prerequisite: MATH 126 or MATH 146, and CE 260 or AE 260 or CE 250 or AE 250 with a grade of C- or higher. Corequisite: AE 211, ME 208, or EECS 138.

AE 400. Special Topics: _____. 1-3 Credits.
A course in a topic related to undergraduate studies in Aerospace Engineering. Varies by topic or with consent of instructor.

AE 421. Aerospace Computer Graphics. 3 Credits.
Development of skills in depicting aerospace vehicles and their components and subsystems for the purpose of illustration, design, and analysis using traditional and modern (Computer Aided Design) drafting tools. Prerequisite: C- or higher in MATH 126 or MATH 146, and CE 201 or AE 201, and CE 250 or CE 260 or AE 260. Corequisite: CE 310 or AE 310 or CE 312 or AE 312 or equivalent, or permission of instructor.

AE 430. Aerospace Instrumentation Laboratory. 3 Credits.
Review and hands-on laboratory experiments with basic electronic elements (resistors, capacitors, conductors, transistors, linear circuits, logic devices, and integrated circuits). Overview and hands-on laboratory experiments using various experimental techniques available to the aerospace engineers (pressure probes, thermocouples, strain gauges, hot-wire anemometer, laser Doppler velocimeter, and flow visualization techniques). Prerequisite: AE 445 with a grade of C- or higher.

AE 445. Aircraft Aerodynamics and Performance. 3 Credits.
Study of airfoil and wing aerodynamics, component drag, static and special performance, and maneuvers of aircraft. Open enrollment. Prerequisite: AE 345 and CE 260 or CE 201 and CE 250, all with grades of C- or higher.

AE 490. Aerospace Industrial Internship. 1 Credits.
Engineering internship in an approved company. Internship hours do not satisfy any course requirements for the bachelors degree in Aerospace Engineering but will appear on the official transcript. Credit assigned after review of report on internship experience. Graded on a satisfactory/fail basis. Prerequisite: Completion of junior year.

AE 500. Undergraduate Extended Topics: _____. 1 Credits.
An extension of specific AE 500-level courses in order to meet transitional degree requirements. This course does not meet the AE Technical Elective requirements. Prerequisite: Varies by topic or with consent of instructor.

AE 506. Aerospace Structures I, Honors. 3 Credits.
In depth analysis and design of aerospace structures from the standpoint of preliminary design. Deflection and stress analysis of structural components, including thin-walled beams and built-up (semimonocoque) structures. Material failure of highly stressed components, including connections. Buckling of thin-walled beams and semimonocoque structures. Durability and damage tolerance strategies for aerospace structures to avoid corrosion, fatigue, and fracture. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312 with a grade of C- or higher and permission of instructor. Must have minimum 3.25 KU GPA.

AE 507. Aerospace Structures I. 3 Credits.
Analysis and design of aerospace structures from the standpoint of preliminary design. Deflection and stress analysis of structural components, including thin-walled beams and built-up (semimonocoque) structures. Material failure of highly stressed components, including connections. Buckling of thin-walled beams and semimonocoque structures. Durability and damage tolerance strategies for aerospace structures to avoid corrosion, fatigue, and fracture. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312 with a grade of C- or higher.

AE 508. Aerospace Structures II. 3 Credits.
Stress and deflection analysis of aerospace structures using the finite element method. Introduction to work-energy principles, including Castigliano's Theorems, for the analysis of statically indeterminate structures. Rod, beam, shaft, membrane, and plate finite elements. Prerequisite: AE 506 or AE 507, and MATH 290 or MATH 291 with a grade of C- or higher.

AE 509. Honors Aerospace Structures II. 3 Credits.
Indeterminate structures, principle of virtual work, Castigliano's theorems, displacement method of finite element analysis; rod, beam, shaft, and membrane elements; analysis of aerospace structures with the finite element method. Prerequisite: AE 506 or AE 507, and MATH 290 or MATH 291 with a grade of C- or higher, and minimum 3.25 KU GPA.

AE 510. Aerospace Materials and Processes. 3 Credits.
Properties and applications of aircraft materials, forming methods, and manufacturing processes. Ethics and social responsibility for engineers. Oral technical presentations. Prerequisite: AE 507 or AE 506, and CHEM 150 or CHEM 130 and CHEM 149.

AE 520. Space Systems Design I. 4 Credits.
Preliminary design techniques for a space system. Systems engineering; orbital mechanics; spacecraft subsystems including propulsion, attitude control, power, thermal command and data, communications, and structures; and ethics and social responsibility for engineers. Written technical reports. Prerequisite: AE 360 or EPHX 521, AE 421, AE 508 or AE 509, ME 212 with a C- or higher, and CHEM 150 or CHEM 130 and CHEM 149, or permission of instructor.

AE 521. Aerospace Systems Design I. 4 Credits.
Preliminary design techniques for an aerospace system. Aerodynamic design, drag prediction, stability and control criteria, civil and military specifications. Weight and balance, Configuration integration, design and safety, design and ethics, and social responsibility for engineers. Written technical reports. Prerequisite: AE 421, AE 508 or AE 509, AE 551 or AE 552, AE 572 or AE 573, and CHEM 150 or CHEM 130 and CHEM 149 or permission of instructor.

AE 522. Aerospace Systems Design II. 3 Credits.
Preliminary design project of a complete aircraft system. Technical written reports and oral presentations. Prerequisite: AE 521 or AE 520 and permission of instructor. Co-requisite: ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 523. Space Systems Design II. 3 Credits.
Preliminary design project of a complete space system. Technical written reports and oral presentations. Prerequisite: AE 520 or AE 521 and permission of instructor. Co-requisite: ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 545. Fundamentals of Aerodynamics. 3 Credits.
Basic gas dynamic equations, potential flow for airfoils and bodies, thin airfoil theory, finite wing, subsonic similarity rules, one and two dimensional supersonic flow, boundary layers, heat transfer, and laboratory experiments. Prerequisite: A grade of C- or higher in AE 445,

ME 212, MATH 127 or MATH 147, and MATH 220 or MATH 221 or MATH 320.

AE 546. Aerodynamics, Honors. 3 Credits.
Basic gas dynamic equations, potential flow for airfoils and bodies, thin airfoil theory, finite wing, subsonic similarity rules, one and two dimensional supersonic flow, boundary layers and viscous flow, heat transfer, and laboratory experiments. A special project in aerodynamics for AE 546 students. Prerequisite: AE 445, ME 212, MATH 220 or MATH 221 or MATH 320, all with C- or higher and minimum 3.25 KU GPA.

AE 550. Dynamics of Flight I. 3 Credits.
Introduction to Tensors Algebra. Frames and coordinates in dynamics systems. General equations of motion of rigid airplanes and reduction to steady state flight situations. Steady state forces and moments. Stability derivatives. Static stability, control and trim. Trim envelope. Relationships with handling quality requirements. Engine-out flight. Effects of the control system. Implications to airplane design. Prerequisite: Grade of C- or higher in AE 211, and MATH 127 or MATH 147, and MATH 220 or MATH 221. Corequisite: AE 545 or AE 546 and MATH 290 or MATH 291, or permission of instructor.

AE 551. Dynamics of Flight II. 3 Credits.
General equations of motion of rigid airplanes and reduction to perturbed state flight situations. Mathematical modeling of airplane and control system analysis in state space. Dynamic stability, phugoid, short period, dutch roll, roll, spiral, and other important modes. Transfer functions and their application. Relationships with handling quality requirements. Fundamentals of classical control theory and applications to automatic flight controls. Implications to airplane design. Prerequisite: AE 545 or AE 546, AE 550, and a grade of C- or higher in MATH 290 or MATH 291.

AE 552. Honors Dynamics of Flight II. 3 Credits.
General equations of motion of rigid airplanes and reduction to perturbed state flight situations. Perturbed state forces and moments, stability derivatives, dynamic stability, phugoid, short period, dutch roll, roll, spiral, and other important modes. Transfer functions and their application. Relationships with handling quality requirements. Fundamentals of classical control theory and applications to automatic flight controls. Implications to airplane design. Prerequisite: AE 545 or AE 546, AE 550, and a grade of C- or higher in MATH 290 or MATH 291, and minimum 3.25 KU GPA.

AE 571. Fundamentals of Airplane Reciprocating Propulsion Systems. 3 Credits.
Study of the basic principles of operation and systems of internal and external combustion engines with emphasis on airplane reciprocating engines. Cycle analysis, propeller theory, propeller selection and performance analysis. Prerequisite: AE 445 and ME 212 with grades of C- or higher.

AE 572. Fundamentals of Jet Propulsion. 3 Credits.
Lecture and laboratory, study of basic principles of propulsion systems with emphasis on jets and fan systems. Study of inlets, compressors, burners, fuels, turbines, jets, methods of analysis, testing, performance; environmental considerations. Prerequisite: AE 545 or AE 546, AE 571, and CHEM 150 or CHEM 130 and CHEM 149.

AE 573. Honors Propulsion. 3 Credits.
Lecture and laboratory, study of basic principles of propulsion systems with emphasis on jets and fan systems. Study of inlets, compressors, burners, fuels, turbines, jets, methods of analysis, testing, performance; environmental considerations. Prerequisite: AE 545 or AE 546, AE 571, and CHEM 150 or CHEM 130 and CHEM 149, and minimum 3.25 KU GPA.

AE 590. Aerospace Senior Seminar. 1 Credits.
Presentation and discussion of technical and professional paper reports. Methods for improving oral communication. Discussion of topics such as ethics, registration, interviewing, professional societies, personal planning. Prerequisite: Senior standing.

AE 592. Special Projects in Aerospace Engineering for Undergraduate Students. 0.25-5 Credits.
Directed design and research projects in aerospace engineering. Prerequisite: Consent of instructor.

AE 593. Honors Research. 1-5 Credits.
Directed design and research projects in aerospace engineering. Prerequisite: Consent of instructor.

AE 600. Special Topics: _____. 1-3 Credits.
A graduate course or colloquium in a topic related to graduate studies in Aerospace Engineering. This course does not count towards hours needed for completion of degree program. Prerequisite: Varies by topic or with consent of instructor.

AE 621. Advanced Aircraft Design Techniques I. 3 Credits.
The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through design work. This design work will involve detailed design of efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design and aerodynamic design. Prerequisite: AE 507, AE 521, AE 545, AE 551, and AE 571. AE 521 may be taken concurrently.

AE 639. Introduction to Scientific Computing. 3 Credits.
A basic introduction to scientific computing and numerical analysis. Topics include linear equation solving, least squares, nonlinear equation-solving, optimization, interpolation, numerical integration and differentiation, ordinary differential equations, and the fast Fourier transform (FFT). Vectorization, efficiency, reliability, and stability of numerical algorithms will be stressed. Applications of algorithms to real-world problems, such as image processing, medicine, electronic circuits, flight trajectories, and molecular modeling, will be emphasized. The course is not open to students with prior credit in MATH 781 or EECS 781. In addition, students may not simultaneously enroll in EECS 639 and MATH 781/EECS 781. (Same as EECS 639.) Prerequisite: C- or higher in MATH 127 or MATH 147, and MATH 290 or MATH 291, and EECS 168 or EECS 169 or AE 211 or equivalent.

AE 690. Professional Development for Graduate Studies. 0.25 Credits.
Professional development for graduate students. Responsible conduct of research. Presentation and discussion of graduate student research. Oral communication to a range of audiences, including short presentations by students on a range of topics. One semester of enrollment required for all MS and ME candidates, and two semesters of enrollment required for all PhD and DE aspirants and candidates. Graded on a satisfactory/unsatisfactory basis.

AE 700. Special Topics: _____. 1-5 Credits.
Courses on special items of current interest in aerospace engineering, given as need arises. May be repeated for additional credit. Prerequisite: Approval of instructor.

AE 704. Dynamics and Vibrations. 3 Credits.
Problems in engineering dynamics and vibrations. Topics include applications of generalized forces and coordinates, Lagrange equations, and a study of the performance of single and multiple degree of freedom in vibrational systems. (Same as CE 704.) Prerequisite: AE 508 or AE 509 or CE 461 or ME 628.

AE 705. Structural Vibrations and Modal Testing. 4 Credits.
Classical theory of structural vibrations. Single and multiple degree of freedom free and forced vibration. Theory of modal summation. Measurement techniques for dynamic data. Methods of identifying modal parameters from measurement data. Numerous laboratory and computational projects. Prerequisite: AE 508 or AE 509.

AE 709. Structural Composites. 3 Credits.
Fiber materials, tapes, cloths, resin systems; general aeolotropic theory, elastic constants, matrix formulation; computer analysis, strength, theory of failure; introduction to design with composites, preliminary design, optimization, processing variables, product design. Prerequisite: AE 508 or AE 509 or CE 761, and CHEM 150 or CHEM 130 and CHEM 149. Corequisite: AE 510 or ME 306 or CE 710.

AE 712. Techniques of Engineering Evaluation. 3 Credits.
The formulation of problems arising in aerodynamics, heat transfer, stress analysis, thermodynamics, and vibrations. The expression of these problems in a form amenable to quantitative evaluation by dimensional reasoning, analog techniques, relaxation methods, and classical analysis.

AE 721. Aircraft Design Laboratory I. 3 Credits.
The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through team design work. This team design work will involve detailed design efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design, and aerodynamic design. Prerequisite: AE 507 or AE 506, AE 545 or AE 546, AE 551 or AE 552, AE 571. Co-requisite: AE 521 or AE 520 and permission of instructor, and ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 722. Aircraft Design Laboratory II. 3 Credits.
The purpose of this course is to provide aerospace engineering students with an opportunity to gain more in-depth airplane design education through team design work. This team design work will involve detailed design efforts in such areas as: landing gear design, systems design, propulsion system integration, structures design, and aerodynamic design. Prerequisite: AE 507 or AE 506, AE 521, AE 545 or AE 546, AE 551 or AE 552, and AE 571. AE 522 may be taken concurrently. Co-requisite: ECON 104, or ECON 105, or ECON 142, or ECON 143, or ECON 144, or ECON 145.

AE 725. Numerical Optimization and Structural Design. 3 Credits.
Classical theories of unconstrained and constrained optimization. Numerical techniques for unconstrained optimization, including the steepest descent, conjugate gradient and "Newton's" methods. Numerical techniques for constrained optimization, including sequential approximate problem techniques as well as the method of feasible directions. Computer aided solutions to practical design problems in aerospace engineering. Final design project. Prerequisite: C- or higher in MATH 220 or MATH 221 and MATH 290 or MATH 291.

AE 727. Aircraft Antenna Systems. 3 Credits.
Aircraft antenna integration and design process. Overview of common aircraft communication, navigation, and sensing systems. CAD tools and analysis and measurement techniques for designing and assessing systems. Low-observable vehicle design concepts. Prerequisite: PHSX 212 and MATH 127 or MATH 147 with a grade of C- or higher, EECS 316, AE 421 or other CAD experience, and CE 310 or equivalent recommended.

AE 730. Advanced Experimental Fluid Dynamics. 3 Credits.
Theory, methods and data analysis of various modern flow measurement techniques including: hotwire cluster, laser-Doppler velocimetry, particle image velocimetry, holography, pressure detection, temperature probing, vorticity measurements, Lagrange particle tracking. Specific experimental technique covers optical measurements in turbulent flow, microfluidic experiments, and spray and multiphase flow measurement. Prerequisite: AE 430, AE 545 or AE 546 or consent of instructor.

AE 732. Introduction to Flight Test Engineering. 3 Credits.
Course presents flight test principles, instrumentation, planning, and operation of aerospace vehicle flight testing. Course is structured with lectures, laboratories, and flight experiments. Student teams plan and execute a series of flight test experiments including: familiarization with flight test measurements, static system calibration, rate-of-climb performance, and determination of vehicle flight dynamics. Prerequisite: AE 445 and AE 550 or consent of instructor.

AE 743. Compressible Aerodynamics. 3 Credits.
Compressible flow with heat and friction; shock polars, 1-D unsteady gas dynamics, shock tube, conical flows, methods of characteristics, hypersonic flow theory. Prerequisite: AE 545 or AE 546.

AE 744. Turbulent Flows. 3 Credits.
Reynolds averaged equations for turbulent flow, basic energy relations and spectra in turbulent flow, analysis of turbulent boundary layer, turbulent pipe flow, turbulence models and simulation. Prerequisite: AE 545 or AE 546 or equivalent.

AE 746. Computational Fluid Dynamics. 3 Credits.
Applications of numerical techniques and digital computers to solving fluid flow problems. Solutions involving incompressible and compressible flows, inviscid and viscous flows. Finite difference techniques for different types of partial differential equations governing the fluid flow. Prerequisite: AE 545 or AE 546.

AE 750. Applied Optimal Control. 3 Credits.
Introduction to optimal control analysis and design tools useful for the design of Multi-Input/Multi-Output controllers. Linear Quadratic Regulator problem extended by including advanced command techniques and advanced controller structures. The techniques are illustrated with aerospace applications. Prerequisite: AE 551 or AE 552 or ME 682 or consent of instructor.

AE 752. Linear Multivariable Control. 3 Credits.
An introduction to the modeling and analysis of multi-input, multi-output control systems. Topics include state space representation, solutions of linear systems, stability analysis, LQR design, cooperative controller design, etc. Prerequisite: AE 551 or AE 552, or EECS 444 or equivalent; or by consent of instructor.

AE 753. Digital Flight Controls. 3 Credits.
Introduction to the analysis and design tools useful for the design of aircraft guidance and flight control systems containing continuous dynamics and a digital computer. Topics include Z-plane analysis, autopilot design using successive loop closure, guidance design models, path planning, vision-guided navigation, etc. Prerequisite: AE 551 or AE 552 or ME 682 or consent of instructor.

AE 755. Robust and Nonlinear Control. 3 Credits.
The robustness is one of the most critical qualities of an appropriately designed feedback control system. In this course the ability of the closed-loop system to continue performing satisfactorily despite uncertainties in estimated state variables and/or large variations in the (open-loop) plant dynamics will be investigated. This course will lay down the mathematical and theoretical background needed for the analysis and design of robust feedback control systems. Modern controller design methods (e.g. H-inf control) will be used to design controller highly nonlinear and transient dynamics. Prerequisite: AE 551 or AE 552, AE 750, and MATH 590 or consent of instructor.

AE 759. Estimation and Control of Unmanned Autonomous Systems. 3 Credits.
An introduction to the modeling, estimation, and control of unmanned autonomous systems. Topics include motion description, navigation sensors, complementary filters, Kalman filters, attitude estimation, position estimation, attitude keeping controller, etc. The successful completion of this course will prepare students for advanced studies in robotics & controls. (Same as EECS 759.) Prerequisite: AE 551 or AE 552 or EECS 444, or by consent of instructor.

AE 765. Orbital Mechanics. 3 Credits.
Motion of space vehicles under the influence of gravitational forces. Two body trajectories, orbit determination, orbit transfer, universal variables, mission planning using patched conics. Transfer orbits. Prerequisite: MATH 220 or MATH 221, and MATH 290 or MATH 291 with a grade of C- or higher, and AE 360 or equivalent.

AE 766. Spacecraft Attitude Dynamics and Control. 3 Credits.
Dynamics of rigid spacecraft, attitude control devices including momentum exchange, mass movement, gravity gradient and reactor rockets. Design of feedback control systems for linear and bang-bang control devices. Prerequisite: AE 551 or AE 552 or permission of instructor.

AE 767. Spacecraft Environments. 3 Credits.
Fundamentals of spacecraft environments. Description and analysis of the natural environment in which spacecraft operate post-launch. Includes optical, electromagnetic, corpuscular radiation, plasma and dust from low Earth orbit, through outer heliosphere. Prerequisite: C- or higher in PHSX 212; PHSX 313 or PHSX 351 recommended.

AE 768. Orbit Determination. 3 Credits.
Develops the theory of batch and sequential (Kalman filter) estimation theory related to orbit estimation, including a review of necessary concepts of probability and statistics. Course work includes a term project that allows students to apply classroom theory to an actual satellite orbit determination problem. Prerequisite: AE 360.

AE 771. Rocket Propulsion. 3 Credits.
Basic elements of rocket propulsion: systems, propellants, and performance. Prerequisite: AE 545 or AE 546 or equivalent.

AE 773. Propulsion Systems for Emerging Aircraft. 3 Credits.
Advanced study of the principles of operation and propulsion systems for UAVs, UAMs and general aviation aircraft. Prerequisite: AE 445, AE 571, ME 212.

AE 774. Introduction to Combustion. 3 Credits.
Study of advanced concepts and principles of combustion, including thermal analysis, chemical reaction, and computational methods. Prerequisite: C- or higher in ME 212, and AE 211 or ME 208 or EECS 138.

AE 790. Special Problems in Aerospace Engineering for Masters Students. 1-5 Credits.
Directed studies of advanced problems in aerospace engineering. Open only to graduate students with departmental approval.

AE 846. Advanced Computational Fluid Dynamics and Heat Transfer. 3 Credits.
Present recent advances in computational fluid dynamics and heat transfer with a focus on numerical algorithms designed for unstructured grids, including grid generation, convergence acceleration techniques, high-order algorithms and parallel computing on CPU and GPU clusters. It is expected that the students will understand the basics of the finite volume method for unstructured grids, and be able to program a 2D Euler solver for arbitrary grids after taking this class. Prerequisite: AE 746. This class is not open to undergraduate students.

AE 892. Special Problems in Aerospace Engineering for Doctoral Students. 1-8 Credits.
Directed studies of advanced problems in aerospace engineering. Open only to graduate students with consent of instructor.

AE 895. M.S. Thesis or Project. 1-6 Credits.
Original research or project which satisfies the requirements for the degree of Master of Science in Aerospace Engineering. Restricted to Aerospace MS students. Graded on a satisfactory progress/limited progress/no progress basis.

AE 996. Ph.D. Dissertation. 1-9 Credits.
Restricted to Aerospace Ph.D. candidates. Graded on a satisfactory progress/limited progress/no progress basis.

AE 997. DE Project. 1-16 Credits.
A major design problem or system study satisfying the project requirements for the Doctor of Engineering in Aerospace Engineering degree. Restricted to Aerospace DE candidates. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Successful completion of Comprehensive Oral Exam.

Bioengineering Courses

BIOE 800. Bioengineering Colloquium. 0.5-1 Credits.
A colloquium series featuring speakers from industry, government, other universities, research centers and research organizations of the university campus presenting talks on various topics related to bioengineering.

BIOE 801. Responsible Conduct of Research in Engineering. 1 Credits.
Lectures and discussion on ethical issues in the conduct of a scientific career, with emphasis on practical topics of special importance in bioengineering. Topics include the nature of ethics, the roles of the scientist as a reviewer, entrepreneur, employer and teacher, research ethics in the laboratory, social responsibility and research ethics regulation. (Same as ME 801.) Prerequisite: Permission of instructor.

BIOE 802. Bioengineering Internship. 1-6 Credits.
An approved bioengineering industrial or clinical internship. The student is supervised by a preceptor at the internship site. Biweekly reports and a final report detailing work performed are filed with the course instructor. Prerequisite: Permission of instructor.

BIOE 860. Advanced Bioengineering Problems. 1-3 Credits.
An analytical or experimental study of problems or subjects of immediate interest to a student and faculty member and which is intended to develop students capability for independent research or application of engineering science and technology. Maximum credit toward any degree is three hours unless waived in writing by the academic director. Prerequisite: Consent of instructor.

BIOE 890. Special Topics: _____. 1-5 Credits.
Advanced courses on special topics of current interest in bioengineering, given as the need arises. Prerequisite: Approval of instructor.

BIOE 899. Independent Investigation. 1-6 Credits.
An original and independent research or design investigation involving analytical, experimental and/or modeling methodology applied to solve a bioengineering problem as a part of the degree requirements for the Master of Science. Graded on a satisfactory progress/limited progress/no progress basis.

BIOE 999. Independent Investigation. 1-12 Credits.
An original and independent research or design investigation involving analytical, experimental and/or modeling methodology applied to solve a bioengineering problem as a part of the degree requirements for the

Doctor of Philosophy. Graded on a satisfactory progress/limited progress/no progress basis.

Chemical & Petroleum Engr Courses

CPE 111. Introduction to the Chemical Engineering Profession I. 1 Credits.
The career opportunities for chemical engineers are described and students are introduced to the resources available to them at KU, in the School of Engineering, and in the Chemical and Petroleum Engineering Department. The students are introduced to the curriculum requirements and emphasis options, engineering ethics, basic safety considerations, teamwork, and technical writing. The course includes fundamental calculations and laboratory experiences in material and energy balances and fluid flow. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145.

CPE 112. Introduction to Chemical Engineering Profession II. 1 Credits.
Students are introduced to engineering ethics, basic safety considerations, teamwork, and technical writing. The course includes fundamental calculations and laboratory experiences in material and energy balances and fluid flow. Prerequisite: Corequisite: CHEM 130 or CHEM 170 or CHEM 190.

CPE 117. Energy in the Modern World. 1 Credits.
A survey course on global energy supply and demand, production methods and energy economics. Course begins with the matrix of energy supply and demand focusing on fossil fuels and nuclear energy and includes transportation/ distribution patterns and issues and current production technologies. We then analyze alternate energy realities and potentials such as solar energy, wind energy, biomass utilization, hydrogen, fuel cells, hydroelectric, geothermal, wave/tidal, and others based on thermodynamic principles and economics. Course is also open to non-engineering students.

CPE 127. Introduction to Petroleum Engineering Profession. 1 Credits.
An introduction to principles of reservoir engineering and an application of economic principles will be introduced along with the use of computer spreadsheets. A mini petroleum engineering design project will be assigned to illustrate the integration of petroleum engineering principles and the use of computers. C&PE 127 is required of all Petroleum Engineering freshmen but is optional for others. Course is also open to non-engineering students.

CPE 211. Material and Energy Balances. 3 Credits.
The application of the laws of chemistry, physics, and mathematics to the solution of material and energy balance problems occurring in the process industries. Prerequisite: MATH 125 or MATH 145; CHEM 135 or CHEM 175 or CHEM 195; or consent of department.

CPE 221. Chemical Engineering Thermodynamics I. 3 Credits.
Fundamentals and applications of the First and Second Laws of Thermodynamics with strong emphasis on material, energy and entropy balances to solve engineering problems involving pure components. Topics include: Cycles (Rankine, Brayton, refrigeration, etc.), the calculus of thermodynamics, equations of state for realistic thermodynamic properties, departure functions, equilibrium and stability criteria, fugacity, and single component phase equilibrium (vaporization, melting, sublimation). Prerequisite: MATH 126 or MATH 146; and C&PE 211. Corequisite: EPHX 210 or PHSX 211 or PHSX 213; or consent of department.

