SCHOOL OF ENGINEERING

Graduation requirements and regulations for every academic program are provided in this catalog. Degree 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* (http://catalog.ku.edu/archives)