CPE 226. Fundamentals of Biomedical and Biomolecular Engineering. 3 Credits.
Introduction to the building blocks of human and other living organisms with a focus on structure/function mechanisms that are critical for design, modeling, and analysis in living systems. Application of chemical engineering principles, including mass, energy, momentum and charge balances and molecular thermodynamics to analysis of living systems. Applies biochemistry, molecular biology and cell biology to fundamental issues in biochemical engineering, biomedical engineering and biotechnology. Prerequisite: C&PE 211, or consent of department. Corequisite: C&PE 221 or ME 212.

CPE 308. Subsurface Energy Engineering Seminar. 0.25 Credits.
A seminar class conducted every year for all undergraduates in the major. Seminars will be presented in hybrid format using in person lectures as well as distance delivery to in class audiences as well as recorded presentations. Presenters will be from industry and academia including KU faculty. Topics will include recent advances in technology, professional development, career opportunities, sustainability, underground H_2/CO_2 storage, and other topics of interest. Graded on a satisfactory/unsatisfactory basis.

CPE 325. Numerical Methods and Statistics for Engineers. 3 Credits.
An introduction to numerical methods and statistics and their application to engineering problems. Numerical methods topics include finding roots of a single nonlinear equation, numerical solution of ordinary differential equations, numerical integration, and solutions of ordinary differential equations. Statistical topics include regression and curve fitting, probability and probability distributions, expected value and hypothesis testing, and optimization of single and multiple-variable systems. Implementing numerical algorithms using computer programming will be emphasized, along with the fundamentals of programming, including data typing, branching, and iteration. Applications specific to chemical and petroleum engineering systems will be considered. Prerequisite: MATH 126 or MATH 146; and CHEM 135 or CHEM 175 or CHEM 195. Corequisite: MATH 220 or MATH 221 or MATH 320 or MATH 321; and MATH 290 or MATH 291; or consent of department.

CPE 327. Reservoir Engineering. 3 Credits.
Properties of porous rocks, reservoir fluids, and fluid saturated rocks. Introduction to multiphase flow in porous media including concepts of wettability, capillary pressure and relative permeability. Introduction to basic thermodynamics and phase behavior. Prerequisite: CHEM 135 or CHEM 175 or CHEM 195, or consent of department.

CPE 511. Momentum Transfer. 3 Credits.
Solutions of continuity, momentum, and energy equations applied to fluids in confined flow or flowing past submerged objects. Laminar and turbulent flows of both incompressible and compressible fluids are considered. Engineering applications include pressure drop and network analysis of piping lines, flow measurements, fluid moving equipment including the performance of pumps. Prerequisite: C&PE 221 or ME 212 or C&PE 327; C&PE 325; and a grade of C- or higher in MATH 127 or MATH 147, and MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 512. Chemical Engineering Thermodynamics II. 3 Credits.
Further application of the laws of thermodynamics to multi-component mixtures and in multi-phase equilibria with focus on vapor-liquid, liquid-liquid, and solid-liquid equilibria. Mixture Fugacity expressions are developed using equations of state with mixing rules or Excess Gibbs Free Energy/activity coefficient models for data correlation or prediction. Chemical equilibrium of reactions is also discussed. Prerequisite: C&PE 325; C&PE 211; C&PE 221; and CHEM 330 or CHEM 380; and

a grade of C- or higher in MATH 127 or MATH 147, and MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 519. Drilling Fluids Laboratory. 1 Credits.
Laboratory study of formulation and properties of drilling fluids. "Mud" measurements covered include density, solids content, filtration control and viscosity. Other measurements include compressive strength of cement and cuttings transport properties. Prerequisite: Corequisite: C&PE 511, or consent of department.

CPE 522. Economic Appraisal of Chemical and Petroleum Projects. 2 Credits. AE51
Consideration of the economic factors important in the development of the chemical or petroleum enterprise. Applications of economic evaluation methods to engineering project development. Consideration of risk and uncertainty in project development. Prerequisite: C&PE 325; and a grade of C- or higher in MATH 126 or MATH 146 and PHSX 210 or EPHX 210 or PHSX 211 or PHSX 213; or consent of department.

CPE 524. Chemical Engineering Kinetics and Reactor Design. 3 Credits.
Development and solution of the material and energy balance equations for continuous and batch reactors. These balance equations are applied in (a) the determination of intrinsic kinetics, (b) the design of reactors and (c) the analysis of reactor behavior. Both homogeneous and heterogeneous reaction systems are considered. Prerequisite: C&PE 511; C&PE 512; and a grade of C- or higher in MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. Corequisite: C&PE 525. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 525. Heat and Mass Transfer. 4 Credits.
An applied study of the various heat and mass transfer mechanisms in solid and fluid systems. Heat transfer mechanisms include conduction and the concept of conductivity at the molecular level, convection, and radiation. Mass transfer fundamentals include diffusion and the concepts of diffusivity at the molecular level and shell mass balances including diffusion, convention, and consumption or generation source terms. Steady state and transient heat and mass transfer engineering applications will be considered. Prerequisite: C&PE 221 or ME 212; C&PE 325; C&PE 511; and a grade of C- or higher in MATH 220 and MATH 127; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 527. Reservoir Engineering II. 3 Credits.
Lectures on fluid flow and pressure distribution in reservoirs. Calculations in drawdown, buildup, multiple rate, fractured systems, gas and injection well testing. Material balance calculations for injection-production processes within subsurface formations. Prerequisite: C&PE 327; a grade of C- or higher in MATH 220 or MATH 221 or MATH 320 or MATH 321; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to junior year courses. Details can be found in the catalog under degree requirements.

CPE 528. Well Logging. 3 Credits.
Analysis of well logs to estimate properties of subsurface formations, fluid saturations and lithology, and production logging. Prerequisite: C&PE 327 or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the Junior year courses. Details can be found in the catalog under degree requirements.

CPE 601. Undergraduate Topics in Chemical and Petroleum Engineering: _____. 1-4 Credits.
Undergraduate study in various branches of Chemical and Petroleum Engineering on topics that may vary from year to year. Prerequisite: Varies.

CPE 611. Design of Unit Operations. 3 Credits.
Application of chemical engineering principles to design pumps, heat exchangers, and separation equipment. Staged separation processes including distillation, extraction and absorption, membrane separations, and modes of operation will be considered. Sizing of equipment, energy consumption and materials of construction will also be addressed. Prerequisite: C&PE 211; C&PE 511; C&PE 512; C&PE 524; C&PE 525; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 613. Chemical Engineering Design I. 4 Credits.
Synthesis, design and economic analysis of petrochemical, and chemical plants. Applications in computer aided engineering applied to these topics. Prerequisite: C&PE 522, C&PE 611 and C&PE 615; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 615. Introduction to Process Dynamics and Control. 3 Credits.

The behavior of chemical processing equipment in the presence of disturbances in operating conditions is analyzed. Control systems are designed based on the criteria of system stability and optimal system performance. Prerequisite: C&PE 511; C&PE 512; C&PE 524; and C&PE 525; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 616. Chemical Engineering Laboratory I. 3 Credits.
Laboratory study of chemical engineering concepts of thermodynamics, fluid flow, heat transfer, mass transfer, and reaction kinetics. Includes emphasis on technical communication skills. Prerequisite: C&PE 511; C&PE 512; C&PE 524; C&PE 525; and ENGL 102 or ENGL 105; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 617. Drilling and Well Completion. 3 Credits.
Design and analysis of rotary drilling and well completion systems; casing design, cementing, HPHT drilling, MWD, and perforating. Safety and ethical considerations in drilling and fluid disposal operations. Prerequisite: C&PE 519; C&PE 327; C&PE 511; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog under degree requirements.

CPE 618. Improved Oil Recovery. 3 Credits.
Improved Oil Recovery processes will be presented in this course. This includes design of waterfloods, miscible/immiscible displacement, chemical processes such as polymer flood, surfactant flood, and thermal recovery techniques such as steam flooding, in-situ combustion, and other EOR techniques. CO2 injection for the purpose of carbon capture, utilizations and storage (CCUS) will be covered in this class. Prerequisite: C&PE 527; or consent of the department. The Petroleum major has a GPA requirement for specific courses to progress to the Junior year courses. Details can be found in the catalog under degree requirements.

CPE 619. Petroleum Engineering Laboratory. 3 Credits.
Laboratory study of methods to determine rock and fluid properties related to subsurface engineering including phase behavior, viscosity, permeability, porosity, capillary pressure, oil recovery, water/oil

displacement, fluid flow, rock compaction, heat transfer coefficients and analysis of experimental uncertainty. Oral and written presentations are required. Prerequisite: C&PE 519; C&PE 327; C&PE 511; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to junior year courses. Details can be found in the catalog under degree requirements.

CPE 620. Enhanced Oil Recovery. 3 Credits.
Enhanced Oil Recovery processes such as primary, secondary, and tertiary oil recovery techniques will be presented. This includes miscible/immiscible displacement, chemical processes such as polymerflood, surfactant and micellar flood, and thermal recovery techniques such as steam flooding, in-situ combustion, and other EOR techniques. Prerequisite: C&PE 527 and C&PE 618 or consent of department.

CPE 624. Process Safety and Sustainability. 3 Credits. AE51
An introductory course designed to acquaint students with the necessary global aspects and ethics of risk-based process safety and sustainability. Topics will include elements of process safety, process safety management, historical and contemporary case studies of major accidents in the chemical and petroleum industry, overview of current government regulation (e.g. OSHA, EPA, etc.), and ethics. Students will receive an introduction to sustainable ("green") chemistry and engineering followed by more quantitative Life Cycle Analysis (LCA) to compare technologies and products. Prerequisite: C&PE 511 or ME 510, or consent of department. The department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 625. Unconventional Reservoirs. 3 Credits.
Principles of unconventional reservoir engineering including properties of unconventional reservoirs, hydraulic fracturing, geomechanical and relevant environmental and economic factors. The course will also cover contributing factors of these rocks in new energy ventures such as CO2 and hydrogen storage. Prerequisite: C&PE 511; C&PE 527; C&PE 528; ME 211; GEOL 332; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog under degree requirements.

CPE 626. Chemical Engineering Laboratory II. 3 Credits. GE22
Laboratory study of chemical engineering concepts of thermodynamics, fluid flow, heat transfer, mass transfer, reaction kinetics, and process control. Includes emphasis on technical communication skills. Prerequisite: ENGL 102 or ENGL 105; C&PE 511; C&PE 512; C&PE 524; C&PE 525; C&PE 615; and C&PE 616; or consent of department. The Department has a GPA requirement for progression in the program. Details can be found in the catalog under degree requirements.

CPE 627. Petroleum Production. 3 Credits.
Design and analysis of natural production and artificial lift systems, including beam pumping, gas lift, and submersible pumps. Vertical and horizontal two-phase flow, compression, metering, acidizing, fracturing, and pipe line flow systems. Additionally, the operational aspects of CO2 injection for permanent underground storage (CCUS) will be covered. Treatment of ethics considerations in production contracts and leasing arrangements. Prerequisite: C&PE 327; C&PE 511; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog under degree requirements.

CPE 628. Petroleum Engineering Design. 3 Credits. AE61 CAP
Design problems related to subsurface reservoir challenges with respect to development of conventional and unconventional reservoirs as well as new energy venture projects such as CO2 storage, hydrogen storage and enhanced geothermal. Designs consider economic, uncertainty analysis, as well as conservation, environmental, and professional ethics factors. Prerequisite: C&PE 522; C&PE 527; C&PE 528; C&PE 618; C&PE 619; GEOL 535; or consent of department. The Petroleum major has a GPA requirement for specific courses to progress to the senior year courses. Details can be found in the catalog under degree requirements.

CPE 640. Natural Gas Engineering. 3 Credits.
Principles of natural gas engineering including resource distribution and evaluation, composition and properties, production, processing, transportation, storage and relevant environmental and economic aspects. Prerequisite: C&PE 625 and C&PE 627, or consent of department.

CPE 641. AI and Machine Learning for Energy and Dynamic Systems. 3 Credits.
This course explores the applications of AI and Machine Learning (ML) techniques to address complex problems in energy systems and dynamic engineering systems more broadly. Students will learn the theory, concepts, and detailed algorithms, and how AI and ML can be leveraged to improve performance, efficiency, and innovation across various energy and dynamic systems. The course will cover key AI/ML concepts and algorithms used in real-world applications, with a focus on areas such as various energy production and management, dynamic system characterization, optimization, and predictive modeling. This course equips students with foundational knowledge of AI and ML, highlighting their powerful potential to solve challenges in both energy and dynamic systems. Prerequisite: C&PE 325 (or EECS 138--Python), or consent of department.

CPE 642. New Energy Ventures. 3 Credits.
This course covers the necessary fundamentals required for new energy venture topics such as Carbon Capture, Utilization and Storage (CCUS), Subsurface Hydrogen Storage and Production, and Enhanced Geothermal Systems. Prerequisite: C&PE 527, C&PE 528, GEOL 332; Corequisite: C&PE 625, or consent of department.

CPE 651. Undergraduate Problems. 1-4 Credits.
Investigation of a particular problem in the field of chemical or petroleum engineering. The problem or research topic is identified jointly by the student and the faculty research supervisor. A final report is required.

CPE 655. Introduction to Semiconductor Processing. 3 Credits.
An overview of various processes to fabricate semiconductor devices and integrated circuits. Topics covered include crystal growth, oxidation, solid-state diffusion, ion implantation, photolithography, chemical vapor deposition, epitaxial growth, metalization, and plasma etching of thin films. (Same as EECS 670.) Prerequisite: Junior or senior standing in C&PE or EECS, or consent of department.

CPE 656. Introduction to Biomedical Engineering. 3 Credits.
An interdisciplinary introduction to the field of biomedical engineering. This course covers a breadth of topics including biotransport, biomechanics, biomaterials, tissue engineering, drug delivery, biomedical imaging, computational biology, and biotechnology. Students are exposed to these broad topics, and go further in depth in a topic of their choice with the semester project. Prerequisite: Junior or Senior-level standing in Engineering or consent of department.

CPE 657. Polymer Science and Technology. 3 Credits.
Introduction to polymer chemistry, science, technology, and processing. The course covers the principles of polymer synthesis and the structure-property relationships in the solid state and in solution, such as solubility, rheology and mechanical properties. Principles of polymer processing are introduced. Students will learn to understand from an engineering perspective how polymers are created and used. Prerequisite: Senior or graduate student standing in chemical engineering, chemistry, or consent of department.

CPE 661. Undergraduate Honors Research. 1-3 Credits.

This course involves the investigation of a particular problem in the field of chemical or petroleum engineering. C&PE 661 should be taken, rather than C&PE 651, for students seeking Departmental Honors in Chemical Petroleum Engineering. C&PE 661 may also be used by students in the Honors Program to help satisfy the course requirement of this program. The design or research topic is identified jointly by the student and faculty research supervisor. Prerequisite: C&PE 211; C&PE 325; C&PE 511; C&PE 512; overall GPA >3.5; and engineering GPA >3.5; or consent of the department.

CPE 676. Principles of Biomolecular Engineering. 3 Credits.
Application of chemical engineering principles, including transport phenomena, reaction kinetics and thermodynamics, to analysis of living systems. Applies biochemistry, molecular biology and cell biology to fundamental issues in biochemical engineering, biomedical engineering and biotechnology. Prerequisite: C&PE 511, C&PE 512; Corequisite: C&PE 524, C&PE 525, or consent of department.

CPE 678. Applied Optimization Methods. 3 Credits.
Study of methods for solving optimization problems encountered in engineering, the natural sciences and business, with specific applications illustrating analytical and numerical techniques. Topics covered include unconstrained optimization methods, penalty functions, linear programming, nonlinear and integer programming, and stochastic optimization approaches. A semester project is required. Prerequisite: Junior or Senior standing or consent of department.

CPE 701. Methods of Chemical and Petroleum Calculations. 3 Credits.
The utilization of advanced mathematical methods and computing techniques in the solution of problems in these fields. Prerequisite: Graduate standing, or consent of department.

CPE 715. Topics in Chemical and Petroleum Engineering: _____. 3 Credits.
Study in various branches of Chemical and Petroleum Engineering on topics that may vary from year to year.

CPE 716. Drug Delivery. 4 Credits.
The course will survey the latest technology for delivering pharmaceuticals and biologicals to reduce side effects and enhance drug efficacy. The course will survey the latest research in this area and examine more classical delivery methods. A qualitative and quantitative understanding of drug delivery practice and theory is the goal. (Same as PHCH 715.) Prerequisite: Master's or PhD candidate in Engineering, Chemistry, Medicinal Chemistry, or Pharmaceutical Chemistry (by appointment for seniors or graduate students in departments not listed).

CPE 721. Chemical Engineering Thermodynamics. 3 Credits.
Chemical engineering applications of advanced thermodynamics and physical chemistry. Prerequisite: Graduate standing, C&PE 512 or equivalent, or consent of department.

CPE 722. Kinetics and Catalysis. 3 Credits.
Modeling and analysis of chemical reactors with emphasis on heterogenous catalytic reaction systems. Prerequisite: Graduate standing, C&PE 524 or equivalent, or consent of department.

CPE 725. Cellular and Molecular Pharmaceutics. 3 Credits.
The pharmaceutical relevance of fundamental and advanced concepts in cell biology and the molecular interactions responsible for cell and tissue functions, homeostasis in health and disease will be presented. Current analytical methods for examining cells and tissues, and molecular components important in understanding drug and protein biodistribution and metabolism will be discussed. Discussion topics will include the chemical and physical properties of small molecules, proteins, nucleic acids and lipids and their impact on cellular and subcellular structures and ultimately of either adverse or therapeutic benefit. (Same as PHCH 725.) Prerequisite: Graduate standing or consent of instructor.

CPE 728. Petroleum Engineering Design. 3 Credits.
Design problems related to subsurface reservoir challenges with respect to development of conventional and unconventional reservoirs as well as new energy venture projects such as CO2 storage, hydrogen storage and enhanced geothermal. Designs consider economic, uncertainty analysis, as well as conservation, environmental, and professional ethics factors. Prerequisite: Graduate standing; C&PE 522; C&PE 527; C&PE 528; C&PE 618; C&PE 619; GEOL 535; or consent of department.

CPE 731. Convective Heat and Momentum Transfer. 3 Credits.
The formulation and solution of steady- and unsteady-state convective heat and momentum transfer problems. Applications of boundary layer equations to free and forced convection with study of similarity and integral methods of solution for laminar and turbulent flow; development of analogies; transport properties from kinetic theory of gases viewpoint; introduction to numerical methods. Prerequisite: Graduate standing, C&PE 511 and C&PE 525 or equivalent, or consent of department.

CPE 732. Advanced Transport Phenomena II. 3 Credits.
The formulation and solution of steady- and unsteady-state mass transfer problems (including those complicated by momentum and heat transfer).The mathematical approach predominates and the methods available for determining suitable mass transfer coefficients are covered. Prerequisite: Graduate standing, C&PE 731 or equivalent, or consent of department.

CPE 740. Natural Gas Engineering. 3 Credits.
Principles of natural gas engineering including resource distribution and evaluation, composition and properties, production, processing, transportation, storage and relevant environmental and economic aspects. Prerequisite: Graduate standing, or consent of department.

CPE 741. AI and Machine Learning for Energy and Dynamic Systems. 3 Credits.
This course explores the applications of AI and Machine Learning (ML) techniques to address complex problems in energy systems and dynamic engineering systems more broadly. Students will learn the theory, concepts, and detailed algorithms, and how AI and ML can be leveraged to improve performance, efficiency, and innovation across various energy and dynamic systems. The course will cover key AI/ML concepts and algorithms used in real-world applications, with a focus on areas such as various energy production and management, dynamic system characterization, optimization, and predictive modeling. This course equips students with foundational knowledge of AI and ML, highlighting their powerful potential to solve challenges in both energy and dynamic systems. Prerequisite: Graduate standing, or consent of department.

CPE 742. New Energy Ventures. 3 Credits.
This course covers the necessary fundamentals required for new energy venture topics such as Carbon Capture, Utilization and Storage (CCUS), Subsurface Hydrogen Storage and Production, and Enhanced Geothermal Systems. Prerequisite: Graduate standing, or consent of department.

CPE 745. Unconventional Reservoirs. 3 Credits.
Principles of unconventional reservoir engineering including properties of unconventional reservoirs, hydraulic fracturing, geomechanical and relevant environmental and economic factors. The course will also cover contributing factors of these rocks in new energy ventures such as CO2 and hydrogen storage. Prerequisite: Graduate standing, or consent of department.

CPE 751. Basic Rheology. 3 Credits.

Basic rheology including classification of classical bodies based on their stress and strain tensors, rheological equation of state, material functions, generalized Newtonian and general linear viscoelastic fluids, mechanical models such as those of Jeffreys and Maxwell. Prerequisite: Graduate standing, C&PE 511 or equivalent, or consent of department.

CPE 752. Tissue Engineering. 3 Credits.
An introduction to the rapidly growing and continuously evolving field of tissue engineering. Tissue engineering applies principles and methods of engineering and life sciences toward understanding and development of biological substitutes to restore, maintain and improve tissues functions. In this course, students study the basic science, engineering and medicine required for tissue engineering, learn state-of-the-art technology and practice, and create a literature-based proposal for a tissue engineered medical product. Prerequisite: Senior or graduate standing in engineering; or consent of department.

CPE 753. Introduction to Electrochemical Engineering. 3 Credits.
Basic principles of electrochemical engineering as they are applied to energy conversion and storage devices, industrial electrolytic processes and corrosion. Areas covered range from electrochemical thermodynamics, ionic phase equilibria, electro-kinetics and ionic mass transport to mathematical modeling of electrochemical systems. Prerequisite: Graduate standing; C&PE 511, C&PE 512, C&PE 524 or equivalent; or consent of department.

CPE 755. Introduction to Semiconductor Processing. 3 Credits.
An overview of various processes to fabricate semiconductor devices and integrated circuits. Topics covered include crystal growth, oxidation, solid-state diffusion, ion implantation, photolithography, chemical vapor deposition, eqitaxial growth, metallization, and plasma etching of thin films. A term paper on an approved topic of fabrication referencing current peer reviewed literature is required. Prerequisite: Graduate standing, or consent of department.

CPE 756. Introduction to Biomedical Engineering. 3 Credits.
The graduate elective form of C&PE 656. Additional assignments commensurate with the graduate-level course designation are required for this section. Prerequisite: Graduate-level standing in Engineering, or consent of department.

CPE 757. Polymer Science and Technology. 3 Credits.
The graduate elective form of C&PE 657. Additional assignments on current research directions in the field commensurate with the graduate-level course designation are required for this section. Prerequisite: Graduate-level standing in engineering, or consent of department.

CPE 765. Corrosion Engineering. 3 Credits.
Electrochemical basis of corrosion. Estimating probability and rate of corrosion. Identifying different conditions likely to cause specific types of corrosion. Corrosion mitigation techniques. Prerequisite: CHEM 135 or CHEM 175 or CHEM 195. Same course as CE 715.

CPE 771. Advanced Reservoir Engineering. 3 Credits.
Physical principles of petroleum production; gas drive performance; partial water drive performance; pressure maintenance through gas and water injection. Prerequisite: Graduate standing, C&PE 527 or equivalent, or consent of department.

CPE 778. Applied Optimization Methods. 3 Credits.
Study of methods for solving optimization problems encountered in engineering and the natural sciences, with specific applications illustrating analytical and numerical techniques. Topics covered include gradient methods, penalty functions, linear programming, nonlinear and integer programming, stochastic optimization approaches, and treatment of constrained problems. Homework problems involving theoretical concepts and a theoretically-based semester project are required. Prerequisite: Graduate standing, or consent of department.

CPE 790. Introduction to Flow in Porous Media. 3 Credits.
Generalized Darcy's law, vector equations, solutions of partial differential equations with various boundary conditions as applied to the flow of fluids in porous media. Prerequisite: Graduate standing, C&PE 527 or equivalent, or consent of department.

CPE 795. Enhanced Petroleum Recovery. 3 Credits.
A study of improved oil recovery processes such as miscible displacement, microemulsion displacement, and thermal methods. Prerequisite: Graduate standing, C&PE 618 or equivalent, or consent of department.

CPE 798. Phase Equilibrium. 3 Credits.
A study of phase behavior and equilibrium from a molecular perspective. Focus will be on vapor-liquid, liquid-liquid and solid-liquid equilibrium with advanced topics in compressed and supercritical fluids, petroleum applications, ionic solutions and others. Prerequisite: Graduate standing, or consent of department.

CPE 800. Seminar. 1 Credits.
Every fall, five to six seminar sessions will be devoted to providing incoming students information on available thesis/dissertation research projects, library resources, computing environment and topics related to the issues of responsible scholarship in the fields of Chemical and Petroleum Engineering. For the remainder of the semester, the seminar will involve three presentations on current research and other topics of interest to chemical and petroleum engineers given by invited guest experts from the field. Other presentations are given by faculty and advanced graduate students. Student attendance is required. Graded on a satisfactory/unsatisfactory basis.

CPE 802. CEBC Colloquium. 0.5-1 Credits.
A forum in which graduate and postdoctoral students, and faculty present the results of CEBC research and literature surveys that support the mission of CEBC.

CPE 803. Research. 1-6 Credits.
For M.S. candidates. Graded on a satisfactory progress/limited progress/no progress basis.

CPE 804. Petroleum Management Seminar. 1 Credits.
Structure, operation, and problems of the petroleum industry from a management viewpoint. Presentations will be made by faculty, advanced students, and invited guests. Prerequisite: Permission of instructor.

CPE 825. Graduate Problems in Chemical and Petroleum Engineering. 1-5 Credits.
Advanced laboratory problems, special research problems, or library reading problems. Three hours maximum acceptable for master's degree.

CPE 902. Preparation for the Ph.D. Comprehensive Examination. 3 Credits.
Preparation of a research proposal in an area assigned by the student's advisory committee. The grade received on the Ph.D. comprehensive examination will apply to this credit. Graded on a satisfactory progress/limited progress/no progress basis.

CPE 904. Research. 1-12 Credits.
For Ph.D. candidates. Graded on a satisfactory progress/limited progress/no progress basis.

CPE 910. Industrial Development of Catalytic Processes. 3 Credits.

Students adopt an interdisciplinary team approach to developing strategies for the design and optimization of catalytic processes. Examples of case studies will be derived from industry or from research testbeds. Students collaborate in multiscale process development involving catalyst and reactor design, reaction system design, modeling and optimization, economic analysis and environmental assessment needed for the development of a catalytic process at either the pilot or production scale.

CPE 911. Industrial Practicum. 1-3 Credits.
Graduate students engage in an industrial research internship experience with collaborators in industry.

CPE 919. Advanced Topics in Process Modeling Simulation or Control: _____. 1-4 Credits.
Advanced study in process modeling, simulation or control on topics which may vary from year to year. Prerequisite: Graduate standing, C&PE 701 or equivalent, or consent of department.

CPE 929. Advanced Topics in Chemical and Petroleum Engineering: _____. 1-4 Credits.
Advanced study in various branches of chemical and petroleum engineering on topics which may vary from year to year.

Civil, Envr & Arch Engineering Courses

ARCE 101. Introduction to Architectural Engineering. 2 Credits.
An introduction to the study of and careers in architectural engineering, including building structures, building mechanical systems, building electrical systems, and construction management. Topics include problem solving and study skills, the building design and construction process, design documents, and professional practice issues such as licensing requirements and ethics.

ARCE 217. Computer-Assisted Building Design. 3 Credits.
Introduction to computer-aided design (CAD) tools. The course covers 2D drafting and 3D modeling using Autodesk's AutoCAD® and building information modeling (BIM) software Revit®. Includes architectural and structural design; mechanical, electrical, and plumbing (MEP) design; and modeling using the Family Editor in Revit. Prerequisite: Must be eligible for MATH 125 or MATH 145, or consent of instructor.

ARCE 315. Electric Circuits and Machines. 3 Credits.
Introduction to DC and AC electrical circuit analysis techniques, AC power calculations, transformers, three-phase systems, magnetic circuits, and DC and AC machines with a focus on applications. Not open to electrical or computer engineering majors. Prerequisite: A course in differential equations and eight hours of physics.

ARCE 350. Building Materials Science. 3 Credits.
An introduction to the structural, thermal, electrical, and optical properties of building materials. Manufacturing, testing, integration, and specification of materials with emphasis on commercial, institutional, and industrial buildings. Prerequisite: PHSX 212 or PHSX 214, and CHEM 150 or CHEM 149; or consent of instructor.

ARCE 351. Building Materials Science, Honors. 3 Credits.
An introduction to the structural, thermal, electrical, and optical properties of building materials. Manufacturing, testing, integration, and specification of materials with emphasis on commercial, institutional, and industrial buildings with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, and presentations. Prerequisite: PHSX 212 or PHSX 214, and CHEM 150 or CHEM 149; or consent of instructor.

ARCE 460. Building Thermal Science. 3 Credits.
The fundamentals of moist air processes, air and moisture exchange, and building heat transfer. Determination of heating and cooling loads under steady-state and transient conditions. Prerequisite: ME 212. Corequisite: CE 330 OR ME 510 OR AE 345 OR C&PE 511; or consent of instructor

ARCE 462. Building Thermal Science, Honors. 3 Credits.
The fundamentals of moist air processes, air and moisture exchange, and building hear transfer. Determination of heating and cooling loads under steady-state and transient conditions with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, and presentations. Prerequisite: ME 212. Corequisite: CE 330 or ME 510 or AE 345 or C&PE 511; or consent of instructor.

ARCE 490. Special Problems. 1-3 Credits.
Special problems in architectural engineering. The study of a particular problem involving individual research and report. Prerequisite: Students must submit, in writing, a proposal including a statement of the problem the student wishes to pursue, the methodology the student plans to use in the program, and objectives of the special problems. The student must also have a signed agreement with the faculty member proposed as instructor for the course. Consent of the instructor.

ARCE 491. Honors Research. 3 Credits.
Research a particular architectural engineering problem. Research will involve defining the problem, developing a research methodology, applying the research methodology and gathering data, analyzing and interpreting the data, and presenting the results of the research. The student must have a faculty sponsor and submit a proposal in writing stating the objective of the research, the planned research method that will be used, and the method of reporting the results. Prerequisite: Participation in the University Honors Program, consent of instructor, and approval of the chair are required.

ARCE 520. Architectural Acoustics. 3 Credits.
An introduction to the physics of sound. Objective and subjective evaluation and control of sound as applied to architectural spaces. Room shaping, mechanical and electrical system noise and vibration control, and electro-acoustic sound reinforcement. May not be taken for credit by students with credit for ARCE 520, ARCE 720, or ARCH 720. (Same as ARCH 520.) Prerequisite: Junior or Senior students or consent of instructor.

ARCE 521. Electro-Acoustical Systems. 3 Credits.
A study of electro-acoustic sound reinforcement and reproduction systems for buildings. May not be taken for credit by students with credit for ARCE 521, ARCE 721, or ARCH 721. (Same as ARCH 521.) Prerequisite: Junior/Senior standing or consent of instructor.

ARCE 540. Power Systems Engineering I. 3 Credits.
This course introduces the design of commercial and industrial power systems. Emphasis is placed on the proper selection, specification, and installation of materials and equipment that comprise commercial and industrial power systems. This course covers the application of materials and equipment in accordance with industry standards, independent laboratory testing, and the National Electrical Code. Prerequisite: ARCE 315 or EECS 315 or consent of instructor.

ARCE 541. Power Systems Engineering II. 3 Credits.
A continuation of ARCE 540 that integrates system components into functional, safe, and reliable power distribution systems for commercial, industrial, and institutional (CII) facilities. Service entrance design, distribution system layout and reliability, emergency and standby power system design, medium-voltage distribution systems, symmetrical fault analysis, and special equipment and occupancies. (Same as EECS 441.) Prerequisite: ARCE 540 or EECS 212 and Upper-Level EECS Eligibility.

ARCE 542. Power System Protection. 3 Credits.
This course introduces techniques and methods used to analyze and predict the performance of commercial and industrial power systems and equipment under balanced and unbalanced fault conditions. Emphasis

is placed on the selection, application, and coordination of protective devices to detect and clear power system faults in a safe and reliable manner. Prerequisite: ARCE 540 or EECS 212 or consent of instructor.

ARCE 545. Electric Energy Production and Storage. 3 Credits.
An introduction to the design of utility scale and small scale (distributed generation) electric energy production and storage systems. This course addresses the technical, operational, economic, and environmental characteristics associated with both traditional and nontraditional electric energy production systems along with associated grid integration, energy delivery, and regulatory issues. Traditional energy production systems covered include fossil fuel, hydroelectric, and nuclear power plants. Non-traditional energy productions systems covered include fuel cells, photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, and other emerging technologies. (Same as EECS 545.) Prerequisite: ARCE 540, or EECS 212 and Upper-Level EECS Eligibility.

ARCE 547. Power System Analysis. 3 Credits.
Introduction to the analysis of commercial, industrial, and utility power systems. Emphasis is placed on modeling system components which include transmission and distribution lines, transformers, induction machines, and synchronous machines and the development of a power system model for analysis from these components. System modeling will be applied to short-circuit studies and used to analyze symmetrical faults, to develop sequence networks using symmetrical components, and analyze unsymmetrical faults. (Same as EECS 547.) Prerequisite: ARCE 540, or EECS 212 and Upper-Level EECS Eligibility.

ARCE 550. Illumination Engineering. 3 Credits.
Students are introduced to lighting fundamentals, measurement, and technology and to their application in the analysis and design of architectural lighting systems. Prerequisite: PHSX 212 or PHSX 214; or consent of instructor.

ARCE 560. HVAC&R Systems Design. 3 Credits.
Analysis and design of heating, ventilating, air-conditioning, and refrigeration equipment and systems. Prerequisite: ARCE 460 or ARCE 462 or consent of the instructor.

ARCE 561. HVAC&R Systems Design, Honors. 3 Credits.
Analysis and design of heating, ventilating, air-conditioning, and refrigeration equipment and systems. The discussion section and its assignments are required. Not open for those with credit for ARCE 560. Prerequisite: ARCE 460 or ARCE 462, and either acceptance into the KU Honors Program or consent of the instructor.

ARCE 562. Water Systems Design. 3 Credits.
The analysis and design of hydronic systems for buildings including piping, plumbing, pumping, and the water-side of heating, ventilating, and air-conditioning (HVAC). Prerequisite: ME 510, AE 345, CE 330, or C&PE 511, or consent of the instructor.

ARCE 563. Energy Management. 3 Credits.
Energy usage in commercial buildings and industry, energy auditing methodology, utility analysis, management measures, and economic evaluation are covered. Includes fieldwork. Prerequisite: Corequisite: ARCE 460 or ARCE 462, or consent of instructor.

ARCE 565. Solar Energy Systems Design. 3 Credits.
A quantitative and qualitative study of active, passive, wind, and photovoltaic energy conversion systems for buildings. Solar radiation and system performance prediction. Prerequisite: ME 212 or C&PE 221, or consent of instructor.

ARCE 566. Fire Protection Engineering. 3 Credits.
An introduction to human response, fire science, combustion calculations, compartment fires, piping and sprinkler design, and smoke management. Analytical methods, experimental data, codes, case-studies, and videos are presented in this engineering design course. Prerequisite: ME 212 or C&PE 221, and ME 510, AE 345, CE 330, or C&PE 511, or consent of instructor.

ARCE 598. Comprehensive Design Project. 3 Credits.
Capstone architectural engineering design course that includes the analysis, design, and integration of a building's structural, mechanical, electrical, and lighting systems. Building codes, standards, performance, and sustainability are addressed, and BIM software utilized. Prerequisite: CMGT 457 and ARCE 540 and ARCE 550 and ARCE 560.

ARCE 720. Architectural Acoustics. 3 Credits.
An introduction to the physics of sound. Objective and subjective evaluation and control of sound as applied to architectural spaces. Room shaping, mechanical and electrical system noise and vibration control, and electro-acoustic sound reinforcement. May not be taken for credit by students with credit in ARCH 520/ARCE 520/ARCE 720. (Same as ARCH 720.)

ARCE 721. Electro-Acoustical Systems. 3 Credits.
A study of electro-acoustic sound reinforcement and reproduction systems for buildings. May not be taken for credit by students with credit in ARCH 521/ARCE 521/ARCE 721. (Same as ARCH 721.)

ARCE 740. Power Systems Engineering I. 3 Credits.
This course introduces the design of commercial and industrial power systems. Emphasis is placed on the proper selection, specification, and installation of materials and equipment that comprise commercial and industrial power systems. This course covers the application of materials and equipment in accordance with industry standards, independent laboratory testing, and the National Electrical Code. May not be taken for credit by students with credit for CE 540. Prerequisite: ARCE 315 or EECS 315 or equivalent, or consent of instructor.

ARCE 741. Power Systems Engineering II. 3 Credits.
A continuation of ARCE 740 that integrates system components into functional, safe, and reliable power distribution systems for commercial, industrial, and institutional (CII) facilities. Service entrance design, distribution system layout and reliability, emergency and standby power system design, medium-voltage distribution systems, symmetrical fault analysis, and special equipment and occupancies. May not be taken for credit by students with credit in ARCE 541. Prerequisite: ARCE 740, or consent of the instructor.

ARCE 742. Power System Protection. 3 Credits.
This course introduces techniques and methods used to analyze and predict the performance of commercial and industrial power systems and equipment under balanced and unbalanced fault conditions. Emphasis is placed on the selection, application, and coordination of protective devices to detect and clear power system faults in a safe and reliable manner. May not be taken for credit by students with credit in ARCE 542. Prerequisite: ARCE 740, or consent of instructor.

ARCE 745. Electric Energy Production and Storage. 3 Credits.
An introduction to the design of utility scale and small scale (distributed generation) electric energy production and storage systems. This course addresses the technical, operational, economic, and environmental characteristics associated with both traditional and nontraditional electric energy production systems along with associated grid integration, energy delivery, and regulatory issues. Traditional energy production systems covered include fossil fuel, hydroelectric, and nuclear power plants. Non-traditional energy productions systems covered include fuel cells, photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, and other emerging technologies. May not be taken for credit by students with credit in ARCE 545. Prerequisite: ARCE 740, or consent of instructor.

ARCE 747. Power System Analysis. 3 Credits.
An introduction to the analysis of commercial, industrial, and utility power systems. Emphasis is placed on modeling system components which include transmission and distribution lines, transformers, induction machines, and synchronous machines and the development of a power system model for analysis from these components. System modeling will be applied to short-circuit studies and used to analyze symmetrical faults, to develop sequence networks using symmetrical components, and analyze unsymmetrical faults. May not be taken for credit by students with credit in ARCE 547. Prerequisite: ARCE 740, or consent of instructor.

ARCE 750. Daylighting. 3 Credits.
This course will cover daylighting design concepts, solar position, daylight availability, sky luminance distribution models, daylight delivery methods, integration of daylighting and electric lighting controls, physical modeling, and computer analysis techniques. Prerequisite: PHSX 212 or PHSX 214, or ARCH 531; or consent of instructor.

ARCE 751. Advanced Lighting Design. 3 Credits.
Advanced analysis, design, and modeling of luminous environments. It covers impact of lighting on human perception and interaction with space, human factors in lighting, camera-aided light measurement technologies, advanced computer-aided lighting simulations, effective and efficient integration of natural and artificial lighting, modeling and analysis of light sources and spaces, simulation of lighting systems, and design of lighting control systems. Prerequisite: ARCE 217 and ARCE 650 or consent of instructor.

ARCE 752. Lighting Measurement and Design. 3 Credits.
This course will cover conventional lighting and solid-state lighting measurement, daylighting measurement, camera-aided lighting measurement technologies and applications, and design and development of custom luminaries in an LED workshop and innovative daylighting devices. Prerequisite: ARCE 650, or consent of instructor

ARCE 762. Water Systems Design. 3 Credits.
The analysis and design of hydronic systems for buildings including piping, plumbing, pumping, and the water-side of heating, ventilating, and air-conditioning (HVAC). May not be taken for credit by students with credit in ARCE 562. Prerequisite: ME 510, AE 345, CE 330, or C&PE 511, or equivalent, or consent of instructor.

ARCE 764. Advanced Thermal Analysis of Buildings. 3 Credits.
Manual and computational methods for determining steady-state and transient thermal loads in buildings. Advanced analysis of energy consumption given choices in building materials and mechanical systems. Prerequisite: ARCE 217 and ARCE 660 or ARCE 670; or consent of instructor.

ARCE 766. Fire Protection Engineering. 3 Credits.
An introduction to human response, fire science, combustion calculations, compartment fires, piping and sprinkler design, and smoke management. Analytical methods, experimental data, codes, case-studies, and videos are presented in this engineering design course. May not be taken for credit by students with credit in ARCE 566. Prerequisite: ME 212 or C&PE 331, and ME 510 or AE 345 or CE 330 or C&PE 511, or consent of instructor.

ARCE 767. Building Energy Modeling. 3 Credits.
This course introduces the basics and tools for building energy modeling. It covers the basic concepts and principles of building energy modeling, building energy analysis with whole building performance simulation tool EnergyPlus, and building energy systems and controls modeling with Modelica. Prerequisite: ARCE 560 or ARCE 561, or consent of instructor.

ARCE 891. Advanced Special Problems. 1-3 Credits.
A directed study of a particular complex problem in an area of architectural engineering or allied field. Prerequisite: Varies by topic, or with consent of instructor.

ARCE 895. Master's Project. 1-3 Credits.
Directed study and reporting of a specialized topic of interest to the architectural engineering profession. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

ARCE 899. Master's Thesis. 1-6 Credits.
Directed research and reporting of a specialized topic of interest to the architectural engineering profession. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

Civil, Envr & Arch Engineering Courses

CE 101. Introduction to Civil and Environmental Engineering. 2 Credits.
An introduction to the study of and careers in civil and environmental engineering, including structural engineering, transportation engineering, geotechnical engineering, construction management, water resources engineering, and environmental design and sustainability. Topics include problem solving and study skills, the engineering design and construction process, design documents, and professional practice issues such as licensing requirements and ethics.

CE 191. Introduction to Civil Engineering. 2 Credits.
A discussion of engineering logic through examination of current concepts in engineering education, practice and professional development. Not open to juniors and seniors.

CE 201. Statics. 2 Credits.
The principles of statics, with particular attention to engineering applications. (Same as AE 201.) Prerequisite: MATH 125 or MATH 145 or MATH 116. Corequisite: EPHX 210 or PHSX 211 or PHSX 213.

CE 240. Geomatics. 3 Credits.
This course introduces engineering applications of surveying and geographic information systems GIS) using surveying instruments and ArcGIS. The focus of this course is on practical application of geomatics to civil engineering problems. Two lectures periods and one lab period per week. Prerequisite: MATH 125 or MATH 145 or MATH 116; ARCE 217; or consent of instructor.

CE 250. Dynamics. 3 Credits.
The principles of kinematics and kinetics, with particular attention to engineering applications. (Same as AE 250.) Prerequisite: CE 201 or AE 201 or ME 201 or ME 211, and MATH 126 or MATH 146, and EPHX 210 or PHSX 211 or PHSX 213.

CE 260. Statics and Dynamics. 5 Credits.
A combination of statics and dynamics covered in CE 201 and CE 250. This course must be taken as a five-hour unit. (Same as AE 260.) Prerequisite: EPHX 210 or PHSX 211 or PHSX 213, and MATH 126 or MATH 146.

CE 310. Strength of Materials. 3 Credits.
Principles of stress and deformation in solid objects. (Same as AE 310.) Prerequisite: CE 201 or AE 201 or CE 260 or AE 260 or ME 201 or ME 211, and EPHX 210 or PHSX 211 or PHSX 213. Corequisite: MATH 220 or MATH 221 or MATH 320; or consent of instructor.

CE 312. Strength of Materials, Honors. 3 Credits.
Principles of stress and strain in solid objects with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, and presentations. (Same as AE 312.) Prerequisite: CE 201 or AE 201 or CE 260 or AE 260 or ME 201 or ME 211, and EPHX 210 or PHSX 211

or PHSX 213. Corequisite: MATH 220 or MATH 221 or MATH 320; or consent of instructor.

CE 320. Numerical Methods for Civil Engineering. 3 Credits.
This course covers basic concepts of computational methods including; errors and accuracy; matrix operations; eigenvalues and vectors; numerical solution of non-linear equations; iterative methods for solving systems of linear algebraic equations; interpolation and numerical differentiation and integration. This is all done within a Python programming framework as students solve problems within a Civil Engineering context. Prerequisite: MATH 126 or MATH 146.

CE 330. Fluid Mechanics. 3 Credits.
This course covers the fundamentals of fluid mechanics and includes the topics fluid properties, hydrostatics, applications of conservation of mass, energy and momentum equations, pipe flow, dimensional analysis and open channel flow. Prerequisite: ENGL 101 or ENGL 102 or ENGL 105 or have an English ACT score of 27 or higher or a Verbal SAT score of 600 or higher, and CE 250 or AE 250 or CE 260 or AE 260.

CE 331. Fluid Mechanics Lab. 1 Credits.
This is an experimental course that consists of several laboratory experiments intended to illustrate the concepts presented in CE 330, Fluid Mechanics. Prerequisite: ENGL 101 or ENGL 102 or ENGL 105 or have an English ACT score of 27 or higher or a Verbal SAT score of 600 or higher, and CE 250 or AE 250 or CE 260 or AE 260. Corequisite: CE 330.

CE 412. Structural Engineering Materials. 3 Credits.
Study of the engineering properties of structural materials and their control with emphasis on timber, concrete, and steel. Two one-hour lectures and one three-hour laboratory. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312 and ENGL 102 or ENGL 105; or consent of instructor.

CE 413. Structural Engineering Materials, Honors. 3 Credits.
Study of the engineering properties of structural materials and their control with emphasis on timber, concrete, and steel. Two one-hour lectures and one three-hour laboratory. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312 and ENGL 102 or ENGL 105. Open only to students admitted to the University Honors Program or by consent of instructor.

CE 455. Hydrology. 3 Credits.
An introduction to the fundamentals of hydrologic analysis. Subjects covered include collection and initial reduction of hydrologic data; rainfall-runoff relationships, hydrograph development; hydrologic routing, well equations and their application and hydrologic frequency analysis. Prerequisite: ENGL 101, ENGL 102 or ENGL 105. Co or pre-requisite: CE 330.

CE 461. Structural Analysis. 3 Credits.
Three one-hour lectures and one two-hour laboratory. Analysis of statically determinate and indeterminate beams, frames, and trusses using classical methods and introducing computer-based methods. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312.

CE 477. Introduction to Environmental Engineering and Science. 3 Credits.
Application of fundamental scientific principles to the protection of atmospheric, aquatic, and terrestrial environments through the use of pollution abatement processes, with consideration also given to economic, social, political, and legal aspects of pollution control. Prerequisite: ENGL 102 or ENGL 105, MATH 101 or MATH 104, and CHEM 135 or CHEM 175 or CHEM 195 or CHEM 149 or CHEM 150.

CE 479. Introduction to Environmental Engineering and Science, Honors. 3 Credits.
Application of fundamental scientific principles to the protection of atmospheric, aquatic, and terrestrial environments through the use of pollution abatement processes, with consideration also given to economic, social, political, and legal aspects of pollution control. Open only to students admitted to the University Honors Program or by consent of instructor. Prerequisite: ENGL 102 or ENGL 105, MATH 101 or MATH 104, and CHEM 135 or CHEM 175 or CHEM 195 or CHEM 150 or CHEM 149.

CE 480. Introduction to Transportation Engineering. 3 Credits.
Students are provided with a solid introduction to the principles of highway engineering and traffic analysis. This course will present a large number of practical problems, and in sufficient depth, such that the student will be capable of solving real highway-related problems. Prerequisite: CE 240.

CE 484. Materials for Transportation Facilities. 3 Credits.
Principles involved in the testing, behavior, and selection of materials for use in the transportation field. Emphasis is on bituminous materials, aggregate, and soil stabilization. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312.

CE 485. Materials for Transportation Facilities, Honors. 3 Credits.
Principles involved in the testing, behavior, and selection of materials for use in the transportation field. Emphasis is on bituminous materials, aggregate, and soil stabilization with added honors-enhancement activities. The activities include one or more of the following: extra meetings outside the classroom, written work, projects, presentations, and lab activities. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312, or consent of instructor.

CE 487. Soil Mechanics. 4 Credits.
Three lecture periods and one laboratory period. Fundamental theories of soil mechanics and their applications in engineering. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312, corequisite or prerequisite CE 330.

CE 490. Special Problems. 1-5 Credits.
An advanced study related to a special problem in the field of civil engineering or allied fields, for upper-division undergraduate students.

CE 495. Special Topics: _____. 1-3 Credits.
A course or colloquium to present topics of special interest. Prerequisite: Varies by topic.

CE 497. Extended Topics: _____. 1 Credits.
An extension of specific CE courses in order to meet transitional degree requirements. This course does not meet the CE technical elective requirements or the ARCE engineering science/engineering design elective. Prerequisite: Varies by topic or with consent of instructor.

CE 501. Engineering Ethics. 2 Credits. AE51
An examination of the ethical and social implications of being a professional engineer. Through the use of case studies, issues such as professional responsibility to clients, employers, and the public will be evaluated in light of professional codes of ethics. Prerequisite: Junior or Senior standing.

CE 525. Applied Probability and Statistics. 3 Credits.
Course topics include data description, measures of central tendency and dispersion, sampling and sampling designs, quality control, persistence, periodicity, sampling distributions, hypothesis testing, ANOVA, correlation, linear regression, multiple correlation, and multiple regression. Applications and real world problems are stressed. This course is offered at the 500 and 700 level with additional assignments at the 700 level. May not be taken for credit by students with credit in CE 725. Prerequisite: MATH 125 or MATH 145 or MATH 116.

CE 535. Engineering Applications of GIS. 3 Credits.
This course introduces engineering applications of geographic information system (GIS) using ArcGIS. The focus of this course is on practical

application of GIS to civil engineering problems. Prerequisite: Junior or Senior standing, or consent of instructor.

CE 550. Life Cycle Assessment. 3 Credits.
Life cycle assessment (LCA) is a tool used across engineering fields to determine the life cycle, cradle-to-grave environmental impacts of a product or process. LCA practice helps develop a systems-thinking perspective and a deeper understanding of sustainability. Students will evaluate LCA methods and design appropriate LCA frameworks. Prerequisite: CE 477 or CE 479 or C&PE 211.

CE 552. Water Resources Engineering Design. 3 Credits.
Three one-hour lectures and one three-hour laboratory. Study of water resources structures and systems with design emphasis on the hydraulic features: dams, drainage, river engineering, pipelines, channels and hydraulic machinery. Prerequisite: CE 330 and CE 455.

CE 555. Open Channel Flow. 3 Credits.
Study of uniform and non-uniform steady flow of water in open channels, including backwater curves, the hydraulic jump, and the delivery of canals. Prerequisite: CE 330 or equivalent.

CE 562. Design of Steel Structures. 3 Credits. AE61 CAP
Two one-hour lectures and one three-hour laboratory. Fundamentals of structural design with steel. Prerequisite: CE 461.

CE 563. Design of Reinforced Concrete Structures. 3 Credits.
Fundamentals of structural design with reinforced concrete. Prerequisite: CE 461 and CE 412 or CE 413 or CE 484 or ARCE 350; or consent of the instructor.

CE 570. Concepts of Environmental Chemistry. 3 Credits.
The fundamentals of aquatic chemistry, with emphasis on application to water purification and wastewater treatment. Prerequisite: Undergraduate standing, CE 477 or CE 479, and MATH 115 or MATH 125 or MATH 145.

CE 571. Environmental Engineering Laboratory. 3 Credits.
A laboratory course introducing standard practices for measurement, analysis, and reporting of environmental data. Emphasis is placed on learning common analytical techniques used in environmental engineering and science. Prerequisite: Undergraduate standing, CE 477 or CE 479 or equivalent, and MATH 115 or MATH 125 or MATH 145.

CE 573. Biological Principles of Environmental Engineering. 3 Credits.
A basic study of the microorganisms of importance in environmental engineering. Emphasis is placed on the microbiology of dilute nutrient solutions. Microbial physiology, microbial ecology, and biochemistry will be discussed as they pertain to environmental engineering and science. Both biodegradation and public health aspects are included. Prerequisite: Undergraduate standing, CE 477 or CE 479 or equivalent, and MATH 115 or MATH 125 or MATH 145.

CE 574. Design of Air Pollution Control Systems. 3 Credits.
This course emphasizes understanding of air pollution problems and their solution through engineering design and science. Topics covered include: types of air pollutants; monitoring of air pollutants; transport of air pollutants in the atmosphere; and control of air pollution emissions from both stationary and mobile sources. Prerequisite: CE 330, CE 477 or CE 479, MATH 126 or MATH 146, PHSX 212 or PHSX 214; or consent of instructor.

CE 576. Municipal Water Supply and Wastewater Treatment. 3 Credits. AE61 CAP
The principles of public water supply design, including source selection, collection, purification, and distribution; for municipal wastewater, collection, treatment, and disposal. Prerequisite: CE 330 or C&PE 511, CE 477 or CE 479.

CE 582. Highway Engineering. 3 Credits.
A comprehensive study of the planning, design, construction, operations, and maintenance of highway systems with emphasis on the design aspects of a highway. Prerequisite: CE 455 and CE 480.

CE 588. Foundation Engineering. 3 Credits.
A study of the interaction of the characteristics of soil or rocks and structures. The estimation of settlement and bearing capacity of foundation elements. Principles governing the choice and design of footings, rafts, piers, and piles. Prerequisite: CE 487.

CE 677. Graduate Fundamentals of Environmental Engineering. 3 Credits.
Application of fundamental scientific principles to the protection of atmospheric, aquatic, and terrestrial environments through the use of pollution abatement processes, with consideration also given to economic, social, political, and legal aspects of pollution control. May not be taken for credit by students with credit in CE 477. Prerequisite: ENGL 102 or ENGL 105, MATH 101 or MATH 104, and CHEM 135 or CHEM 175 or CHEM 150.

CE 684. Materials for Transportation Facilities. 3 Credits.
Principles involved in the testing, behavior, and selection of materials for use in the transportation field. Emphasis is on bituminous materials, aggregate, and soil stabilization. Readings. Prerequisite: CE 310 or AE 310 or CE 312 or AE 312, and CE 487.

CE 701. Engineering Ethics. 3 Credits.
An examination of the ethical and social implications of being a professional engineer and doing engineering research. Through the use of case studies, issues such as professional responsibility to clients, employers, and the public will be evaluated in light of professional codes of ethics. May not be taken for credit by students with credit in CE 501. Prerequisite: Graduate standing.

CE 704. Dynamics and Vibrations. 3 Credits.
Problems in engineering dynamics and vibrations. Topics include applications of generalized forces and coordinates, Lagrange equations, and a study of the performance of single and multiple degree of freedom in vibrational systems. (Same as AE 704.) Prerequisite: AE 508 or AE 509 or CE 461 or ME 628.

CE 710. Structural Mechanics. 3 Credits.
Basic concepts in the analysis of stress and strain and the behavior of materials. Topics include elementary theory and problems in elasticity, theories of failure of materials including fracture mechanics and introduction to plasticity.

CE 711. Probabilistic Design and Reliability. 3 Credits.
Learn to evaluate statistical data and develop engineering design criteria for natural and man-made random phenomena. Develop and be able to use material or system fragility curves. Analyze complex systems or alternate system probabilities using Monte Carlo Simulation. Determine system reliability for statistically evaluated hazard probabilities. Techniques are applied to realistic design problems in Civil Engineering. Prerequisite: Graduate standing or permission of the instructor.

CE 712. Structural Engineering Materials. 3 Credits.
Study of the engineering properties of structural materials and their control with emphasis on timber, concrete, and steel. Two one-hour lectures and one three-hour laboratory. Not open for credit to students with credit in CE 412 or CE 413. Prerequisite: CE 310 or CE 312 or equivalent, and ENGL 102 or ENGL 105 or equivalent, or consent of instructor.

CE 713. Cold-formed Steel and Aluminum Design. 3 Credits.
Learn the principles of designing thin cold-formed and extruded materials. Focus is on cold-formed-steel with basic application to aluminum and

concepts of curtainwall design. Load bearing and non-load bearing applications. Determine properties and strengths of columns and beams composed of arbitrary formed shapes. Learn to apply Direct Design. Seismic and wind design of cold formed steel structures. Prerequisite: CE 562.

CE 714. Professional Practice. 3 Credits.
This course is the business of engineering. Topics include: case studies of design and construction litigation, proposals and contracts, managing risk and liability, principles of management and leadership, developing professional relationships, developing a quality culture, project and design accounting, errors and omissions, insurance, organizational structures, globalization, total quality management, and communications. Class participation is required. Prerequisite: Graduate standing or permission of the instructor.

CE 715. Corrosion Engineering. 3 Credits.
Electrochemical basis of corrosion. Estimating probability and rate of corrosion. Identifying different conditions likely to cause specific types of corrosion. Corrosion mitigation techniques. Prerequisite: CHEM 135, CHEM 150 or equivalent.

CE 716. Wind Engineering. 3 Credits.
This course teaches the assessment of wind loads on structures and structural response to wind loads. Topics include atmospheric boundary layer, non-synoptic winds (hurricanes, tornadoes, etc), modeling of wind turbulence using random process theory, bluff-body aerodynamics, response of structures to fluctuating wind loads, aeroelastic phenomena, and wind-load standards and design applications. Prerequisite: Graduate standing, or consent of instructor.

CE 721. Experimental Stress Analysis. 3 Credits.
Introduction to experimental stress-analysis techniques. Theory and application of mechanical strain gages, electrical strain gages, photoelastic techniques, and brittle coatings.

CE 725. Applied Probability and Statistics. 3 Credits.
Course topics include data description, measures of central tendency and dispersion, sampling and sampling designs, quality control, persistence, periodicity, sampling distributions, hypothesis testing, ANOVA, correlation, linear regression, multiple correlation, and multiple regression. Applications and real world problems are stressed. This course is offered at the 500 and 700 level with additional assignments at the 700 level. May not be taken for credit by students with credit in CE 525. Prerequisite: MATH 125 or MATH 145 or MATH 116.

CE 731. Applied Groundwater Modeling. 3 Credits.
This course focuses on how to construct simple to complex computer models of groundwater systems and systems in which water flows between groundwater and surface water bodies such as springs, streams and lakes. We consider water flow, transport of solutes, and density effects (from saltwater or brines). We consider the conjunctive use of groundwater and surface water (demand-driven, supply-limited problems), and managed aquifer recharge (MAR). We consider three aspects of model development: (1) how to compare the computer models we construct to the systems modelers intend them to represent, (2) how accurate the models are likely to be and how uncertainty can be quantified, and (3) how useful the models are in practice. (Same as GEOL 758.) Prerequisite: GEOL 751 or CE 752, or approved by the professor.

CE 732. River Engineering and Restoration. 3 Credits.
Principles of how rivers form and respond to disturbance, quantitative fluvial geomorphology, design of in-stream structures for bank stabilization and grade control, natural and nature-based features, sediment budgeting, and physical aspects of river restoration. This class utilizes industry standard software tools including HEC-RAS for geomorphic analysis and river stabilization design. Class includes site visits and/or float trips to observe natural river processes and river engineering structures. Prerequisite: CE 330 or equivalent and CE 487 or equivalent.

CE 735. Engineering Applications of GIS. 3 Credits.
This course introduces engineering applications of geographic information system (GIS) using ArcGIS. The focus of this course is on practical application of GIS to civil engineering problems.

CE 736. Environmental Monitoring and Field Methods. 3 Credits.
A lecture-laboratory-field sampling course to familiarize students with environmental monitoring techniques and open source data availability. Dimensions of environmental monitoring will be considered for air, soil, and water measurements. The major emphasis will be on surface water monitoring techniques and their principles, utility, and limitations. Prerequisite: CE 330 or consent of instructor.

CE 747. Principles of Sustainability and Resilience. 3 Credits.
This course teaches the core competencies of sustainability and resilience regarding the built environment. The course focuses on fundamental concepts and how they can be applied in engineering and community planning practice. Prerequisite: Senior or graduate standing or permission of the instructor.

CE 748. Climate Change: Assessment and Tools. 3 Credits.
The changing climate poses an increasing challenge to individuals, communities, and societies. The focus of this course is to provide students with a broad understanding of climate change, mitigation, adaptation, and resilience. With regard to mitigation, an examination is made of the technologies that are coming on-line and the progress being made to transition toward electrification and away from fossil fuels. Thereafter, the difference between adaptation and resilience is discussed in detail. The U.S. Global Climate Change Program's resilience toolbox and other tools are also reviewed. Case studies, inland and coastal, are used to examine the approach taken by the federal entity responsible for the navigable waters of the United States to design civil infrastructure and address climate change as part of the design process. Prerequisite: Senior or graduate standing or permission of the instructor.

CE 749. Solid and Hazardous Wastes. 3 Credits.
Fundamental issues associated with solid and hazardous wastes are presented. Topics include government regulations, waste characteristics and quantities, the transport and attenuation of wastes in the environment, risk assessment, and handling, treatment and disposal techniques. Special emphasis is placed on hazardous waste remediation strategies in terrestrial systems. Prerequisite: Graduate standing in the Environmental Science and Engineering program, or consent of instructor.

CE 751. Physical Hydrology. 3 Credits.
In this course students will develop a land surface model based on the underlying physics and mechanisms of radiative transfer, precipitation, snow processes, evapotranspiration, infiltration and runoff generation. The course will also cover numerical and uncertainty issues associated with hydrologic modeling and its application to real world problems. Prerequisite: CE 455 or equivalent.

CE 752. Physical Hydrogeology. 3 Credits.
Study of fluid flow in subsurface hydrologic systems. Investigation of the ground water environment including porosity, and hydraulic conductivity and their relationship to typical geologic materials. Examination of Darcy's law and the continuity equation leading to the general flow equations. Discussion of typical hydraulic testing methods to estimate aquifer parameters in various situations and apply these to water resource problems. Study of the basic mechanisms that determine the behavior of typical regional flow systems. (Same as GEOL 751.)

CE 753. Chemical and Microbial Hydrogeology. 3 Credits.
Lecture and discussion of chemical and microbiological controls on groundwater chemistry. Topics include thermodynamic and microbiological controls on water-rock reactions; kinetics; and microbiological, chemical and isotopic tools for interpreting water chemistry with respect to chemical weathering and shallow diagenesis. Origins of water chemistry, changes along groundwater flow paths, and an introduction to contaminant biogeochemistry will be discussed through the processes of speciation, solubility, sorption, ion exchange, oxidation-reduction, elemental and isotopic partitioning, microbial metabolic processes and microbial ecology. An overview of the basics of environmental microbiology, including cell structure and function, microbial metabolism and respiration, microbial genetics and kinetics of microbial growth will be covered. (Same as GEOL 753.) Prerequisite: One year of chemistry, one year of calculus, one year of biology, an introductory course in hydrogeology, or consent of the instructors.

CE 754. Contaminant Transport. 3 Credits.
A study of the transport of conservative and non-conservative pollutants in subsurface waters. Case studies are used to illustrate and develop a conceptual understanding of such processes as diffusion, advection, dispersion, retardation, chemical reactions, and biodegradation. Computer models are developed and used to quantify these processes. (Same as GEOL 754.) Prerequisite: Introductory Hydrogeology or consent of instructor.

CE 755. Open Channel Flow. 3 Credits.
A study of uniform and non-uniform steady flow of water in open channels, including backwater curves, the hydraulic jump, and the delivery of canals. Prerequisite: CE 330.

CE 756. Wetlands Hydrology and Introduction to Management. 3 Credits.
A study of the basic structure and functions of wetlands; the physical, chemical, and biological processes involved; and an introduction to the management of wetlands. Also a brief introduction to the legal aspects of wetlands, the Section 404 permitting processes, and mitigation requirements. Prerequisite: Senior or graduate standing in engineering or a science area, or consent of instructor.

CE 757. Pipe-Flow Systems. 3 Credits.
Hydraulic analysis and design of pipelines, pipe networks, and pumping systems. Analysis and control of hydraulic transients. Engineering of water distribution systems. Prerequisite: CE 330 or equivalent.

CE 759. Water Quality Modeling. 3 Credits.
Analytical and numerical modeling of transport and transformation processes in the aquatic environment. Mass balance principles in multi-dimensional transport phenomena including advection, turbulent diffusion, and dispersion. Prerequisite: CE 330, MATH 127 or MATH 147, and MATH 220 or MATH 221 or equivalent.

CE 760. Stochastic Hydrology. 3 Credits.
This methods-based course includes probability models, parameter estimation, ensemble forecasting and verification, time series analysis, multivariate distributions, principal component analysis along with other stochastic methods imperative to hydrologic analysis and prediction. The application of these methods will be explored through examples in hydrology related to rainfall, streamflow, groundwater and land-atmosphere interactions. Prerequisite: CE 455, MATH 290 or MATH 291 or equivalent.

CE 761. Matrix Analysis of Framed Structures. 3 Credits.
Analysis of 2-D and 3-D frame and truss structures by the direct stiffness method. Computer techniques required to implement the analysis procedure.

CE 763. Design of Prestressed Concrete Structures. 3 Credits.
The theory and design of prestressed concrete structures based on service load and strength criteria. Prerequisite: CE 563.

CE 764. Advanced Design of Reinforced Concrete Structures. 3 Credits.
The theory and design of reinforced concrete members and structures with emphasis on frames and slabs. Introduction to bridge design and earthquake design. Prerequisite: CE 563.

CE 765. Advanced Steel Design - Building Structures. 3 Credits.
The theory and design of standard steel framed structures (primarily buildings). Design philosophies, stability, composite design, structural behavior, preliminary design, and connections. Prerequisite: CE 562 or equivalent.

CE 766. Advanced Steel Design - Bridge Structures. 3 Credits.
Introduction to simple plastic design principles. Analysis and design of steel bridges including composite and noncomposite plate girders, curved girders, box girders, and other specialized bridge types. Fatigue and connection design considered. Prerequisite: CE 562 or equivalent.

CE 767. Introduction to Fracture Mechanics. 3 Credits.
Theories and modes of structural failure as related to structural design. Application of fracture mechanics to failure analysis, fracture control plans, fatigue crack growth, and stress-corrosion crack growth. Prerequisite: CE 310 or CE 312 plus a structural or mechanical design course.

CE 768. Design of Timber Structures. 3 Credits.
Provide an introduction to behavior, analysis and design of timber components and systems. Prerequisite: CE 461.

CE 769. Design of Masonry Structures. 3 Credits.
Provide an introduction to behavior, analysis and design of masonry components and systems. Prerequisite: CE 461.

CE 770. Concepts of Environmental Chemistry. 3 Credits.
The fundamentals of aquatic chemistry, with emphasis on application to water purification and wastewater treatment. May not be taken for credit by students with credit in CE 570. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and five hours of chemistry.

CE 771. Environmental Engineering Laboratory. 3 Credits.
A laboratory course introducing standard practices for measurement, analysis, and reporting of environmental data. Emphasis is placed on learning common analytical techniques used in environmental engineering and science. May not be taken for credit by students with credit in CE 571. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and five hours of chemistry.

CE 772. Physical Principles of Environmental Engineering Processes. 3 Credits.
Physical principles of suspensions, kinetics, fluid flow, filtration, and gas transfer are applied to various environmental physical processes. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and four hours of physics.

CE 773. Biological Principles of Environmental Engineering. 3 Credits.
A basic study of the microorganisms of importance in environmental engineering. Emphasis is placed on the microbiology of dilute nutrient solutions. Microbial physiology, microbial ecology, and biochemistry will be discussed as they pertain to environmental engineering and science. Both biodegradation and public health aspects are included. May not be taken for credit by students with credit in CE 573. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and five hours of chemistry.

CE 774. Chemical Principles of Environmental Engineering Processes. 3 Credits.
Chemical principles of stoichiometry, thermodynamics, and kinetics are applied to various chemical processes having application in the field of environmental engineering and science, including adsorption, ion exchange, coagulation, oxidation, and precipitation. Prerequisite: CE 477 or CE 479 or equivalent, calculus, and credit or registration in CE 570 or CE 770.

CE 775. Stormwater Treatment Systems Design. 3 Credits.
This course will address the design of stormwater treatment systems to provide hydrological control and water quality improvement. Specific topics include common stormwater pollutants, contaminant loading during storm events, design of structural BMPs (detention basins, traps, filters, and vegetated control systems) and low impact development practices. Prerequisite: CE 477 or CE 479, either CE 455 or C&PE 511 or consent of instructor.

CE 776. Water Reuse. 3 Credits.
This course addresses past and current water reclamation and reuse practices; health and environmental concerns associated with water reuse; technologies and systems for water treatment, reclamation, and reuse; water reuse applications, including agricultural reuse, direct and indirect potable reuse, landscape irrigation, industrial uses, urban non-irrigation applications, environmental and recreational uses, and groundwater recharge; and planning and implementation of water reuse systems. Prerequisite: CE 477 or CE 479 or equivalent.

CE 777. Industrial Water and Wastes. 3 Credits.
A review of the methods of industrial water treatment and the fundamentals of industrial wastewater pollution control. Topics include: water budgets, cooling tower and boiler treatment, corrosion control, government regulations, wastewater characterization, waste minimization, pilot plants, pretreatment, final treatment, and site selection. May not be taken for credit by students with credit in CE 577. Prerequisite: CE 477 or CE 479 or equivalent.

CE 778. Air Quality. 3 Credits.
The course is intended to provide a working knowledge of pollutant sources, effects, meteorological factors, measurements, modeling approaches, legislation and controls associated with air quality problems. Students work on problems drawn from typical industrial situations, and use models to address specific air pollution scenarios. Prerequisite: CE 477 or CE 479 or equivalent, and MATH 115 or MATH 125 or MATH 145.

CE 781. Traffic Engineering Characteristics. 3 Credits.
A study of fundamental traits and behavior patterns of the road user and his or her vehicle in traffic. The major content involves techniques for obtaining data, analyzing data and interpreting data on traffic speed, volume, streamflow, parking and accidents. Capacity analyses using the most up to date procedures for major traffic facilities such as undivided highways, city streets, freeways, interchanges and intersections are also discussed at length. Prerequisite: CE 582 or equivalent.

CE 786. Highway Safety. 3 Credits.
Several topics dealing with highway safety are presented and discussed. Typical topics are railroad/highway crossings, accident reconstruction, distractions to the drivers, speed and crashes, elderly drivers, traffic control devices, roadside design, access management, traffic calming devices, and crash rates.

CE 787. Advanced Soil Mechanics. 3 Credits.
A comprehensive study of soil behavior. Topics include stress-strain behavior for soils under a variety of loading conditions, critical state soil mechanics theory, consolidation prediction, modeling subsurface water flow, and other topics. Prerequisite: CE 487 or equivalent.

CE 788. Geotechnical Engineering Testing. 3 Credits.
Three lectures. Field testing techniques, sampling methods, and laboratory testing procedures used to determine soil properties for engineering projects. Prerequisite: CE 487.

CE 790. Traffic Simulation Modeling and Analysis. 3 Credits.
This course introduces popular tools for modeling, analyzing and optimizing various transportation elements. Students will learn to formulate and apply basic principles of simulation modeling; use simulation and optimization techniques for improving traffic operations of a signalized intersection, an urban street network, and a freeway facility; and apply processes for developing simulation applications. Prerequisite: CE 781 or equivalent, or consent of instructor.

CE 799. Graduate Internship. 1-3 Credits.
An applied course intended to provide a practical educational opportunity which prepares students for professional practice in the fields of civil, environmental, and/or architectural engineering and any sub-discipline therein. Prerequisite: Graduate standing and department approval required to enroll.

CE 801. Energy Methods. 3 Credits.
The methods of analysis by energy methods of mechanics problems. Includes variational energy principles, calculus of variations, stationary energy and complementary energy principles, and the principle of virtual work. Applications. Prerequisite: CE 310 or CE 312 and MATH 320.

CE 804. Advanced Structural Dynamics. 3 Credits.
Advanced topics in structural dynamics, including experimental modal analysis, digital signal processing, data acquisition and analysis, random vibration concepts, system identification, structural health monitoring and damage detection, and introduction to smart structures technology (e.g. smart sensing, estimation, and control). This course provides practical laboratory experience through state-of-the-art commercial testing equipment and software. Prerequisite: CE 704 or consent of instructor.

CE 810. Theory of Elastic Stability. 3 Credits.
Buckling of columns in the elastic or hyperelastic region. Lateral and torsional buckling of straight and curved members. Buckling of plates and shells.

CE 815. Viscoelasticity of Solids. 3 Credits.
This course provides the basics of mechanical and mathematical modeling and characterization of linear viscoelastic materials. Topics include different viscoelastic models, experimental methods for characterization of viscoelastic materials, design methods for viscoelastic members, and introduction to temperature effects and nonlinear viscoelastic response of materials. Prerequisite: CE 310 or CE 312 or equivalent.

CE 820. Responsible Scholarship in CEAE. 1 Credits.
Principles and practices of responsible scholarship in research, with emphasis on ethical and professional conduct in engineering and the sciences. The course prepares doctoral students to identify and address ethical challenges in scholarship and to contribute to their discipline with integrity and accountability. Prerequisite: Graduate standing, or consent of instructor.

CE 850. Life Cycle Assessment. 3 Credits.
Life cycle assessment (LCA) is a tool used across engineering fields to determine the life cycle, cradle-to-grave environmental impacts of a product or process. LCA practice helps develop a systems-thinking perspective and a deeper understanding of sustainability. Students

will evaluate LCA methods and design appropriate LCA frameworks. Prerequisite: CE 477 or CE 479 or C&PE 211 or equivalent.

CE 857. Sediment Transport. 3 Credits.
A study of the transport of sediment in alluvial channels. Specific topics include properties of sediment, mechanics of bed forms, particle entrainment, scour analysis, prediction of suspended load and bed load, design of stable channels and diversion works, and sedimentation of reservoirs. Prerequisite: CE 755 or consent of instructor.

CE 859. Erosion and Sedimentation. 3 Credits.
A study of sediment erosion, transport, and deposition at the watershed scale with particular application to water quality degradation and reservoir infilling. Prerequisite: Graduate standing.

CE 861. Finite Element Methods for Solid Mechanics. 3 Credits.
Stress analysis of 2-D and 3-D solids, plates, and shells by the finite element method. Element formulations and behavior with emphasis on the isoparametric concept. Computer modeling and interpretation of results. Introduction to material and geometric nonlinear analysis of solids. Prerequisite: CE 761 or equivalent.

CE 862. Behavior of Reinforced Concrete Members. 3 Credits.
This mechanics course covers in detail the constitutive behavior of reinforced concrete members subjected to various types of loading and presents the basis for modeling the response of reinforced concrete structures in the nonlinear range of response. Topics covered include: stress-strain behavior of concrete under multi axial states of stress; moment-curvature analysis; advanced analysis of r/c members subjected to shear (variable angel truss models, modified compression field theory, strut-and-tie models); behavior of r/c members subjected to cyclic loading; modeling and effects of slip at the interface between reinforcing steel and concrete. Suggested prerequisite CE 764 or equivalent. Prerequisite: CE 563.

CE 864. Seismic Performance of Structures. 3 Credits.
This course builds on topics from structural dynamics to introduce principles of structural performance during earthquake events. Emphasis is placed on estimating the response of building structures as represented by simple and complex models. Topics covered include strong ground motion, response of simple systems to ground motion, nonlinear response of building systems, and performance-based earthquake engineering. Prerequisite: CE 704.

CE 874. Air Pollution Control. 3 Credits.
The design of control devices for the abatement of air pollutants, both gaseous and particulate, emitted from stationary sources. This includes the basic theory of control device operation and economic factors associated with each type of control device design. Prerequisite: CE 772 and CE 778 or equivalent.

CE 876. Wastewater Treatment Plant Design. 3 Credits.
Application of physical, chemical, and biological principles to the design of wastewater treatment systems for domestic and other wastewaters. Special emphasis is placed on biological treatment processes. Prerequisite: CE 576 or equivalent, or CE 573 or CE 773 or equivalent.

CE 877. Water Treatment Plant Design. 3 Credits.
Application of physical, chemical, and biological principles to the design of water treatment plants and processes for domestic water supply from surface and ground water sources. Prerequisite: CE 774, or concurrent enrollment.

CE 878. Air Quality Modeling. 3 Credits.
Fundamental physical and mathematical principles applied to air quality modeling; considered are factors that influence the choice and application of air quality models, as well as the interpretation of model output data. Practical applications are stressed using standard models. Prerequisite: CE 778 or equivalent and MATH 125 or MATH 145 or MATH 526 or CE 625.

CE 881. Traffic Engineering Operations. 3 Credits.
A study of theory and practical applications of a number of traffic operational and management tools to achieve the convenient, safe and efficient movement of people and goods in urban street networks. The major content involves signalized intersection capacity, design and operation; signalized intersection coordination; and modern roundabout design. Prerequisite: CE 582 or equivalent.

CE 882. Geometric Design of Traffic Facilities. 3 Credits.
A study of basic principles in the design of freeways, urban street systems, parking terminal and other traffic facilities with emphasis on capacity, safety, level of service, and dynamic design concept. Prerequisite: CE 781 or equivalent.

CE 883. Transportation Cyber-Physical Systems. 3 Credits.
This course provides a comprehensive introduction to the methods and principles of cyber-physical systems (CPS), with a focus on applications in the transportation domain—specifically, transportation cyber-physical systems (T-CPS). Topics include systems theory, data-driven CPS methods, security and privacy, and emerging frontiers. Upon completing this course, students will: (i) gain an understanding of what CPS are and how they relate to civil infrastructure and intelligent transportation systems; (ii) learn the fundamentals of systems theory necessary to analyze T-CPS within a systems-theoretic framework; and (iii) learn how to apply data-driven CPS methods to transportation-related problems. Prerequisite: MATH 290 or equivalent; or consent of instructor.

CE 884. Principles of Pavement Design. 3 Credits.
A study of the scientific principles of pavement design as applied to airfield and highway pavements, considering loading conditions, stress distribution, and the properties of the various pavement components, for both rigid and flexible pavements. Prerequisite: CE 487 or equivalent.

CE 885. Advanced Foundation Engineering. 3 Credits.
A study in the design, construction, and behavior of footings and rafts, piles and drilled shafts founded on soils and rocks. Prerequisite: CE 588 or equivalent.

CE 887. Earth Structures. 3 Credits.
Current theory and practice relating to the design of retaining walls, earth slopes, large embankments, and landslide mitigation. Application of geotextiles to the design of earth retaining structures and slope stabilization. Prerequisite: CE 588 or consent of instructor.

CE 888. Ground Improvement. 3 Credits.
Basic descriptions, classification, principles, advantages, and limitations of ground improvement techniques. Design, construction, and quality assurance/control of ground improvement techniques. Prerequisite: CE 588 or equivalent.

CE 889. Designing with Geosynthetics. 3 Credits.
Basic description and properties of geosynthetics including geotextiles, geogrids, geomembranes, geonets, geocomposites, and geosynthetic clay liners. Geosynthetic functions and mechanisms including separation, filtration, drainage, reinforcement, and containment. Design with geosynthetics for roadways, embankments/slopes, earth retaining structures, and landfills. Prerequisite: CE 588 or equivalent.

CE 890. Master's Project. 1-4 Credits.
Directed study and reporting of a specialized topic of interest in civil engineering or an allied field. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

CE 891. Advanced Special Problems. 1-3 Credits.

A directed study of a particular complex problem in an area of civil engineering or allied field. Prerequisite: Varies by topic, or with consent of instructor.

CE 892. Structural Engineering and Mechanics Seminar. 1 Credits.

Presentation and discussion of current research and design in structural engineering and engineering mechanics.

CE 895. Advanced Special Topics: _____. 1-3 Credits.
A graduate course or colloquium in a topic of civil engineering or an allied field. Prerequisite: Varies by topic, or with consent of instructor.

CE 899. Master's Thesis. 1-10 Credits.
Directed research and reporting of a specialize topic of interest in civil engineering or an allied field. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

CE 991. Research. 1-15 Credits.
An investigation of a special problem directly related to civil engineering. Graded on a satisfactory progress/limited progress/no progress basis.

CE 999. Ph.D. Dissertation. 1-15 Credits.
Restricted to Ph.D. candidates. Before candidacy, aspirants performing their research should enroll in CE 991. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

Civil, Envr & Arch Engineering Courses

CMGT 457. Construction Project Management. 3 Credits.
An introduction to the management of construction projects with an emphasis on engineering economics. This course addresses time value of money, cash flow and interest, financial analysis of alternatives, and taxes and depreciation. Also included are projects management fundamentals, project scheduling, and project controls. Prerequisite: MATH 126 or MATH 146 or consent of the instructor.

CMGT 500. Construction Engineering. 3 Credits.
An introduction to the construction industry, construction project management, and construction operations. Topics include project participant roles and responsibilities; project delivery systems; procurement of construction services; sustainable construction; contracts, bonds, and insurance; equipment selection and use; constructability and value engineering; estimating and bidding; planning and scheduling; operations management; safety; and project commissioning and closeout. Prerequisite: Junior or Senior standing in the School of Engineering, or consent of the instructor.

CMGT 700. Construction Project Management. 3 Credits.
An introduction to the management of construction projects. This course addresses project delivery systems, project organization, estimating and bidding, planning and scheduling, legal and safety issues, among other topics. Prerequisite: Graduate standing or consent of instructor. Not open to those with credit in CMGT 500.

CMGT 701. Construction Planning and Scheduling. 3 Credits.
An introduction to the planning and scheduling of projects, for both construction and design. Emphasis is placed on the critical path method including network development, production of time schedules, time-cost considerations, and the efficient utilization of resources. Manual and computer techniques are covered. Prerequisite: Graduate standing or consent of instructor.

CMGT 702. Construction Equipment and Methods. 3 Credits.
This course introduces the student to the multitude of construction equipment employed in construction. The underlying technology and engineering principles are reviewed. Principles of equipment selection, equipment utilization, and equipment economic analysis are covered. Prerequisite: Graduate standing or consent of instructor.

CMGT 703. Construction Quality and Productivity. 3 Credits.
Operations analysis for work improvement in construction using process charts, work sampling, productivity tracking, and planning techniques. Quality control and quality assurance techniques are covered, including the measurement, collection, and interpretation of quality data. Prerequisite: CMGT 500 or CMGT 700, or consent of instructor.

CMGT 704. Construction Estimating and Bidding. 3 Credits.
A study of the quantity survey, cost estimating, scheduling and project controls; construction operations; and methods of building construction. Prerequisite: Graduate standing or consent of instructor.

CMGT 705. Construction Contracts, Bonds, and Insurance. 3 Credits.
Legal doctrines relating to owners, design professionals, and contractors. Sources of law, forms of association, and agency. Contract formation, rights and duties, interpretation, performance problems, disputes, and claims. Surety bonds and insurance. Prerequisite: Graduate standing or consent of instructor.

CMGT 706. Construction Alternative Project Delivery Methods. 3 Credits.
Learn the types of alternative project delivery methods that are increasingly used in the design and construction industry, including Design-Build (DB), Construction Manager at Risk (CMAR or CM/GC), Integrated Project Delivery (IPD), Public-Private-Partnerships (P3), and more. Within these methods, the course focuses on the industry's expanding scope of preconstruction services and increasing integration between design and construction professionals. Prerequisite: Graduate standing or consent of instructor.

CMGT 707. Engineering Risk and Decision Analysis. 3 Credits.
The course investigates the fundamental principles and techniques of risk and decision analysis. It applies these principles in project-level decisions in which risk or uncertainty play a central role. The course examines various risk and decision tools including Monte Carlo analyses, influence diagrams, and other types of multi-criteria decision analyses. In addition to teaching to the skills and techniques, the course will introduce students to new ideas and concepts regarding decision and risk analysis. Prerequisite: CMGT 500 or CMGT 700, CE 625 or MATH 526, or consent of instructor.

CMGT 711. Construction Safety. 3 Credits.
This course's primary purpose is to help students understand construction safety theories and practices. Methods used to improve construction safety are introduced. A class project is used to help students explore and identify opportunities to improve construction safety. Prerequisite: Graduate standing or consent of instructor.

CMGT 712. Construction Safety Solution Development. 3 Credits.
This course aims to help students develop solutions to improve construction safety. Solution development focuses on improving safety issues faced in the construction industry, including but not limited to software, hardware, processes, methods, and concepts. Prerequisite: Graduate standing or consent of instructor.

CMGT 713. Request for Proposals in Design and Construction. 3 Credits.
The design & construction industry is shifting away from low bid toward qualifications-based procurement methods. The course examines the most common Request for Proposal processes used by owners to select design & construction teams in a variety of delivery methods. The course

will also introduce students to practical strategies to compete in these RFP scenarios. Prerequisite: Graduate standing or consent of instructor.

CMGT 891. Advanced Special Problems. 1-3 Credits.
A directed study of a particular complex problem in an area of construction management or allied field. Prerequisite: Varies by topic, or with consent of instructor.

CMGT 895. Construction Management Project. 1-3 Credits.
Graduate-level investigation and report on a construction management topic mutually agreed on by the student and project advisor. This is the capstone course in the Master of Construction Management (MCM) degree program. Successful completion of this project requires acceptance of the written report and oral presentation to the student's graduate committee. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Approval of project topic by project advisor, CMGT 500 or CMGT 700, CMGT 701, CMGT 702, CMGT 703, CMGT 704, CMGT 705, and nine elective credit hours, or consent of instructor.

Electrical Engr & Computer Sci Courses

EECS 101. New Student Seminar. 1 Credits.
A seminar intended to help connect freshmen and transfer EECS students to the EECS department, their chosen profession, and each other. Topics include overviews of the various disciplines, curricula and advising, ethics and professionalism, student organizations and extracurricular activities, senior projects, and career planning. Graded on a satisfactory/unsatisfactory basis. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145.

EECS 138. Introduction to Computing: _____. 3 Credits.
Algorithm development, basic computer organization, syntax and semantics of a high-level programming language, including testing and debugging. Concept of structure in data and programs, arrays, top-down design, subroutines and library programs. Abstract data types. System concepts such as compilation and files. Nature and scope of computer science. Not open to electrical engineering, computer engineering, computer science, and interdisciplinary computing majors. Prerequisite: MATH 101 or MATH 104, or meeting the requirements to enroll in MATH 115 or MATH 125 or MATH 145.

EECS 140. Introduction to Digital Logic Design. 4 Credits.
An introductory course in digital logic circuits covering number representation, digital codes, Boolean Algebra, combinatorial logic design, sequential logic design, and programmable logic devices. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145.

EECS 141. Introduction to Digital Logic: Honors. 4 Credits.
An introductory course in digital logic circuits covering number representation, digital codes, Boolean algebra, combinatorial logic design, sequential logic design, and programmable logic devices. This course is intended for highly motivated students and includes honors-level assignments. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145; and either acceptance into the KU Honors Program or consent of instructor.

EECS 168. Programming I. 4 Credits.
Problem solving using a high level programming language and object oriented software design. Fundamental stages of software development are discussed: problem specification, program design, implementation, testing, and documentation. Introduction to programming using an object oriented language: using classes, defining classes, and extending classes. Introduction to algorithms and data structures useful for problem solving: arrays, lists, files, searching, and sorting. Student will be responsible for designing, implementing, testing, and documenting independent programming projects. Professional ethics are defined and discussed in particular with respect to computer rights and responsibilities. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145.

EECS 169. Programming I: Honors. 4 Credits.
Problem solving using a high level programming language and object oriented software design. Fundamental stages of software development are discussed: problem specification, program design, implementation, testing, and documentation. Introduction to programming using an object oriented language: using classes, defining classes, extending classes. Introduction to algorithms and data structures useful for problem solving: arrays, lists, files, searching, and sorting. Students will be responsible for designing, implementing, testing, and documenting independent programming projects. Professional ethics are defined and discussed in particular with respect to computer rights and responsibilities. This course is intended for highly motivated students and includes honors-level assignments. Prerequisite: Corequisite: MATH 104 or MATH 125 or MATH 145; and either acceptance into the KU Honors Program or consent of instructor.

EECS 202. Circuits I. 4 Credits.
Analysis of linear electrical circuits: Kirchoff's laws; source, resistor, capacitor and inductor models; nodal and mesh analysis; network theorems; transient analysis; Laplace transform analysis; steady-state sinusoidal analysis. The lab provides training and practice in the use of computational tools (e.g., Matlab), computer-aided circuit analysis (e.g., Pspice), and laboratory skills. Prerequisite: Corequisite: MATH 220 or MATH 221 or MATH 320, and MATH 290 or MATH 291.

EECS 210. Discrete Structures. 4 Credits.
An introduction to the mathematical foundations and techniques of computer science. Throughout, there is an emphasis on general reasoning, problem solving, and technical communication. Topics include basic proof techniques and logic, induction, recurrences, relations, number theory, basic algorithm design and analysis, and applications. Prerequisite: C- or higher in EECS 140 or EECS 141, and EECS 168 or EECS 169 (or equivalent), and MATH 126 or MATH 146.

EECS 212. Circuits II. 4 Credits.
Continued study of electrical circuits: Steady-state power analysis, three-phase circuits, transformers, frequency response, and two-port network analysis. Prerequisite: C- or higher in EECS 202.

EECS 220. Electromagnetics I. 4 Credits.
Vector analysis. Electrostatic and magnetostatic fields in a vacuum and material media. Electromagnetic fields and Maxwell's equations for time-varying sources. The relationship between field and circuit theory. Simple applications of Maxwell's equations. Prerequisite: C- or higher in MATH 127 or MATH 147, and MATH 220 or MATH 221 or MATH 320, and MATH 290 or MATH 291, and EPHX 210 or PHSX 211 or PHSX 213, and EECS 202.

EECS 268. Programming II. 4 Credits.
This course continues developing problem solving techniques by focusing on the imperative and object-oriented styles using Abstract Data Types. Basic data structures such as queues, stacks, trees, and graphs will be covered. Recursion. Basic notions of algorithmic efficiency and performance analysis in the context of sorting algorithms. Basic Object-Oriented techniques. An associated laboratory will develop projects reinforcing the lecture material. Three class periods and one laboratory period per week. Prerequisite: C- or higher in EECS 168 or EECS 169.

EECS 312. Electronic Circuits I. 3 Credits.
Introduction to diodes, BJTs and MOSFETs, and their use in electronic circuits, especially digital circuits. Prerequisite: Upper-level eligibility. Corequisite: EECS 212.

EECS 316. Circuits, Electronics and Instrumentation. 3 Credits.
Introduction to DC and AC electrical circuit analysis, operational amplifiers, semiconductors, digital circuits and systems, and electronic instrumentation and measurements with a focus on applications. Not open to electrical or computer engineering majors. Students may not receive credit for both EECS 316 and EECS 317. Prerequisite: A course in differential equations and eight hours of physics.

EECS 318. Circuits and Electronics Lab. 1 Credits.
Laboratory exercises intended to complement EECS 316 and EECS 317. Experiments include DC circuits, analog electronics, and digital electronics. Not open to electrical or computer engineering majors. Prerequisite: Corequisite: EECS 316 or EECS 317.

EECS 330. Data Structures and Algorithms. 4 Credits.
A first course in abstract data structures and algorithmic design making use of these structures. Topics include asymptotic analysis, trees, dictionaries, heaps, disjoint set structures; divide and conquer, greedy, and dynamic programming algorithms. Prerequisite: C- or higher in EECS 210 and EECS 268, and upper-level EECS eligibility.

EECS 331. Introduction to Data Science. 3 Credits.
This course covers the core concepts in data science via programming. Topics include data lifecycle activities such as data collection, data analysis and integration, data cleaning and wrangling, and data visualization. Data science concepts such as classification, KNN and linear regression analysis, clustering, and statistical inference will be presented. The course includes practical case studies and problem solving in science, engineering, business, medicine, and social sciences. Programming tools include Python, R, SQL, and Unix shell. Prerequisite: EECS 138 or EECS 168 and MATH 365 or MATH 526 or EECS 461 or C&PE 325 or CE 525.

EECS 348. Software Engineering I. 4 Credits.
This course is an introduction to software development fundamentals and software engineering. It incorporates a thorough introduction to a compiled programming language. A baseline knowledge of tools and utilities is covered including the shell, common programs, version control, IDEs, editors, and build tools. Topics include: software development principles (e.g., design patterns, modularity, loose coupling), extending larger codebases, developing larger codebases, continuous integration, continuous deployment, debugging, unit testing, test-driven development, and databases. Prerequisite: C- or higher in EECS 268.

EECS 361. Signal and System Analysis. 3 Credits.
Fourier signal analysis (series and transform); linear system analysis (continuous and discrete); z-transforms, analog and digital filter analysis; analysis and design of continuous and discrete time system using MATLAB. Prerequisite: C- or higher in EECS 212, and upper-level EECS eligibility.

EECS 388. Embedded Systems. 4 Credits.
This course will address internal organization of micro-controller systems, sometimes called embedded systems, used in a wide variety of engineered systems: programming in C and assembly language; input and output systems; collecting data from sensors; and controlling external devices. This course will focus on one or two specific microprocessors, software development and organization, and building embedded systems. Prerequisite: C- or higher in EECS 140 or EECS 141, and EECS 168 or EECS 169, and upper-level EECS eligibility.

EECS 399. Projects. 1-5 Credits.
An electrical engineering, computer engineering, or computer science project pursued under the student's initiative, culminating in a comprehensive report, with special emphasis on orderly preparation and effective composition. Prerequisite: Upper-level EECS eligibility and consent of instructor.

EECS 412. Electronic Circuits II. 4 Credits.
Discrete and integrated amplifier analysis and design. Introduction to feedback amplifier analysis and design. Introduction to feedback amplifiers. Prerequisite: EECS 312 and upper-level EECS eligibility.

EECS 420. Electromagnetics II. 4 Credits.
This course applies electromagnetic analysis to high frequency devices and systems where wave propagation effects cannot be neglected. Topics covered include transmission lines, space waves, waveguides, radiation, and antennas. Laboratory experiments include transmission line, waveguide, and antenna measurements and characterizations. 3 hours lecture, 1 hour laboratory. Prerequisite: C- or higher in EECS 220, and upper-level EECS eligibility.

EECS 441. Power Systems Engineering II. 3 Credits.
A continuation of ARCE 540 that integrates system components into functional, safe, and reliable power distribution systems for commercial, industrial, and institutional (CII) facilities. Service entrance design, distribution system layout and reliability, emergency and standby power system design, medium-voltage distribution systems, symmetrical fault analysis, and special equipment and occupancies. (Same as ARCE 541.) Prerequisite: ARCE 540 or EECS 212 and Upper-Level EECS Eligibility.

EECS 443. Digital Systems Design. 4 Credits.
The design of digital systems from a hardware point of view. The implementation of functional and control units using programmable logic devices. Introduction to VHDL and its use in modeling and designing digital systems. Prerequisite: EECS 388.

EECS 444. Control Systems. 3 Credits.
An introduction to the modeling, analysis, and design of linear control systems. Topics include mathematical models, feedback concepts, state-space methods, time response, system stability in the time and transform domains, design using PID control and series compensation, and digital controller implementation. Prerequisite: EECS 212 with a grade of C- or higher, and EECS 361.

EECS 447. Introduction to Database Systems. 3 Credits.
Introduction to the concept of databases and their operations. Basic concepts, database architectures, storage structures and indexing, data structures: hierarchical, network, and relational database organizations. Database design and normalization: ER model, candidates keys, functional dependencies, normal forms, decomposition. Emphasis on relational databases, relational algebra, and SQL. Introduction to views, transactions, and database access control. Introduction to database security, big data, NoSQL, CAP theorem, key-value stores. Prerequisite: Upper-level EECS eligibility or departmental consent.

EECS 461. Probability and Statistics. 3 Credits.
Introduction to probability and statistics with applications. Reliability of systems. Discrete and continuous random variables. Expectations, functions of random variables, and linear regression. Sampling distributions, confidence intervals, and hypothesis testing. Joint, marginal, and conditional distribution and densities. Prerequisite: C- or higher in MATH 127 or MATH 147, and MATH 290 or MATH 291; and upper-level EECS eligibility.

EECS 465. Cyber Defense. 3 Credits.
An introduction to critical knowledge and skills needed to administer and defend computer networks and systems. This course focuses on hands-on activities, learning cybersecurity defensive techniques, and understanding well know techniques used by adversaries. Prerequisite: C- or higher in EECS 268. Corequisite: EECS 388.

EECS 468. Programming Paradigms. 3 Credits.
This course is a survey of programming languages: their attributes, uses, advantages, and disadvantages. Topics include the evolution of programming languages; programming language processing (i.e., compilation, interpretation, and mixed approaches); imperative, functional, and declarative languages; parameter passing and evaluation order; iteration, recursion, and continuation; and the basics of cloud programming (i.e., web services, client/server, synchronous vs. asynchronous programming, building reliable systems, and programming at scale). Prerequisite: C- or higher in EECS 268, and upper-level EECS eligibility.

EECS 470. Electronic Devices and Properties of Materials. 3 Credits.
An introduction to crystal structures, and metal, insulator, and semiconductor properties. Topics covered include the thermal, electric, dielectric, and optical properties of these materials. A significant portion of this course is devoted to the properties of semiconductors and semiconductor devices. Prerequisite: PHSX 313 and upper-level EECS eligibility.

EECS 498. Honors Research. 1-2 Credits.
Arranged to allow students to satisfy the independent research requirement for graduation with departmental honors. Prerequisite: Consent of instructor and upper-level EECS eligibility.

EECS 501. Senior Design Laboratory I. 3 Credits.
A lecture/laboratory course involving the design and implementation of prototypes of electrical and computer type products and systems. The project specifications require consideration of ethics, economics, manufacturing, and safety. Intended for students graduating the following calendar year. EECS 501 should be immediately followed by EECS 502 in the following semester. Prerequisite: EECS 220 with a grade of C- or higher, and EECS 361 and EECS 412.

EECS 502. Senior Design Laboratory II. 3 Credits. AE61 CAP
A lecture/laboratory course involving the design and implementation of prototypes of electrical and computer type products and systems. The project specifications require consideration of ethics, economics, health, manufacturing, and safety. Must be taken in semester immediately following completion of EECS 501. Prerequisite: EECS 501.

EECS 510. Introduction to the Theory of Computing. 3 Credits.
Finite state automata and regular expressions. Context-free grammars and pushdown automata. Turing machines. Models of computable functions and undecidable problems. The course emphasis is on the theory of computability, especially on showing limits of computation. (Same as MATH 510.) Prerequisite: C- or higher in EECS 210 and upper-level EECS eligibility.

EECS 512. Electronic Circuits III. 3 Credits.
Feedback amplifier circuit analysis, power amplifiers, analog IC op-amp techniques and analysis, filter approximation and realization, oscillators, wave generators and shapers. Prerequisite: EECS 412.

EECS 541. Computer Systems Design Laboratory I. 3 Credits.
A two semester lecture/laboratory course involving the specification, design, implementation, analysis, and documentation of a significant hardware and software computer system. Laboratory work involves software, hardware, and hardware/software trade-offs. Project requirements include consideration of ethics, economics, manufacturing, safety, and health aspects of product development. Intended for students graduating the following calendar year. EECS 541 should be immediately followed by EECS 542 in the following semester. Prerequisite: EECS 348 with a grade of C- or higher, and EECS 443.

EECS 542. Computer Systems Design Laboratory II. 3 Credits. AE61 CAP
A two semester lecture/laboratory course involving the specification, design, implementation, analysis, and documentation of a significant hardware and software computer system. Laboratory work involves software, hardware, and hardware/software trade-offs. Project requirements include consideration of ethics, economics, manufacturing, safety, and health aspects of product development. Must be taken in semester immediately following completion of EECS 541. Prerequisite: EECS 541.

EECS 545. Electric Energy Production and Storage. 3 Credits.
An introduction to the design of utility scale and small scale (distributed generation) electric energy production and storage systems. This course addresses the technical, operational, economic, and environmental characteristics associated with both traditional and nontraditional electric energy production systems along with associated grid integration, energy delivery, and regulatory issues. Traditional energy production systems covered include fossil fuel, hydroelectric, and nuclear power plants. Non-traditional energy productions systems covered include fuel cells, photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, and other emerging technologies. (Same as ARCE 545.) Prerequisite: ARCE 540, or EECS 212 and Upper-Level EECS Eligibility.

EECS 547. Power System Analysis. 3 Credits.
Introduction to the analysis of commercial, industrial, and utility power systems. Emphasis is placed on modeling system components which include transmission and distribution lines, transformers, induction machines, and synchronous machines and the development of a power system model for analysis from these components. System modeling will be applied to short-circuit studies and used to analyze symmetrical faults, to develop sequence networks using symmetrical components, and analyze unsymmetrical faults. (Same as ARCE 547.) Prerequisite: ARCE 540, or EECS 212 and Upper-Level EECS Eligibility.

EECS 562. Introduction to Communication Systems. 4 Credits.
A first course in communications, including lectures and integrated laboratory experiments. After a review of spectral analysis and signal transmission, analog and digital communications are studied. Topics include: sampling, pulse amplitude modulation, and pulse code modulation; analog and digital amplitude, frequency, and phase modulation; frequency and time division multiplexing; and noise performance of analog modulation techniques. Prerequisite: EECS 212 with a grade of C- or higher, and EECS 361.

EECS 563. Introduction to Communication Networks. 3 Credits.
An introduction to the principles used in communication networks is given in this course. Topics include a discussion of the uses of communications networks, network traffic, network impairments, standards, layered reference models for organizing network functions. Local Area Network technology and protocols are discussed. Link, network, transport layer protocols, and security are introduced. TCP/IP networks are stressed. VoIP is used as an example throughout the course. Basic concepts of network performance evaluation are studied, both analytical and simulation techniques are considered. Prerequisite: EECS 168 with a grade of C- or higher, and MATH 526 or EECS 461, and upper-level EECS eligibility.

EECS 565. Introduction to Information and Computer Security. 3 Credits.
An introduction to the fundamentals of cryptography and information and computer security. Introduces the basic concepts, theories, and protocols in computer security. Discusses how to apply such knowledge to analyze, design and manage secure systems in the real world. Topic covered: the basics of cryptography, software security, operating system

security, database security, network security, privacy and anonymity, social engineering, digital forensics, etc. Prerequisite: Upper-Level EECS Eligibility.

EECS 568. Introduction to Data Mining. 3 Credits.
This course studies algorithms and computational paradigms to discover knowledge in large and complex datasets. The course explains the fundamental principles, technical details, and real-life applications of data mining techniques through lectures, case studies, and hands-on projects. The core topics to be covered include data preprocessing, classification models, cluster analysis, association analysis, anomaly detection, result evaluation and visualization. Prerequisite: EECS 330, EECS 461 or MATH 526, and MATH 290 or MATH 291.

EECS 569. Computer Forensics. 3 Credits.
This course covers both the theoretical and practical aspects of computer forensics. The course introduces the basic concepts, methodologies, and techniques to recover, preserve, and examine digital evidence on or transmitted by digital devices. Topics include: crime investigation and digital evidence, file system forensics, application analysis, network evidence acquisition and analysis, mobile device forensics, etc. Prerequisite: Corequisite: EECS 565.

EECS 572. Applied Computing Capstone. 3 Credits. CAP
Team-orientated lecture/laboratory course involving the specification, design, implementation, testing, and documentation of a significant software project over the full course of the semester. The course includes the consideration of project management, economics, and technical writing. Prerequisite: EECS 581, EECS 468, and upper-level EECS eligibility.

EECS 581. Software Engineering II. 3 Credits.
This lecture/laboratory course covers the systematic development of software products. Topics include: scope of software engineering, life-cycle models, software process, teams, ethics, tools, testing, planning, and estimating. It concentrates on requirements, analysis, design, implementation, and maintenance of software products. Prerequisite: EECS 348 with a grade of C- or higher, and EECS 330, and upper-level EECS eligibility. Corequisite: EECS 565.

EECS 582. Computer Science Capstone. 3 Credits. AE61 CAP
Team-orientated lecture/laboratory course involving the specification, design, implementation, testing, and documentation of a significant software project over the full course of the semester. The course includes the consideration of project management, economics, and technical writing. Prerequisite: EECS 581, EECS 468, and upper-level EECS eligibility.

EECS 592. Cybersecurity Design. 3 Credits. AE61 CAP
Team-oriented lecture and laboratory course involving the specification, design, implementation, testing, and documentation of a significant cybersecurity projects over the full course of the semester. The course includes the consideration of project management, economics, and technical writing. Prerequisite: EECS 581.

EECS 611. Electromagnetic Compatibility. 3 Credits.
A study of unwanted generation and reception of radio-frequency radiation from analog and digital electronic systems and how these emissions/receptions can be reduced. Topics covered include sources of radiation, grounding, shielding, crosstalk, electrostatic discharge, and practical design and layout schemes for reducing unwanted radiation and reception. Also covered are the major governmental electromagnetic compatibility (EMC) regulations and standards that apply to commercial electronic devices and systems. Prerequisite: EECS 220 with a grade of C- or higher, and EECS 312.

EECS 622. Microwave and Radio Transmission Systems. 3 Credits.

Introduction to radio transmission systems. Topics include radio transmitter and receiver design, radiowave propagation phenomenology, antenna performance and basic design, and signal detection in the presence of noise. Students will design radio systems to meet specified performance measure. Prerequisite: Corequisite: EECS 420 and MATH 526 or EECS 461.

EECS 623. Interdisciplinary Collaborations. 3 Credits.
This course focuses on team based projects that will have students collaborating with teams from other schools around the University. The type of projects that are collaborated on may include interactive software, apps, or websites and will involve working with artists, animators, musicians, composers, and/or voice actors. Students from the EECS department will do the software development for the project over the course of several sprints. Students will gain experience in software development and applying Agile development to a real-world project. Prerequisite: C- or higher in EECS 348; or consent of instructor and undergraduate standing.

EECS 628. Fiber Optic Communication Systems. 3 Credits.
Description and analysis of the key components in optical communication systems. Topics covered include quantum sources, fiber cable propagation and dispersion characteristics, receiver characteristics, and system gain considerations. Prerequisite: EECS 220 with a grade of C- or higher; and PHSX 313 or equivalent; and upper-level EECS eligibility.

EECS 630. Advanced Data Structures and Algorithms. 3 Credits.
A second course in abstract data structures and algorithmic design making use of these structures. Emphasis will be on understanding the high-level theoretical intuitions and principles, as well as a concrete understanding of implementation and applications. Topics include advanced treatment of trees, heaps, disjoint set structures, network flow, greedy algorithms, divide and conquer, dynamic programming, and complexity theory. Prerequisite: Upper-level EECS eligibility, EECS 330 and either EECS 461 or MATH 526.

EECS 635. Embedded Machine Learning. 3 Credits.
As AI moves to the edge, the ability to deploy machine learning algorithms on embedded systems is becoming increasingly valuable. This introductory course explores the development and deployment of machine learning models on resource-constrained embedded systems. Students will learn core machine learning principles, model optimization techniques (e.g., quantization), and deployment strategies for microcontrollers and edge devices. Through hands-on assignments and projects, they will gain practical skills and a deeper understanding of the challenges and opportunities of deploying machine learning models on embedded hardware. Prerequisite: EECS 388, or consent of instructor.

EECS 639. Introduction to Scientific Computing. 3 Credits.
A basic introduction to scientific computing and numerical analysis. Topics include linear equation solving, least squares, nonlinear equation-solving, optimization, interpolation, numerical integration and differentiation, ordinary differential equations, and the fast Fourier transform (FFT). Vectorization, efficiency, reliability, and stability of numerical algorithms will be stressed. Applications of algorithms to real-world problems, such as image processing, medicine, electronic circuits, flight trajectories, and molecular modeling, will be emphasized. The course is not open to students with prior credit in MATH 781 or EECS 781. In addition, students may not simultaneously enroll in EECS 639 and MATH 781/EECS 781. (Same as AE 630.) Prerequisite: C- or higher in MATH 127 or MATH 147, and MATH 290 or MATH 291, and EECS 168 or EECS 169 or AE 211 or equivalent.

EECS 643. Computer Architecture. 3 Credits.

The structure and design of computing systems. Examination and analysis of computing systems. Examination and analysis of instruction set architectures, pipelined control and arithmetic units, vector processors, memory hierarchies, and performance evaluation. Prerequisite: EECS 443.

EECS 644. Introduction to Digital Signal Processing. 3 Credits.
Discrete time signal and systems theory, sampling theorem, z-transforms, digital filter design, discrete Fourier transform, FFT, and hardware considerations. Prerequisite: EECS 361.

EECS 645. Computer Systems Architecture. 3 Credits.
This is an introductory course to the design of single-chip microprocessors and systems. The course covers materials including instruction set architecture, datapath design, control path design, pipelining, multiple-issue superscalar processors, out-of-order processors, memory hierarchy, memory management, multicore, caches, memory technologies, data parallel architectures, interrupts and I/O structures. Only one of EECS 643 and EECS 645 may be used to satisfy EECS degree requirements. Prerequisite: EECS 388.

EECS 649. Introduction to Artificial Intelligence. 3 Credits.
General concepts, search procedures, two-person games, predicate calculus and automated theorem proving, nonmonotonic logic, probabilistic reasoning, rule based systems, semantic networks, frames, dynamic memory, planning, machine learning, natural language understanding, neural networks. Prerequisite: EECS 330.

EECS 658. Introduction to Machine Learning. 3 Credits.
This course provides an introduction to the basic methods of machine learning and how to apply them to solve software engineering problems. Topics covered are: supervised learning, unsupervised learning, and reinforcement learning methods; feature selection techniques; structuring machine learning solutions; and evaluation metrics. Prerequisite: EECS 330 and EECS 461 or MATH 526 or equivalent and upper-level EECS eligibility.

EECS 662. Programming Languages. 3 Credits.
Formal definition of programming languages including specification of syntax and semantics. Simple statements including precedence, infix, prefix, and postfix notation. Global properties of algorithmic languages including scope of declaration, storage allocation, grouping of statements, binding time of constituents, subroutines, coroutines, and tasks. Run-time representation of program and data structures. Prerequisite: EECS 468 and EECS 330.

EECS 665. Compiler Construction. 4 Credits.
Compilation of programming language constructs. Organization of a compiler including symbol tables, lexical analysis, syntax analysis, intermediate and object code generation, error diagnostics, code optimization techniques and run-time structures in a block-structured language such as C or Rust. Programming assignments include construction of various modules of a compiler. Prerequisite: EECS 348 with a grade of C- or higher, and EECS 468, and EECS 510, and upper-level EECS eligibility.

EECS 666. Introduction to Network Security. 3 Credits.
This course covers fundamental cryptographic algorithms, security designs, protocols, attacks, and controls in computer networks. Topics include security designs and analysis of network protocols such as TCP/IP, BGP, and DNS; network vulnerabilities and attacks such as spoofing, MITM, DDoS, and botnets; network security controls such as cryptography primitives, authentication, key management, firewall and intrusion detection; privacy and anonymity such as spams, web tracking, and Internet censorship. Prerequisite: EECS 563 and EECS 565 or instructor's consent.

EECS 670. Introduction to Semiconductor Processing. 3 Credits.
An overview of various processes to fabricate semiconductor devices and integrated circuits. Topics covered include crystal growth, oxidation, solid-state diffusion, ion implantation, photolithography, chemical vapor deposition, epitaxial growth, metalization, and plasma etching of thin films. (Same as C&PE 655.) Prerequisite: Junior or senior standing in C&PE or EECS, or consent of department.

EECS 677. Advanced Software Security Evaluation. 3 Credits.
Heuristic and formal analysis of software systems with an emphasis on integrity and secrecy. Students in the course will learn to assess the quality, vulnerabilities, and behavior of software. Topics include bug finding, anomaly detection, dynamic analysis, static analysis, dataflow analysis, fuzzing, linting, software supply chain auditing, and security best practices. Prerequisite: C- or higher in EECS 348, and upper-level EECS eligibility, or consent of instructor.

EECS 678. Introduction to Operating Systems. 4 Credits.
The objective of this course is to provide the students with the concepts necessary to enable them to: a) identify the abstract services common to all operating system, b) define the basic system components that support the operating system's machine independent abstractions on particular target architectures, c) consider how the design and implementation of different systems components interact and constrain one another, not merely how one or two important parts work in isolation, and d) understand the means by which fundamental problems in operating systems can be analyzed and addressed. Programming assignments address topics including process creation, inter-process communication, system call implementation, process scheduling and virtual memory. Laboratory exercises primarily focus on use of tools and concepts required for the programming assignments but include a small number of independent topics. Prerequisite: EECS 348 with a C- or higher, and EECS 388, and upper-level EECS eligibility.

EECS 683. Introduction to Hardware Security and Trust. 3 Credits.

This course will investigate various security and trust issues related to integrated circuits and systems during their design and manufacturing process, as well as during field operation. A wide range of threats including piracy, reverse engineering, hardware Trojan insertion, side-channel attack, and various invasive non-invasive attacks will be introduced. Potential hardware and software-based countermeasures to detect and prevent these attacks will be studied. Implementation of design-time solutions like physically unclonable functions (PUFs), true random number generator (TRNG), security monitors, hardware obfuscation, and many others will be covered. Prerequisite: EECS 388 and upper-level EECS eligibility.

EECS 685. Introduction to IoT Security. 3 Credits.
This course covers the concept of Internet of Things (IoT) including its components, architectures, and enabling technologies and introduces full-stack of security and privacy issues in IoT and its applications including hardware, software, network, and data. The goal is to expose students to new developments in cybersecurity for IoT as well as familiarize them with tools and techniques for IoT security design and analysis. Students will gain hands-on experiences on implementing security techniques for IoT through mini projects. Prerequisite: EECS 565 or instructor's consent.

EECS 687. Mobile Security. 3 Credits.
Security and privacy issues through the lens of mobile computing. Topics include an overview of the mobile computing ecosystem, including smartphones and autonomous devices such as unmanned aerial systems; core security and privacy principles applied to mobile devices; an exploration of domain-relevant academic literature; exploration of attacks and defenses in mobile security. The course will expose students to new

developments in cybersecurity for mobile security and security tools and techniques in the domain. Prerequisite: EECS 678 or instructor's consent.

EECS 690. Special Topics: _____. 1-3 Credits.
Arranged as needed to present appropriate material to groups of students. May be repeated for additional credit. Prerequisite: Varies by topic, plus Upper-level EECS eligibility and consent of instructor.

EECS 692. Directed Reading. 1-3 Credits.
Reading under the supervision of an instructor on a topic chosen by the student with the advice of the instructor. May be repeated for additional credit. Consent of the department required for enrollment. Prerequisite: Upper-level EECS eligibility and consent of instructor.

EECS 695. Software Reverse Engineering. 3 Credits.
This hands-on course explains the basics of binary software, including binary generation, layout, structure, and execution. It will explain the basics of binary reverse engineering (RE), including binary analysis, disassembly, and instrumentation. The course teaches relevant tools and frameworks for RE. Students practice RE concepts using code problems. Topics include: Linux command-line tools, binary build process, high-level language constructs in assembly, the ELF format, static and run-time tools for RE, advanced RE frameworks, binary rewriting, anti-reversing, etc. Prerequisite: EECS 388 or instructor's consent.

EECS 700. Special Topics: _____. 1-5 Credits.
Courses on special topics of current interest in electrical engineering, computer engineering, or computer science, given as the need arises. May be repeated for additional credit. Prerequisite: Varies by topic.

EECS 713. High-Speed Digital Circuit Design. 3 Credits.
Basic concepts and techniques in the design and analysis of high-frequency digital and analog circuits. Topics include: transmission lines, ground and power planes, layer stacking, substrate materials, terminations, vias, component issues, clock distribution, cross-talk, filtering and decoupling, shielding, signal launching. Prerequisite: EECS 312 and senior or graduate standing. EECS 420 recommended.

EECS 721. Antennas. 3 Credits.
Gain, Pattern, and Impedance concepts for antennas. Linear, loop, helical, and aperture antennas (arrays, reflectors, and lenses). Cylindrical and biconical antenna theory. Prerequisite: EECS 360 and EECS 420, or EECS 720, or permission of the instructor.

EECS 723. Microwave Engineering. 3 Credits.
Survey of microwave systems, techniques, and hardware. Guided-wave theory, microwave network theory, active and passive microwave components. Prerequisite: EECS 420.

EECS 725. Introduction to Radar Systems. 3 Credits.
Basic radar principles and applications. Radar range equation. Pulsed and CW modes of operation for detection, ranging, and extracting Doppler information. Prerequisite: EECS 360, EECS 420, EECS 461 or MATH 526. EECS 622 recommended.

EECS 727. Photonics. 3 Credits.
The course presents the theory and the design principles of photonic systems. Topics include: Light propagation, interference, and diffraction, permittivity models and effective media, electromagnetic propagation in complex media, dispersion engineering, and fundamentals of nonlinear optics. Prerequisite: EECS 420 or equivalent.

EECS 728. Fiber-optic Measurement and Sensors. 3 Credits.
The course will focus on fundamental theory and various methods and applications of fiber-optic measurements and sensors. Topics include: optical power and loss measurements, optical spectrum analysis, wavelength measurements, polarization measurements, dispersion measurements, PMD measurements, optical amplifier characterization, OTDR, optical components characterization and industrial applications of fiber-optic sensors. Prerequisite: EECS 628 or equivalent.

EECS 730. Introduction to Bioinformatics. 3 Credits.
This course provides an introduction to bioinformatics. It covers computational tools and databases widely used in bioinformatics. The underlying algorithms of existing tools will be discussed. Topics include: molecular biology databases, sequence alignment, gene expression data analysis, protein structure and function, protein analysis, and proteomics. Prerequisite: Data Structures class equivalent to EECS 330, and Introduction to Biology equivalent to BIOL 150, or consent of instructor.

EECS 732. Introduction to Biometric Authentication. 3 Credits.
This graduate-level course introduces the fundamental concepts of biometric systems for human authentication. It covers the design and operation of biometric systems, including familiarization with various biometric modalities (e.g., fingerprint, face, iris), multimodal biometric systems, and performance evaluation methods. Students will explore vulnerabilities, attacks, and the security and privacy mechanisms required to build robust biometric solutions. Prerequisite: EECS 268, or consent of instructor.

EECS 739. Parallel Scientific Computing. 3 Credits.
This course is concerned with the application of parallel processing to real-world problems in engineering and the sciences. State-of-the-art serial and parallel numerical computing algorithms are studied along with contemporary applications. The course takes an algorithmic design, analysis, and implementation approach and covers an introduction to scientific and parallel computing, parallel computing platforms, design principles of parallel algorithms, analytical modeling of parallel algorithms, MPI programming, direct and iterative linear solvers, numerical PDEs and meshes, numerical optimization, GPU computing, and applications of parallel scientific computing. Prerequisite: MATH 126, MATH 290, experience programming in C, C++, or Fortran; EECS 639 (or equivalent.) Highly recommended: MATH 127.

EECS 740. Digital Image Processing. 3 Credits.
This course gives a hands-on introduction to the fundamentals and applications of digital image processing. Topics include: image formation and camera calibration, image transforms, image filtering in spatial and frequency domains, image enhancement, image restoration and reconstruction, image segmentation, feature detection, segmentation, and the latest developments and applications in image processing. Prerequisite: MATH 290 and MATH 526, or consent from the instructor.

EECS 743. Advanced Computer Architecture. 3 Credits.
Topics of this course will be divided into three main categories: (a) theory of parallelism, (b) hardware technologies, and (c) parallel and scalable architectures. For example, principles of performance and scalability, processors and memory hierarchy, linear/nonlinear pipelining and superscalar techniques, and scalable multiprocessors and dataflow architectures will be among the topics to be covered. The course will also focus on emerging and heterogeneous architectures and their performance potential and programming models. For example, reconfigurable computing (RC), quantum computing (QC), and neuromorphic computing (NC) will be covered in some details. This would be achieved through practical experiments, and homework projects using realistic workloads on some state-of- the-art high-performance reconfigurable and quantum computers. Finally, students will select published related research work for discussions and oral presentations. Prerequisite: EECS 643 or EECS 645, or equivalent. A good understanding of C/C++ and having basic Unix/Linux skills is required.

EECS 744. Digital Signal Processing Implementation in Programmable Logic Devices. 3 Credits.

Implementation of communication and radar DSP algorithms in programmable logic devices focusing on design methodology, resource utilization, and timing closure. Specific topics include number formats, numerical operators, waveform generation, mixed-signal converters (ADCs & DACs), digital filters, multi-rate designs, DFTs, software defined radios, and embedded processors. Course structure will consist of a combination of class lectures and hardware design projects. Prerequisite: An introductory course in DSP such as EECS 644; and digital system design using HDL such as EECS 443 or equivalent.

EECS 750. Advanced Operating Systems. 3 Credits.
In this course, we will study advanced topics in operating systems for modern hardware platforms. The topics include: multicore CPU scheduling, cache and DRAM management, flash-based storage systems and I/O management, power/energy management, and cloud systems. We will discuss classical and recent papers in each of these topics. We will also study advanced resource management capabilities in recent Linux kernels. The course will consist of lectures, student presentations, and a term project. Prerequisite: EECS 678.

EECS 751. Algorithms for HPC. 3 Credits.
This course introduces basic models, algorithms and optimization techniques for high-performance computing (HPC). It covers techniques to parallelize classical applications (e.g., matrix algorithms, sorting) as well as algorithms to facilitate efficient job execution on HPC platforms (e.g., resource scheduling, fault tolerance). Students will also have the chance to learn about the intersection of HPC and machine learning or do a course project on a related topic. Prerequisite: EECS 330.

EECS 752. Modern Computer Organization and Design. 3 Credits.

The main objective of this course is to discuss various computer architectures at an abstract level. A large number of machines, memory structures, and interconnections will be discussed. We will learn about state-of-the-art computer systems as they are designed today, including processors, memories, interconnects, and multiprocessors. The focus of the course is not on research but on actual, commercial, existing machines. The students taking the course will be ready to conduct research in the area of computer architecture or work on projects related to designing chip architecture for components of a computer system. More importantly, the students will gain experience in using architectural simulators and analytical models to design and evaluate future computer architectures. Prerequisite: EECS 645 or EECS 643 or instructor’s consent.

EECS 753. Embedded and Real Time Computer Systems. 3 Credits.

This course will cover emerging and proposed techniques and issues in embedded and real time computer systems. Topics will include new paradigms, enabling technologies, and challenges resulting from emerging application domains. Prerequisite: EECS 645 and EECS 678.

EECS 755. Software Modeling and Analysis. 3 Credits.
Modern techniques for modeling and analyzing software systems. Course coverage concentrates on pragmatic, formal modeling techniques that support predictive analysis. Topics include formal modeling, static analysis, and formal analysis using model checking and theorem proving systems. Prerequisite: EECS 368 or equivalent.

EECS 759. Estimation and Control of Unmanned Autonomous Systems. 3 Credits.
An introduction to the modeling, estimation, and control of unmanned autonomous systems. Topics include motion description, navigation sensors, complementary filters, Kalman filters, attitude estimation, position estimation, attitude keeping controller, etc. The successful completion of this course will prepare students for advanced studies in robotics & controls. (Same as AE 759.) Prerequisite: AE 551 or AE 552 or EECS 444, or by consent of instructor.

EECS 762. Programming Language Foundation I. 3 Credits.
This course presents a basic introduction to the semantics of programming languages. The presentation begins with basic lambda calculus and mechanisms for evaluating lambda calculus terms. Types are introduced in the form of simply typed lambda calculus and techniques for type inference and defining type systems are presented. Finally, techniques for using lambda calculus to define, evaluate and type check common programming language constructs are presented. Prerequisite: EECS 662 or equivalent.

EECS 764. Analysis of Algorithms. 3 Credits.
Models of computations and performance measures; asymptotic analysis of algorithms; basic design paradigms including divide-and-conquer, dynamic programming, backtracking, branch-and-bound, greedy method and heuristics; design and analysis of approximation algorithms; lower bound theory; polynomial transformation and the theory of NP-Completeness; additional topics may be selected from arithmetic complexity, graph algorithms, string matching, and other combinatorial problems. Prerequisite: EECS 630 or equivalent.

EECS 765. Introduction to Cryptography and Computer Security. 3 Credits.
Comprehensive coverage to the fundamentals of cryptography and computer and communication security. This course serves as the first graduate level security course, which introduces the core concepts, theories, algorithms and protocols in computer and communication security, and also prepares students for advanced security courses. This course first covers the mathematical foundation of cryptography and its applications in computer security. The course also covers a wide range of topics: information and database security, software and computer systems security, network security, Internet and web security. Prerequisite: EECS 678 and EECS 563 or EECS 780, or the instructor's approval.

EECS 766. Network Security. 3 Credits.
This course covers cryptographic algorithms and security protocols for computer networks, as well as advanced topics and research frontiers in network security. Topics include security of network design and protocols such as TCP/IP, BGP, and DNS security; network vulnerabilities and attacks such as spoofing, MITM, DDoS, and botnets; network security controls such as cryptography primitives, authentication, key management, firewall and intrusion detection; privacy and anonymity such as spams, web tracking, Internet censorship; network security research fundamentals and emerging topics. Student cannot receive credit for both EECS 666 and EECS 766. Prerequisite: EECS 563 and EECS 565 or instructor’s consent.

EECS 767. Information Retrieval. 3 Credits.
This class introduces algorithms and applications for retrieving information from large document repositories, including the Web. Topics span from classic information retrieval methods for text documents and databases, to recent developments in Web search, including: text algorithms, indexing, probabilistic modeling, performance evaluation, web structures, link analysis, multimedia information retrieval, social network analysis. Prerequisite: EECS 447 or permission of instructor.

EECS 768. Virtual Machines. 3 Credits.
Understand the fundamental principles and advanced implementation aspects of key virtual machine concepts. Topics include principles of virtualization, binary translation, process and system level virtual machines, JIT complication and optimizations in managed environments, garbage collection, virtual machine implementation issues, and virtual machine security. Includes in-depth coverage of the latest developments

and research issues in the filed of virtual machines. Prerequisite: EECS 665 and either EECS 643 or EECS 645 or consent of instructor.

EECS 769. Information Theory. 3 Credits.
Information theory is the science of operations on data such as compression, storage, and communication. It is one of the few scientific fields fortunate enough to have an identifiable beginning - Claude Shannon's 1948 paper. The main topics of mutual information, entropy, and relative entropy are essential for students, researchers, and practitioners in such diverse fields as communications, data compression, statistical signal processing, neuroscience, and machine learning. The topics covered in this course include mathematical definitions and properties of information, mutual information, source coding theorem, lossless compression of data, optimal lossless coding, noisy communication channels, channel coding theorem, the source channel separation theorem, multiple access channels, broadcast channels, Gaussian noise, time-varying channels, and network information theory. Prerequisite: EECS 461 or MATH 526 or an equivalent undergraduate probability course.

EECS 777. Advanced Software Security Auditing. 3 Credits.
Heuristic and formal analysis of software systems with an emphasis on integrity and secrecy. Students in the course will learn to assess the quality, vulnerabilities, and behavior of software. Topics include bug finding, anomaly detection, dynamic analysis, static analysis, dataflow analysis, fuzzing, linting, software supply chain auditing, and security best practices. Students will gain hands-on experience in conducting research in software auditing through a final project/report. Student cannot receive credit for both EECS 677 and EECS 777. Prerequisite: EECS 448, or EECS 348 and upper-level EECS eligibility, or instructor’s consent.

EECS 780. Communication Networks. 3 Credits.
Comprehensive in-depth coverage to communication networks with emphasis on the Internet and the PSTN (wired and wireless, and IoT-Internet of Things). Extensive coverage of protocols and algorithms will be presented at all levels, including: social networking, overlay networks, client/server and peer-to-peer applications; session control; transport protocols, the end-to-end arguments and end-to-end congestion control; network architecture, forwarding, routing, signaling, addressing, and traffic management, programmable and software-defined networks (SDN); quality of service, queuing and multimedia applications; LAN architecture, link protocols, access networks and MAC algorithms; physical media characteristics and coding; network security and information assurance; network management. Prerequisite: EECS 563 or equivalent or permission of instructor.

EECS 781. Numerical Analysis I. 3 Credits.
Finite and divided differences. Interpolation, numerical differentiation, and integration. Gaussian quadrature. Numerical integration of ordinary differential equations. Curve fitting. Students may not enroll in EECS 639 after enrolling in MATH 781/EECS 781. In addition, students may not simultaneously enroll in MATH 781/EECS 781 and EECS 639. (Same as MATH 781.) Prerequisite: MATH 320 and knowledge of a programming language.

EECS 782. Numerical Analysis II. 3 Credits.
Direct and interactive methods for solving systems of linear equations. Numerical solution of partial differential equations. Numerical determination of eigenvectors and eigenvalues. Solution of nonlinear equations. (Same as MATH 782.) Prerequisite: EECS 781 or MATH 781.

EECS 783. Hardware Security and Trust. 3 Credits.
This course will investigate various security and trust issues related to integrated circuits and systems during their design and manufacturing process, as well as during field operation. A wide range of threats including piracy, reverse engineering, hardware Trojan insertion, side-channel attack, micro-architectural vulnerabilities, and various invasive non-invasive attacks will be introduced. Potential hardware and software-based countermeasures to detect and prevent these attacks will be studied. Implementation of design-time solutions like physically unclonable functions (PUFs), true random number generator (TRNG), security monitors, hardware obfuscation, and many others will be covered. This course will also cover the fundamentals of hardware security research. Student cannot receive credit for both EECS 683 and EECS 783. Prerequisite: EECS 388 and upper-level EECS eligibility.

EECS 785. Internet of Things Security. 3 Credits.
This course covers the concept of Internet of Things (IoT) including its components, architectures, and enabling technologies and introduces full-stack of security and privacy issues in IoT and its applications including hardware, software, network, and data. The goal is to expose students to new developments in cybersecurity for IoT as well as familiarize them with tools and techniques for IoT security design and analysis. Students will gain hands-on experiences on implementing security techniques for IoT through mini projects and a research project/report. Student cannot receive credit for both EECS 685 and EECS 785. Prerequisite: EECS 565 or instructor’s consent.

EECS 786. Digital Very-Large-Scale-Integration. 3 Credits.
This course covers the basic concepts of Integrated Circuit (IC) design, various methods of designing VLSI circuits, and techniques to analyze and optimize performance metrics, such as: speed, area, power and signal integrity. Clocking, interconnect and scaling issues of IC will also be discussed. The topic will cover device, interconnect and circuit level implementation issues of both logic and memory circuits. It will also briefly introduce the high performance issues, fabrication technologies and system level implementation approaches of IC to establish bridges to the advanced courses. Prerequisite: EECS 312.

EECS 787. Mobile Security. 3 Credits.
Security and privacy issues through the lens of mobile computing. Topics include an overview of the mobile computing ecosystem, including smartphones and autonomous devices such as unmanned aerial systems; core security and privacy principles applied to mobile devices; an exploration of domain-relevant academic literature; exploration of attacks and defenses in mobile security. New developments in cybersecurity for mobile security and security tools and techniques in the domain. Students will gain hands-on experience in conducting research in the field of mobile security, including producing a research-quality final project/report. Student cannot receive credit for both EECS 687 and EECS 787. Prerequisite: EECS 678 or instructor’s consent.

EECS 795. Software Reverse Engineering. 3 Credits.
This hands-on course explains the basics of binary software, including binary generation, layout, structure, and execution. It will explain the basics of binary reverse engineering (RE), including binary analysis, disassembly, and instrumentation. The course teaches relevant tools and frameworks for RE. Students practice RE concepts using advanced code problems and a term project/report. Topics include: Linux command-line tools, binary build process, high-level language constructs in assembly, the ELF format, static and run-time tools for RE, advanced RE frameworks, binary rewriting, anti-reversing, etc. Student cannot receive credit for both EECS 695 and EECS 795. Prerequisite: EECS 388 or instructor’s consent.

EECS 800. Special Topics: _____. 1-5 Credits.
Advanced courses on special topics of current interest in electrical engineering, computer engineering, or computer science, given as the need arises. May be repeated for additional credit. Prerequisite: Varies by topic.

EECS 801. Directed Graduate Readings. 1-3 Credits.

Graduate level directed readings on a topic in electrical engineering, computer engineering, or computer science, mutually agreed-on by the student and instructor. May be repeated for credit on another topic. Prerequisite: Consent of instructor.

EECS 802. Electrical Engineering and Computer Science Colloquium and Seminar on Professional Issues. 1 Credits.
A colloquium/seminar series in which presentation are provided on a broad variety of scholarly and professional topics. Topics related to the issues of responsible scholarship in the fields of computing and electrical engineering will be discussed. Student are also required to attend a series of colloquia and submit written reports. Course will be graded Satisfactory/Fail and is required for all EECS graduate students. Prerequisite: Graduate standing in the EECS Department.

EECS 812. Software Requirements Engineering. 3 Credits.
Objectives, processes, and activities of requirements engineering and requirements management; characteristics of good requirements; types of requirements; managing changing requirements; languages, notations, and methodologies; formal and semi-formal methods of presenting and validating the requirements; requirements standards; traceability issues. Prerequisite: EECS 810.

EECS 820. Advanced Electromagnetics. 3 Credits.
A theorem-based approach to solving Maxwell's equations for modeling electromagnetic problems encountered in microwave systems, antennas, scattering. Topics include waves, source modeling, Schelkunoff equivalence principle, scattered filed formulations, electromagnetic induction, reciprocity principles, Babinet's principle, and construction of solutions in various coordinate systems. Prerequisite: EECS 420.

EECS 823. Microwave Remote Sensing. 3 Credits.
Description and analysis of basic microwave remote sensing systems including radars and radiometers as well as the scattering and emission properties of natural targets. Topics covered include plane wave propagation, antennas, radiometers, atmospheric effects, radars, calibrated systems, and remote sensing applications. Prerequisite: EECS 420 and EECS 622.

EECS 825. Introduction to Radar Signal Processing. 3 Credits.
This course covers the foundations of radar from a signal processing perspective. It explores the relationships between various aspects of radar and signal modeling and processing, including antennas, propagation, scattering, systems, and collection geometries. The course emphasizes simplifying assumptions in radar signal processing and their validity. Topics include: propagation modeling, maximum signal-to-interference plus noise ratio filtering, moving target indication, waveform design, detection theory, spatial beamforming, and space-time adaptive processing. Prerequisite: EECS 861, or consent of instructor.

EECS 828. Advanced Fiber-Optic Communications. 3 Credits.
An advanced course in fiber-optic communications. The course will focus on various important aspects and applications of modern fiber-optic communications, ranging from photonic devices to systems and networks. Topics include: advanced semiconductor laser devices, external optical modulators, optical amplifiers, optical fiber nonlinearities and their impact in WDM and TDM optical systems, polarization effect in fiber-optic systems, optical receivers and high-speed optical system performance evaluation, optical solution systems, lightwave analog video transmission, SONET & ATM optical networking, and advanced multi-access lightwave networks. Prerequisite: EECS 628 or equivalent.

EECS 835. Advanced Data Science. 3 Credits.
This course covers topics in data collection, data transmission, and data analysis, in support of discoveries and innovations based on massive amounts of data. This course surveys current topics in data science. It provides a comprehensive review of theory, algorithms, and tools that are used in data science and prepares students to take in-depth following up courses in EECS. This is a project-oriented course. It offers hands-on experience for students to integrate knowledge from a wide-range of topics in data science without dwelling on any particular subfield of data science. Prerequisite: EECS 268 or experience with object oriented programming and large programs. MATH 290 or experience with linear algebra. EECS 461 or MATH 526 or experience with probability and statistics. Or consent from the instructor.

EECS 836. Machine Learning. 3 Credits.
"Machine learning is the study of computer algorithms that improve automatically through experience" (Tom Mitchell). This course introduces basic concepts and algorithms in machine learning. A variety of topics such as Bayesian decision theory, dimensionality reduction, clustering, neural networks, hidden Markov models, combining multiple learners, reinforcement learning, Bayesian learning etc. will be covered. Prerequisite: Graduate standing in CS or CoE or consent of instructor.

EECS 841. Computer Vision. 3 Credits.
This course gives a hands-on introduction to the fundamentals and applications of computer vision. Topics include: Image processing fundamentals, feature detection and matching, projective geometry and transformation, camera geometry and calibration, two-view geometry and stereo vision, structure from motion, parameter estimation and optimization, and the latest developments and applications in computer vision. Prerequisite: MATH 290 and MATH 526, or consent from the instructor.

EECS 843. Programming Language Foundation II. 3 Credits.
This course presents advanced topics in programming language semantics. Fixed point types are presented followed by classes of polymorphism and their semantics. System F and type variables are presented along with universal and existential types. The lambda cube is introduced along with advanced forms of polymorphism. Several interpreters are developed implementing various type systems and associated type inference algorithms. Prerequisite: EECS 762.

EECS 844. Adaptive Signal Processing. 3 Credits.
This course presents the theory and application of adaptive signal processing. Topics include adaptive filtering, mathematics for advanced signal processing, cost function modeling and optimization, signal processing algorithms for optimum filtering, array processing, linear prediction, interference cancellation, power spectrum estimation, steepest descent, and iterative algorithms. Prerequisite: Background in fundamental signal processing (such as EECS 644.) Corequisite: EECS 861.

EECS 861. Random Signals and Noise. 3 Credits.
Fundamental concepts in random variables, random process models, power spectral density. Application of random process models in the analysis and design of signal processing systems, communication systems and networks. Emphasis on signal detection, estimation, and analysis of queues. This course is a prerequisite for most of the graduate level courses in radar signal processing, communication systems and networks. Prerequisite: An undergraduate course in probability and statistics, and signal processing.

EECS 862. Principles of Digital Communication Systems. 3 Credits.

A study of communication systems using noisy channels. Principal topics are: information and channel capacity, baseband data transmission, digital carrier modulation, error control coding, and digital transmission of analog signals. The course includes a laboratory/computer aided design component integrated into the study of digital communication systems. Prerequisite: EECS 562. Corequisite: EECS 861.

EECS 863. Network Analysis, Simulation, and Measurements. 3 Credits.
Prediction of communication network performance using analysis, simulation, and measurement. Topics include: an introduction to queueing theory, application of theory to prediction of communication network and protocol performance, and analysis of scheduling mechanisms. Modeling communication networks using analytic and simulation approaches, model verification and validation through analysis and measurement, and deriving statistically significant results. Analysis, simulation, and measurement tools will be discussed. Prerequisite: EECS 461 or MATH 526, and EECS 563 or EECS 780.

EECS 865. Wireless Communication Systems. 3 Credits.
The theory and practice of the engineering of wireless telecommunication systems. Topics include cellular principles, mobile radio propagation (including indoor and outdoor channels), radio link calculations, fading (including Rayleigh, Rician, and other models), packet radio, equalization, diversity, error correction coding, spread spectrum, multiple access techniques (including time, frequency, and code), and wireless networking. Current topics of interest will be covered. Prerequisite: Corequisite: EECS 861.

EECS 866. Network Security. 3 Credits.
This course provides in-depth coverage on the concepts, principles, and mechanisms in network security and secure distributed systems. The topics that will be covered include: network security primitives, risks and vulnerabilities, authentication, key management, network attacks and defense, secure communication protocols, intrusion detection, exploit defenses, traffic monitoring and analysis, and privacy mechanisms. Prerequisite: EECS 765 and EECS 563 or EECS 780, or the instructor's approval.

EECS 868. Mathematical Optimization with Applications. 3 Credits.

A mathematical study of the minimization of functions. The course provides an introduction to the mathematical theory, implementation, and application of a variety of optimization techniques, with an emphasis on real-world applications. Optimization problem formulation. Unconstrained and constrained minimization, including conditions for optimality. Specific techniques for solving linear and nonlinear programming problems. Convergence of algorithms. Prerequisite: MATH 590 or EECS 639, or the consent of the instructor.

EECS 869. Error Control Coding. 3 Credits.
A study of communication channels and the coding problem. An introduction to finite fields and linear block codes such as cyclic, Hamming, Golay, BCH, and Reed-Solomon. Convolutional codes and the Viberbi algorithm are also covered. Other topics include trellis coded modulation, iterative (turbo) codes, LDPC codes. Prerequisite: EECS: 562 or equivalent.

EECS 891. Graduate Problems. 1-5 Credits.
Directed studies of advanced phases of electrical engineering, computer engineering, computer science or information technology not covered in regular graduate courses, including advanced laboratory work, special research, or library reading. Graded on a satisfactory progress/limited progress/no progress basis. Prerequisite: Consent of instructor.

EECS 899. Master's Thesis or Report. 1-6 Credits.
Graded on a satisfactory progress/limited progress/no progress basis.

EECS 965. Detection and Estimation Theory. 3 Credits.
Detection of signals in the presence of noise and estimation of signal parameters. Narrowband signals, multiple observations, signal detectability and sequential detection. Theoretical structure and performance of the receiver. Prerequisite: EECS 861.

EECS 998. Post-Master's Research. 1-6 Credits.
Graded on a satisfactory progress/limited progress/no progress basis.

EECS 999. Doctoral Dissertation. 1-12 Credits.
Graded on a satisfactory progress/limited progress/no progress basis.

Engineering Courses

ENGR 101. Engineering Academic Success Seminar. 0 Credits.
This course will provide an introduction to the University and School of Engineering community and the value and role of higher education in our society, strategies for successful transition to and participation in that community, exploration of the University and School commitment to diversity and multiculturalism, and information about University and School resources and procedures. Graded on a satisfactory/unsatisfactory basis. Prerequisite: Eligible students must have fewer than thirty credit hours from the University of Kansas.

ENGR 111. Freshman Self Seminar. 1 Credits.
This seminar course will serve as an introduction to the Self Engineering Leadership Fellows Program and will focus on building student's skills in leadership, business, entrepreneurship, management, communication, engineering, and interpersonal skills. Graded on a satisfactory/ unsatisfactory basis. Prerequisite: Students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow.

ENGR 112. Sophomore Self Seminar. 1 Credits.
This seminar course will focus on continued development of building student's skills in leadership, business, entrepreneurship, management, communication, engineering, and interpersonal skills. Students will use the principles of engineering project management to deliver objectives of the program. Graded on a satisfactory/unsatisfactory basis. Prerequisite: ENGR 111 and students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow.

ENGR 113. Junior Self Seminar. 1 Credits.
This seminar course will focus on continued development of building student's skills in leadership, business, entrepreneurship, management, communication, engineering, and interpersonal skills. Students will use the principles of engineering project management to deliver objectives of the program. Graded on a satisfactory/unsatisfactory basis. Prerequisite: Students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow.

ENGR 114. Senior Self Seminar. 1 Credits.
This seminar course will focus on continued development of building student's skills in leadership, business, entrepreneurship, management, communication, engineering, and interpersonal skills. Students will use the principles of engineering project management to deliver objectives of the program. Graded on a satisfactory/unsatisfactory basis. Prerequisite: ENGR 113 and students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow.

ENGR 177. First Year Seminar: _____. 3 Credits. GE11 GLBC
A limited-enrollment, seminar course for first-time freshmen, organized around current issues in mechanical engineering. Course is designed to meet the critical thinking learning outcome of the KU Core. May not contribute to major requirements for School of Engineering students. First year seminar topics are coordinated and approved through the Office of Academic Programs and Experiential Learning. Prerequisite: Open to Freshmen only (less than 30 hours).

ENGR 300. Cooperative Engineering Education Experience. 1 Credits.

Engineering work experience with a recognized engineering organization. The work must be professional in nature and not merely routine. A final summary report must be submitted to the student's major department at the conclusion of each continuous period of employment and may cover more than one sequential semester or summer session. Credit for this course cannot be used toward graduation requirements. Graded on a satisfactory/unsatisfactory basis. Prerequisite: Permission of major department.

ENGR 360. Special Topics: _____. 1-5 Credits.
Courses on special topics of current interest to engineers, such as ethics, engineering economics, engineering practice, communications, teamwork, and professional and career development. Prerequisite: Approval of the instructor.

ENGR 490. Engineering Internship. 1-6 Credits.
Engineering internship in an approved company. Internship hours do not satisfy any course requirements for a bachelors degree in any School of Engineering major, but will appear on the transcript. Credit assigned after review of report on internship experience.

ENGR 504. Technical Writing for Engineers. 3 Credits.
The process of planning, organizing, initiating, drafting, and editing engineering documents is covered through writing assignments and discussion. Writing, editing, and publishing the Kansas Engineer magazine. Prerequisite: ENGL 102.

ENGR 515. Verbal Communications in Engineering. 1 Credits.
Meets one hour per week. Planning, preparing, and presenting speeches on a variety of topics throughout the semester. Includes preparing speeches, spontaneous speeches and the evaluation of speeches by other students. Prerequisite: Two English courses and at least junior or senior standing in engineering or consent of instructor.

ENGR 600. Engineering Applications in India: Technical, Business, and implementation Issues. 3 Credits.
Business principles play a crucial role in shaping engineering solutions. This course will communicate key differences between the United States and India in how engineering challenges and opportunities are shaped by these principles and by culture. Students will travel to India to attend lectures from schools, visit companies, engage in class discussion/debate, and attend cultural excursions. Prerequisite: Major in Engineering.

ENGR 940. Project (DE). 1-16 Credits.
A major design problem or system study satisfying the project requirement for the Doctor of Engineering degree.

Engineering Physics Courses

EPHX 210. General Physics I for Engineers. 3 Credits. GE11 GE3N NLEC
This course is an introduction to classical mechanics and thermodynamics designed for students in the School of Engineering who have completed MATH 125 or MATH 145 with a grade of C or better. Students not admitted to the School of Engineering must receive permission from instructor. EPHX 210 and PHSX 211 cannot both be taken for credit. Prerequisite: MATH 125 or MATH 145 with a grade of C or better. Corequisite: MATH 126 or MATH 146; courses in high school physics and/or chemistry recommended.

EPHX 400. Topics in Engineering Physics: _____. 1-3 Credits.
A course on special topics in engineering physics, given as the need arises. Course may be repeated for different topics. Each section may have additional prerequisites to be determined by the instructor.

EPHX 501. Honors Research. 1-4 Credits. AE61 CAP
This course is for students seeking Departmental Honors in Astronomy, Engineering Physics, or Physics to fulfill the undergraduate research requirement. At the completion of the required four hours of total enrollment, a written and oral report of the research is required. (Same as ASTR 501 and PHSX 501.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor.

EPHX 503. Undergraduate Research. 1-4 Credits. AE61 CAP
This course is for students seeking to fulfill the undergraduate research requirement. Students are expected to participate in some area of ongoing research in the department, chosen with the help of their advisor. At the end of the term, students will present their results in a seminar to other students and faculty. (Same as ASTR 503 and PHSX 503.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor.

EPHX 518. Mathematical Physics. 3 Credits.
Applications of modern mathematical methods to problems in mechanics and modern physics. Techniques include application of partial differential equations and complex variables to classical field problems in continuous mechanics, unstable and chaotic systems, electrodynamics, hydrodynamics, and heat flow. Applications of elementary transformation theory and group theory, probability and statistics, and nonlinear analysis to selected problems in modern physics as well as to graphical representation of experimental data. (Same as PHSX 518.) Prerequisite: PHSX 313; MATH 220 or MATH 221 or MATH 320; or permission of instructor.

EPHX 521. Mechanics I. 3 Credits.
Newton's laws of motion. Motion of a particle in one, two, and three dimensions. Motion of a system of particles. Moving coordinate systems. (Same as PHSX 521.) Prerequisite: PHSX 213 or PHSX 211 and PHSX 216; MATH 127 or MATH 147; MATH 290 or MATH 291; and MATH 220, MATH 221 or MATH 320.

EPHX 531. Electricity and Magnetism. 3 Credits.
This course will explore the properties of electric and magnetic fields, including electrostatics, Gauss' Law, boundary value methods, electric fields in matter, electromagnetic induction, magnetic fields in matter, the properties of electric and magnetic dipoles, and of dielectric and magnetic materials. (Same as PHSX 531.) Prerequisite: PHSX 214, or PHSX 212 and PHSX 236; PHSX 521 or EPHX 521 or special permission; MATH 127 or MATH 147; MATH 290 or MATH 291; and MATH 220, MATH 221, or MATH 320.

EPHX 536. Electronic Circuit Measurement and Design. 4 Credits. LFE
A laboratory course that explores the theory and experimental techniques of analog and digital electronic circuit design and measurement. Topics include transient response, transmission lines, transistors, operational amplifiers, and digital logic. (Same as PHSX 536.) Prerequisite: PHSX 214 or PHSX 212 and PHSX 236; MATH 127 or MATH 147; and MATH 290 or MATH 291. PHSX 313 and 316 recommended.

EPHX 600. Special Topics in Physics and Astrophysics: _____. 1-3 Credits.
Different topics will be covered as needed. This course will address topics in physics and astrophysics not covered in regularly offered courses. May be repeated if topic differs. (Same as PHSX 600.) Prerequisite: Permission of instructor.

EPHX 601. Design of Physical and Electronic Systems. 4 Credits. LFE AE61 CAP
A laboratory course emphasizing the application of physical principles to the design of systems for research, monitoring, or control. Topics include the use of microcomputers as controllers, interfacing microcomputers

with measurement devices, and use of approximations and/or computer simulation to optimize design parameters, linear control systems, and noise. (Same as PHSX 601.) Prerequisite: Twelve hours of junior-senior credit in physics or engineering, including one laboratory course.

EPHX 611. Introductory Quantum Mechanics. 3 Credits.
An introduction to quantum mechanics, emphasizing a physical overview. Topics include the formalism of nonrelativistic quantum mechanics with emphasis on linear algebra, the 3-dimensional Schrodinger equation with applications to the hydrogen atom; harmonic oscillator; and time-independent perturbation theory. (Same as PHSX 511.) Prerequisite: PHSX 313, PHSX 521 or EPHX 521, and MATH 290 or MATH 291.

EPHX 614. Introduction to Quantum Algorithms. 3 Credits.
This course provides an overview of various quantum algorithms and quantum machine learning. Topics include quantum circuits, quantum algorithms for algebraic problems, quantum random walk, quantum algorithms for simulating quantum mechanics, quantum machine learning, limitations on the power of quantum computers, and selected recent developments in quantum algorithms. (Same as PHSX 614.) Prerequisite: PHSX 313 (PHSX 611 preferred); MATH 290, MATH 291 or equivalent (MATH 590 preferred); PHSX/ASTR 315 or approval of instructor.

EPHX 615. Numerical and Computational Methods in Physics. 3 Credits.
An introduction to the use of numerical methods in the solution of problems in physics for which simplifications allowing closed-form solutions are not applicable. Examples are drawn from mechanics, electricity, magnetism, thermodynamics, and optics. (Same as PHSX 615.) Prerequisite: PHSX 313, MATH 320 or equivalent, and EECS 138 or equivalent.

EPHX 616. Physical Measurements. 4 Credits. LFE
A laboratory course emphasizing experimental techniques and data analysis, as well as scientific writing and presentation skills. Experiments will explore a range of classical and modern physics topics. Students will also practice ethical decision making using case studies appropriate for the discipline. (Same as PHSX 616.) Prerequisite: PHSX 313, PHSX 316 or EPHX 316, and PHSX 521 or EPHX 521. (PHSX 521 or EPHX 521 may be taken concurrently.)

EPHX 621. Mechanics II. 3 Credits.
Continuation of PHSX 521. Lagrange's equations and generalized coordinates. Mechanics of continuous media. Tensor algebra and rotation of a rigid body. Special relativity and relativistic dynamics. (Same as PHSX 621.) Prerequisite: EPHX 521 or PHSX 521.

EPHX 631. Electromagnetic Theory. 3 Credits.
Maxwell's equations, wave propagation, optics and waveguides, radiation, relativistic transformations of fields and sources, use of covariance and invariance in relativity. Normally a continuation of PHSX 531. (Same as PHSX 631.) Prerequisite: EPHX 531 or PHSX 531.

EPHX 641. Introduction to Nuclear Physics. 3 Credits.
Experimental methods in nuclear physics, elementary concepts and simple considerations about nuclear forces, alpha and beta decay, gamma radiation, nuclear structure, and reaction systematics. (Same as PHSX 641.) Prerequisite: PHSX 313 and PHSX 611 or EPHX 611.

EPHX 655. Optics. 3 Credits.
Geometric optics. Wave properties of light: interference, diffraction, coherence. Propagation of light through matter. Selected topics in modern optics, e.g., lasers, fibers. (Same as PHSX 655.) Prerequisite: PHSX 531 or EPHX 531 or PHSX 212 or PHSX 214 and special permission from instructor.

EPHX 661. Introduction to Elementary Particle Physics. 3 Credits.

This course covers properties and interactions of quarks, leptons, and other elementary particles; symmetry principles and conservation laws; broken symmetry; gauge bosons; the fundamental interactions, grand unified theories of strong, electromagnetic, and weak interactions; the cosmological implications of elementary particle physics. (Same as PHSX 661.) Prerequisite: PHSX 611 or EPHX 611, and MATH 220, MATH 221, or MATH 320.

EPHX 671. Thermal Physics. 3 Credits.
This course introduces thermodynamics from statistical considerations and presents the associated techniques for calculating the thermodynamic properties of systems. Highlighted applications of these techniques include the elementary kinetic theory of transport processes and statistical descriptions of both Fermi-Dirac and Bose-Einstein systems. (Same as PHSX 671.) Prerequisite: PHSX 611 or EPHX 611.

EPHX 681. Introduction to Solid State Physics. 3 Credits.
This course is an introduction to the properties of crystals and amorphous solids, including lattice vibrations and thermal properties, with a particular emphasis on the behavior of electrons and holes in the energy bands of metals, semiconductors, superconductors, and insulators. (Same as PHSX 681.) Prerequisite: PHSX 313 and PHSX 611 or EPHX 611.

EPHX 691. Astrophysics I. 3 Credits.
An introduction to radiation processes, thermal processes, and radiative transfer in stellar atmospheres and the interstellar medium. (Same as ASTR 691 and PHSX 691.) Prerequisite: PHSX 313 and ASTR 391.

EPHX 693. Gravitation and Cosmology. 3 Credits.
An overview of topics relevant to gravitation and modern cosmology: special relativity, tensor notation, the equivalence principle, the Schwarzschild solution, black holes, and Friedmann models. Cosmic black body radiation, dark matter, and the formation of large-scale structure. The idea of quantum gravity and an introduction to the current literature in cosmology. (Same as PHSX 693.) Prerequisite: PHSX 313, PHSX 521 (or EPHX 521), and MATH 220, MATH 221, or MATH 320.

Mechanical Engineering Courses

ME 101. Mechanical Engineering Freshman Seminar. 0-1 Credits.
This seminar is intended to provide the student with an overview of the mechanical engineering profession. Seminar topics will include an overview of the engineering profession, career opportunities within mechanical engineering, an introduction to the mechanical engineering department (faculty, research and student groups), and strategies to be successful at the university. Prerequisite: Fewer than 30 credit hours from the University of Kansas.

ME 208. Introduction to Digital Computational Methods in Mechanical Engineering. 3 Credits.
Digital computing methods for solving mechanical engineering problems utilizing current programming languages and commercial software. Topics from the course are applied through open-ended team projects throughout the semester which also give students an introduction to mechanical engineering. Prerequisite: Corequisite: MATH 116 or MATH 125 or MATH 145.

ME 210. Introduction to Mechanics. 1 Credits.
An introduction to mechanics of materials including stress, strain, and axial loading. Prerequisite: ME 201 or CE 201 or CE 260.

ME 211. Statics and Introduction to Mechanics. 3 Credits.
The principles of statics, with particular attention to engineering applications and an introduction to mechanics of materials. This course is

a combination of material covered in ME 201 and ME 210. Prerequisite: EPHX 210 or PHSX 211 or PHSX 213.

ME 212. Basic Engineering Thermodynamics. 3 Credits.
An introduction to the concepts of heat, work, the first and second laws of thermodynamics, equations of state, and properties. These concepts are applied to flow and nonflow systems including power and refrigeration cycles. Prerequisite: EPHX 210 or PHSX 211 and MATH 126 or MATH 146, with a grade of C- or higher.

ME 228. Computer Graphics. 3 Credits.
An introduction to solid modeling computer graphics used in mechanical design. Visualization skills and drawing practices are developed. Topics from the course are applied through open-ended team projects throughout the semester which also give students an introduction to mechanical engineering.

ME 301. Mechanical Engineering in a Global Market. 3 Credits.
This course will critically analyze the societal and cultural differences across the world as they pertain to mechanical engineers in practice. Topics covered may include the following: historical, religious, economic, financial, and ethical differences between cultures and their effect on engineering practice with consideration of public health, safety, and welfare. These societal and cultural differences will be emphasized and epitomized given the broad diversity within the mechanical engineering students, faculty, and staff. Prerequisite: Sophomore standing in Mechanical Engineering.

ME 306. Science of Materials. 3 Credits.
An introductory course on materials. Emphasis is placed on structure and the relation of structure to the behavior and properties of engineering materials. Prerequisite: CHEM 150 or CHEM 130 or CHEM 135 or CHEM 170 or CHEM 175 or CHEM 190 or CHEM 184 or CHEM 185 or consent of instructor.

ME 307. Engineering Materials Laboratory. 2 Credits.
Laboratory to supplement lecture on engineering materials properties and selection, manufacturing processes, and design for manufacturing. Prerequisite: CHEM 150 or CHEM 130 or CHEM 170 and ME 228 or ARCE 217 or AE 421. Corequisite: ME 306 and ME 311 or ME 309.

ME 309. Introduction to Mechanical Design. 1 Credits.
An introduction to mechanical design after completing a course in mechanics of materials. Topics include theories of failure and energy methods. ME 201, CE 310, and ME 309 together are equivalent to ME 211 and ME 311. Prerequisite: Permission of instructor.

ME 311. Mechanics of Materials. 3 Credits.
The principles of mechanics of materials with particular emphasis on mechanical systems including theories of failure. Prerequisite: ME 211 or ME 210 with a grade of C- or higher, and MATH 126 or MATH 146, with a grade of C- or higher.

ME 320. Dynamics. 3 Credits.
Kinematics and kinetics of particles and of rigid bodies as applied to mechanical engineering problems. Prerequisite: ME 201 or ME 211 or CE 201 or ME 210, with a grade of C- or higher, and MATH 220 or MATH 221 or MATH 320. Corequisite: ME 508.

ME 321. Dynamics Simulations. 1 Credits.
Introduction to dynamics simulations on the computer. Prerequisite: Corequisite: ME 320 or CE 250 or CE 260.

ME 360. Mechanical Engineering Problems. 1-3 Credits.
An analytical or experimental study of problems or subjects of immediate interest to a student and faculty member and which is intended to develop student capability for independent research or application of engineering science and technology. After completion of the project, a report is required. Maximum credit is three hours. Not open to students who have taken ME 361. Prerequisite: Approval of an outline of the proposed project by the instructor and department chair.

ME 361. Undergraduate Honors Research. 1-3 Credits.
Investigation of a particular mechanical engineering problem. Research will involve defining the problem, developing a research methodology, applying the research methodology and gathering data, analyzing and interpreting the data, and presenting the results of the research. The student must have a faculty sponsor and submit a proposal in writing stating the objective of the research, the planned research method that will be used, and the method of reporting the results. Maximum credit is three hours. Not open to students who have taken ME 360. Prerequisite: Participation in the University Honors Program, consent of instructor, and approval of the chair required.

ME 390. Special Topics: _____. 1-5 Credits.
Courses on special topics of current interest in mechanical engineering, given as the need arises. Prerequisite: Approval of instructor.

ME 412. Thermal Systems. 3 Credits.
Application of the principles of thermodynamics to the analysis and design of thermal systems. Prerequisite: ME 212 or ME 312.

ME 455. Mechanical Engineering Measurements and Experimentation. 4 Credits.
Lectures and laboratories on the basics of measurement, instrumentation, data acquisition, analysis, design and execution of experiments, and written and oral reports. Topics selected from heat transfer, fluid mechanics, thermodynamics, mechanics, strength of materials, and dynamics. Prerequisite: ME 208 or EECS 168 or EECS 138 or AE 211, ME 307, ME 320 or CE 250 or CE 260, and MATH 365 or MATH 526. Corequisite: EECS 318 and ME 612.

ME 501. Mechanical Engineering Design Process. 2 Credits.
The design process of a mechanical or thermal system. Establishment of specifications and consideration of realistic constraints such as safety, codes, economic factors, reliability, oral and written communications, and other factors as they impact the design process. Prerequisite: ME 228 or ARCE 217 or AE 421 and ME 311 or ME 309.

ME 508. Numerical Analysis of Mechanical Engineering Problems. 3-4 Credits.
Introduction to numerical methods for solution of mechanical engineering problems by use of digital computers. Prerequisite: ME 208, EECS 138, EECS 168, or AE 211 and MATH 220.

ME 510. Fluid Mechanics. 3 Credits.
An introduction to the mechanics of fluid flow. The principles of conservation of mass, momentum, and energy are developed in differential and integral form. Laws of dimensional analysis and similitude are presented as the basis for empirical correlations. Engineering applications include: calculation of hydrostatic forces on submerged objects, analysis of flow and pressure loss in piping systems, estimation of aerodynamic lift and drag, and performance characteristics of pumps and fans. Prerequisite: ME 211, ME 201, CE 301 or CE 201 or CE 260 with a grade of C- or higher, and MATH 127 or MATH 147 and ME 212, with a grade of C- or higher.

ME 511. Introduction to Continuum Mechanics. 3 Credits.
This course is designed to provide unified treatment of thermodynamic principles, conservation and balance laws for continuous matter. The material covered in this course is core and fundamental knowledge necessary for thorough understanding of the deformation physics of solid and fluent continua and provides the foundation-level coverage of theory underlying several sub-fields, including Fluid Mechanics, Solid Mechanics and Heat Transfer as well as for advanced studies in

continuum mechanics. Topics covered include the coordinate systems and coordinate transformations, introduction to tensors, measures of stress, kinematics of deformation, conservation and balance laws, constitutive theories and differential operators. Prerequisite: MATH 220 or MATH 221 or MATH 320, ME 212, ME 311. Corequisite: ME 510.

ME 533. Fluid Systems and Gas Dynamics. 3 Credits.
One-third of the course will extend the coverage of ME 510 to include rotating machinery (fans, pumps) and practical fluid-handling issues and fluid-handling systems. The second two-thirds of the course will introduce the basic concepts of compressible fluid flow. Prerequisite: ME 510.

ME 590. Special Topics: _____. 1-5 Credits.
Courses on special topics of current interest in mechanical engineering, given as the need arises. Prerequisite: Approval of instructor.

ME 608. Introduction to Mechatronics. 3 Credits.
This course is a laboratory-based, design course in prototyping, programming, and development of mechatronic systems. The course includes programming of microcontrollers, integration of sensors and actuators, data acquisition, system modeling, and control of mechatronic systems. Prerequisite: ME 208 or equivalent and ME 320 or equivalent, or permission of instructor.

ME 612. Heat Transfer. 3 Credits.
This course introduces the fundamental concepts of conduction, convection, and radiation heat transfer. Specific topics include the analysis of steady-state and transient conduction, free and forced convection as well as boiling and condensation, radiation heat transfer involving opaque solids, and multimode heat transfer. Various engineering devices and applications, such as heat exchangers and those associated with emerging technologies, are analyzed. Prerequisite: MATH 220 and ME 510 or C&PE 511.

ME 617. Research for Design Project Option B. 1 Credits.
Basic research in one targeted area of vehicle design, and competition rules, based on the student's plan for ME 627 and ME 642. Prerequisite: ME 501, ME 510, and ME 628.

ME 627. Automotive Design. 3 Credits.
Basic concepts of automotive design and manufacture. Primary focus of course on vehicle design and performance. Design is subdivided into vehicle components of frame, suspension, front and rear axle, steering power train, front and rear wheel drive, and braking. Integration of these ideas into a vehicle design project with analysis of its performance culminates the course. Prerequisite: ME 617 and permission of instructor.

ME 628. Mechanical Design. 3 Credits.
Design of mechanical components and systems. An introduction to the principles and methods of fatigue analysis. Analysis of machine elements such as shafting and related components, gears, bearings, and threads based on static and fatigue analysis as well as appropriate standards. Prerequisite: ME 311.

ME 633. Basic Biomechanics. 3 Credits.
Provides an overview of musculoskeletal anatomy. Biodynamics includes linear and angular dynamics of human movement, energy expenditure and power required to perform a given activity. Students will learn to determine joint forces and torques (in 2-D) from kinematic data for body segments and force plate data. The tissue mechanics section builds on mechanics of materials. Students will learn about tissue properties, appropriate constitutive models and determination of stresses and strains in tissues and structures under normal loading conditions. Prerequisite: ME 311 or ME 309 and ME 320 or CE 250 or CE 260.

ME 636. Internal Combustion Engines. 3 Credits.
Study and analysis of internal combustion engine physical phenomena, components, and system design. Emphasis on spark ignition and compression ignition engine analysis. Performance, current technology, thermodynamics, fluid-mechanics, combustion products and pollution, fuels, and mechanical design. Prerequisite: ME 212 with a grade of C- or higher.

ME 637. Steam Power Plants. 3 Credits.
A study of steam power plant equipment including thermodynamic analysis, design and performance of modern steam generators, prime movers, and auxiliaries. Prerequisite: ME 212 grade of C- or higher or permission of instructor.

ME 639. Alternative Energy Systems. 3 Credits.
This course is a survey of energy resources and the available technology for meeting current energy needs with alternative energy systems. An overview of the U.S. energy system and world-wide energy consumption is included to provide context. The primary course objective is to develop the students' ability to apply engineering fundamentals to the design and operation of alternative energy systems. The students will be introduced to databases and modeling methods used to represent alternative energy resources. Assignments will include: engineering problem analysis, group design projects, individual research papers, oral and written presentations. Prerequisite: ME 510, AE 345, or C&PE 511.

ME 640. Design Project. 2 Credits. AE61 CAP
Planning for a capstone design project. Development of a formal project proposal is required. Must be used with two credit hours of ME 641 or ME 643 in the subsequent semester to complete the capstone design requirements. Prerequisite: ME 501, ME 510, and ME 628.

ME 641. Design Project Option A. 2 Credits. AE61 CAP
Design and development of a mechanical or thermal/fluid system. An individual or group report that includes designs, analysis/testing, drawings, and/or schematics is required. Establishment of specifications and consideration of realistic constraints such as safety, economic factors, design impact, aesthetics, and reliability are required. Prerequisite: ME 640. Corequisite: ME 455.

ME 642. Design Project Option B. 3 Credits. AE61 CAP
Manufacturing and testing of a mechanical system designed and developed in ME 627 - Vehicle Design. A group report with individual assignments which details the manufacturing procedures and testing procedures and results is required. A completed, working project with a design file documenting all aspects of the project development must be submitted. Prerequisite: ME 617 and ME 627. Corequisite: ME 455.

ME 643. Design Project Option C. 2 Credits. AE61 CAP
Design and development of a mechanical system related to biomechanics that has been investigated in ME 633 - Basic Tissue Mechanics and Biodynamics. A report that includes designs, analysis/testing, drawings and/or schematics is required. Establishment of specifications and consideration of realistic constraints such as safety, ergonomics, economic factors, design impact, aesthetics, and reliability are required. Prerequisite: ME 633 and ME 640. Corequisite: ME 455.

ME 661. The Finite Element Method. 3 Credits.
An introduction to the underlying theory of the finite element (FE) method and its application to linear solid and structural mechanics. FE formulations are derived for bars, beams, 2D formulations such as: plane stress, plane strain, and 3D solids. Basic issues are treated such as assembly and generation of FE equations, computation, post-processing, and interpretation of FE solutions (e.g. stresses and strains analysis). Prerequisite: ME 311 or ME 309, MATH 220 or MATH 221 or MATH 320.

ME 682. System Dynamics and Control Systems. 3 Credits.

An introduction to the modeling and analysis of analog linear systems and the design of control systems. Topics include mathematical models of mechanical, electrical, fluid and thermal systems, feedback concepts, transient response, frequency response and vibration, system stability, and design of feedback control systems including PID. Prerequisite: ME 320 or CE 250 or CE 260.

ME 696. Design for Manufacturability. 3 Credits.
Tools to incorporate manufacturing and life-cycle concerns into the design of products. Prerequisite: ME 501 or equivalent.

ME 702. Mechanical Engineering Analysis. 3 Credits.
A study of advanced methods for engineering analysis of practical problems utilizing fundamental principles from engineering disciplines. The emphasis is on the solution of these problems and the interpretation and generalization of the results. Prerequisite: A course in differential equations.

ME 708. Mechatronics. 3 Credits.
Design and implementation of interfaces of microcomputers to mechanical equipment. Includes laboratory experiments presenting selected industrial applications. Emphasis on human factors, functional design parameters and microprocessor interfaces. Includes instruction concerning specifications of practical hardware configurations and writing of programs necessary to accomplish mechanical systems applications. Prerequisite: ME 208 or equivalent and ME 320 or equivalent, or permission of instructor.

ME 712. Advanced Engineering Thermodynamics. 3 Credits.
An advanced course in thermodynamics, mathematical in nature, with emphasis on a critical re-evaluation of the laws of thermodynamics, thermodynamics of one-dimensional gas flow, development of the classical thermodynamic relations and their application to engineering problems. Prerequisite: ME 212 with a grade of C- or higher.

ME 713. Advanced Heat and Mass Transfer. 3 Credits.
Conduction, convection, and radiation are covered in more detail relative to ME 612, with a focus on the underlying physical phenomena and associated mathematical analyses. Diffusive and convective mass transfer is a significant part of this class, with emphasis on the analogies between conduction heat transfer and diffusive mass transfer, as well as convection heat transfer and convection mass transfer. Prerequisite: ME 612.

ME 716. Introduction to Surface and Interface Science. 3 Credits.
Surface and Interface Science plays a crucial role in various industrial, environmental, and biomedical areas, as well as in emerging technologies. These include wetting, water purification, enhanced oil recovery and other petrochemical processes. Surface and Interface Science also provides an intriguing arena for the integration of fundamental concepts, theoretical methods, and experimental techniques from a variety of scientific disciplines including engineering, physics, chemistry, biology, and medicine. This course presents fundamental and applied aspects of this rapidly developing field. The first segment of the course is devoted to understanding interfacial phenomena by examining the roles of surface composition and surface texture. The second segment covers how this fundamental understanding can be used to design bio-inspired surfaces for various applications that involve self-cleaning mechanisms, anti-reflective coating, fog harvesting and de-icing. Prerequisite: ME 312 or physical chemistry or equivalent.

ME 718. Fundamentals of Fuel Cells. 3 Credits.
The principles of fuel cells, with focus on low temperature fuel cells using polymer electrolytes. Prerequisite: A course in engineering thermodynamics (e.g., ME 412), heat transfer (e.g., ME 612), and fluid Mechanics (e.g., ME 510.)

ME 722. Modeling Dynamics of Mechanical Systems. 3 Credits.
Modeling, analysis and simulation of dynamic mechanical systems. Emphasis on the analysis of kinematics and dynamics of rigid mechanical multibody systems undergoing large overall motion using interactive computer simulation programs. Applications to the design and control of dynamic systems such as robots, machine tools, and artificial limbs. Prerequisite: ME 320 or CE 300.

ME 733. Gas Dynamics. 3 Credits.
A study of the thermodynamics and fluid dynamics of gaseous media. Emphasis is placed on the rigorous application of conservation laws to represent physical processes. Classical and statistical models for the thermodynamic and transport properties are examined. Applications include determination of gas properties, wave propagation, and high-speed flow. Prerequisite: ME 412 and ME 510 or equivalents.

ME 736. Catalytic Exhaust Aftertreatment Modeling. 3 Credits.
Fundamental concepts behind catalysis and its application to catalytic exhaust aftertreatment devices for automobiles. Topics covered are the development of governing equations based on conservation laws, their numerical solutions using finite difference methods, and heterogeneous chemical reactions. Project assignments will be included. Prerequisite: ME 212 with a grade of C- or higher and ME 510 or permission of instructor.

ME 743. Mechanical Metallurgy. 3 Credits.
This course will present an area of knowledge which deals with the behavior and response of metals to applied forces. This knowledge will be presented in four parts: 1) Mechanical fundamentals; 2) Metallurgical fundamentals; 3) Applications in materials testing; 4) Plastic forming of metals. Prerequisite: ME 306 and ME 307 and ME 311; or consent of instructor.

ME 750. Biomechanics of Human Motion. 3 Credits.
Fundamental concepts of anatomy and physiology are introduced but the focus is on the biomechanics of human motion. Human body segment kinematics and joint kinematics are analyzed. An introduction to muscle mechanics is provided. Applications in balance and gait are covered. Prerequisite: Corequisite: ME 320 or equivalent.

ME 751. Experimental Methods in Biomechanics. 3 Credits.
This course will focus on methods of experimental measurement and computational modeling used in biomechanics. Instrumentation used to measure three-dimensional motion, ground reaction forces, center of pressure and EMG measures are considered. Methods used for inverse dynamics, direct dynamics and simulation are introduced. Prerequisite: ME 320 or equivalent.

ME 752. Acoustics. 3 Credits.
This course will teach the production, propagation, and effects of sound waves. Detailed topics include plane wave, spherical wave, and cylindrical wave propagation in free space and waveguides, wave reflection and transmission on an interface, piston radiation, wave scattering and diffraction. Prerequisite: ME 320 or permission of instructor.

ME 753. Bone Biomechanics. 3 Credits.
Provides an in-depth knowledge of bone as a living mechanical system. Topics include the microstructure, biology, mechanical properties, mechanical modeling, adaptation of bone to the mechanical environment, and its simulation. Students assignments include homework, a poster presentation, basic finite element analysis laboratory, and bone remodeling simulations. Prerequisite: ME 311 or equivalent.

ME 754. Medical Imaging. 3 Credits.
This course will focus on the fundamental physics of modern medical imaging technologies, which includes X-Ray, Computed Tomography, Magnetic Resonance Imaging, ultrasound imaging, optical imaging, and

more. Recent trends in medical imaging technology development will also be introduced. Prerequisite: ME 508 or permission of instructor.

ME 755. Computer Simulation in Biomechanics. 3 Credits.
Provides an in-depth knowledge of 1) the process of developing a research question to be addressed with computer simulation, 2) various techniques for medical imaging to obtain model geometries (including hands-on experience with low-field MR imaging), 3) image segmentation techniques, 4) issues affecting geometric accuracy in model building, 5) the determination and specification of loading and/or kinematic boundary conditions, 6) the interpretation of model results in the context of the model limitations and the medical application. Knowledge and/or experience with finite elements is desirable, but not required. Prerequisite: ME 311 and ME 320 or equivalent.

ME 757. Biomechanical Systems. 3 Credits.
A course on the dynamics and motor control of human and animal motion. The course will focus on applying mechanical principles of dynamics, lumped parameter systems, and control theory to problems in biomechanics. Topics include muscle mechanics and dynamics, reflex and voluntary control, proprioception, anatomy of the muscular and nervous systems, and system dynamics in locomotion and other movements. Prerequisite: ME 682 or permission of instructor.

ME 758. Physiological System Dynamics. 3 Credits.
This course covers the use of engineering systems modeling approaches to understand the function of physiological systems. Systems covered include the cardiovascular system, the respiratory system, the renal system, the gastrointestinal system, and the musculoskeletal system. Prerequisite: ME 510, ME 320, Physics 212 or permission of instructor.

ME 760. Biomedical Product Development. 3 Credits.
Introduction to methods of taking medical product inventions from conception to initial stage production. Students work in cross-functional teams to investigate development potential of inventions. Topics covered include product development processes, regulatory issues with the FDA, quality system requirements, SBIR/STTR funding pathways, biomaterial and biomechanics issues in medical product design, and ethical considerations. Prerequisite: Senior or graduate student standing in engineering, business, industrial design, or an applicable life science field and permission of instructor.

ME 765. Biomaterials. 3 Credits.
An introductory course on biomaterials science and consideration of biomaterials in the design of biomedical implants. Topics including ethical considerations in biomaterials research and the role of the FDA in medical device design are also presented. Prerequisite: ME 306.

ME 767. Molecular Biomimetics. 3 Credits.
The lessons learned from biological materials are discussed toward developing novel biomimetic materials and systems using environmentally benign processing. Upon completing this course, students will be able to understand the essential features of biological sciences combined with nano- and molecular technologies for next generation bioinspired, biomimetic and bio-enabled materials and systems. Prerequisite: CHEM 130, CHEM 150 or equivalent; introductory course in Material Science (e.g., ME 306.)

ME 770. Design Optimization for Mechanical Systems. 3 Credits.
This course is designed to provide mechanical engineering students with a view of optimization as a tool for decision-making when solving engineering problems. Students will be given a fundamental introduction to optimization techniques and an opportunity to learn how to model design and manufacturing problems and solve them using analytical and numerical optimization techniques. Prerequisite: MATH 125 or MATH 145, and EPHX 210 or PHSX 211 or PHSX 213.

ME 788. Optimal Estimation. 3 Credits.
Covers the principles of optimal estimation theory, with particular focus on Kalman filtering and its engineering applications. Prerequisite: A course in elementary linear algebra (e.g.MATH 290), statistics (e.g. MATH 365, MATH 526, or DSCI 202), and system dynamics and control systems (e.g.ME 682.)

ME 789. Energy Storage Systems and Control. 3 Credits.
This course offers an introduction to the mechanisms, modeling, monitoring and control of energy storage systems with a primary focus on batteries but includes coverage of fuel cells and ultra-capacitors. A major theme is to offer students state-of-the-art knowledge of energy storage systems and aid them in developing the ability to apply estimation and control theory in order to address the problems arising in energy storage management. After completion of the course, a student is expected to: 1) understand the respective work mechanisms, advantages and disadvantages of batteries, fuel cells and ultra-capacitors, 2) understand the mathematical modeling methodologies for batteries, 3) understand the key estimation/control methods and tools, and 4) build effective solutions for energy storage management problems leveraged with estimation/control theory. Prerequisite: ME 682 or equivalent.

ME 790. Special Topics: _____. 1-5 Credits.
Advanced courses on special topics of current interest in mechanical engineering, given as the need arises. Prerequisite: Approval of instructor.

ME 797. Materials for Energy Applications. 3 Credits.
Focus on fundamentals of materials for energy applications. The main topics covered will be: 1) introduction to material science & engineering and electrochemical technologies, 2) microscopic view of solid materials, 3) mass transfer by migration and diffusion, 4) energy related materials and devices, 5) electrochemical engineering fundamentals, etc. Prerequisite: Basic Engineering Thermodynamics (e.g., ME 312) or equivalent.

ME 798. Manufacturing for Energy Applications. 3 Credits.
The focus of the course is on fundamentals of materials for energy applications. The main topics covered include: 1) introduction and overview of manufacturing, 2) material properties and engineering materials, 3) traditional and nontraditional manufacturing processes, 4) surface engineering and processing, and 5) energy-related materials and device fabrication. Prerequisite: ME 508 or equivalent and ME 797.

ME 801. Responsible Conduct of Research in Engineering. 1 Credits.
Lectures and discussion on ethical issues in the conduct of a scientific career, with emphasis on practical topics of special importance in bioengineering. Topics include the nature of ethics, the roles of the scientist as a reviewer, entrepreneur, employer and teacher, research ethics in the laboratory, social responsibility and research ethics regulation. (Same as BIOE 801.) Prerequisite: Permission of instructor.

ME 810. Advanced Fluid Mechanics. 3 Credits.
Topics include kinematic and dynamic behavior of fluids, derivation of Navier-Stokes equations, flow classification, solutions of viscous and inviscid flows for simple geometries, potential flow theory and laminar and turbulent boundary layer theory. Prerequisite: ME 510 or equivalent.

ME 831. Convective Heat and Momentum Transfer. 3 Credits.
The formulation and solution of steady and unsteady convective heat, mass, and momentum transfer problems. Topics include boundary layers, duct flows, natural convection with and without phase change, development of analogies, transport properties, numerical methods. Prerequisite: ME 612 or equivalent.

ME 832. Computational Fluid Dynamics and Heat Transfer. 3 Credits.

The fundamentals of the finite-difference method are presented and applied to the formulation of numerical models for heat and momentum transfer. The accuracy, stability, and computational efficiency of different algorithms are analyzed. Computer programs are developed for classical benchmark problems. Prerequisite: ME 508, ME 510, and ME 612 or equivalents.

ME 836. Hybrid and Electric Vehicles. 3 Credits.
Topics covered include history of electrified vehicles, vehicle modeling, battery chemistry, and electric motors. Review of fundamental electrical engineering concepts provided. Application of real world driving profiles through homework assignments. Laboratories will explore battery and motor fundamentals. Homework assignments will be included along with a semester project involving the design, construction, and testing of a scale electric vehicle. Prerequisite: ME 636 or permission of instructor.

ME 840. Continuum Mechanics I. 3 Credits.
Principles of Continuum Mechanics for solids, fluids, and gases. Frames of references, measures of motion, deformation, strains, stresses, their rates, objectivity and invariance. Conservation laws, constitutive equations, equations of state and thermodynamic principles for developing mathematical models of continuum matter. Theoretical solutions of model problems. Prerequisite: Background in Calculus and Differential Equations is recommended.

ME 841. Continuum Mechanics II. 3 Credits.
Fundamental principles of Continuum Plasticity, measures of plastic strains, stresses and constitutive equations for flow theory of plasticity. Internal variable theory of thermo-mechanical behaviors and endochronic theory of plasticity and viscoplasticity. Anisotropic plasticity and advanced topics. Continuum mechanics principles for viscoelastic solids with emphasis on constitutive equations. Development of complete mathematical models and solutions of selected model problems. Prerequisite: ME 840.

ME 854. Continuum Mechanics for Soft Tissues. 3 Credits.
An introductory course in the analysis of the mechanical behavior of materials modeled on the continuum assumption. The course will provide background on soft tissue properties and will focus on the tools necessary to model soft tissues, including the essential mathematics, stress principles, kinematics of deformation and motion, and viscoelasticity. Prerequisite: ME 311 or equivalent.

ME 860. Advanced Mechanical Engineering Problems. 1-3 Credits.

An analytical or experimental study of problems or subjects intended to develop a student's capability for independent research or application of engineering science and technology. For students also enrolled in thesis or dissertation hours, the topic should be demonstrably distinct from their research efforts. Maximum credit toward any degree is three hours unless approved in writing by the departmental chairperson. Prerequisite: Approval of instructor.

ME 861. Theory of the Finite Element Method. 3 Credits.
Finite element method for solid mechanics, heat transfer, fluid mechanics, and dynamics. Modeling techniques, software implementation, and solution of problems. Prerequisite: Background in Calculus and Differential Equations is recommended.

ME 862. Finite Element Method for Transient Analysis. 3 Credits.
Advanced treatment of dynamic and transient response for linear and nonlinear problems in solid mechanics. Formulation and solution of time dependent linear and nonlinear field problems using finite element techniques. Prerequisite: ME 861.

ME 882. Advanced Control Systems. 3 Credits.
Advanced methods in the modeling, analysis and design of linear and nonlinear control systems. Topics include but not limited to digital controls methods, energy-based modeling, and state-space methods. Prerequisite: ME 682.

ME 890. Special Topics: _____. 1-5 Credits.
Advanced courses on special topics of current interest in mechanical engineering, given as the need arises. Prerequisite: Approval of instructor.

ME 899. Independent Investigation. 1-6 Credits.
An analytical or experimental investigation of an engineering problem requiring independent research. If the thesis option is selected six credit hours are required for the degree. If the project option is selected three credit hours are required for the degree. (See requirements for the Master of Science degree for additional details.) Graded on a satisfactory progress/limited progress/no progress basis.

ME 942. Microcontinuum Theories. 3 Credits.
Microcontinuum theories address physics and mathematics of material with microconstituents in which microconstituents kinematics can have profound influence on macrodeformation. The material in the course considers micromorphic, microdilation and micropolar microcontinum theories. The conservation and the balance laws are initiated for microdeformation physics followed by integral-average definitions that permit derivation of macro conservation and balance law containing influence of micro kinematics. Constitutive theory for all three microcontinuum are derived for thermoelastic and thermoviscoelastic physics with rheology. Ordered rate constitutive theories are derived for dissipation as well as rheology. The dissipation and rheology physics are considered for the microconstituents, for the medium as well as for the interaction of the microconstituents with the medium, yielding dissipation and relaxation time spectra in each case. Prerequisite: ME 840 and ME 841.

ME 990. Special Topics: _____. 1-5 Credits.
Advanced courses on special topics of current interest in mechanical engineering, given as the need arises. Prerequisite: Approval of instructor.

ME 999. Independent Investigation. 1-16 Credits.
An analytical or experimental investigation of an engineering problem requiring independent research. Twenty four hours as a minimum are awarded for the Ph.D. dissertation. An original contribution suitable for publication in a referred journal is required of Ph.D. candidates. Graded on a satisfactory progress/limited progress/no progress basis.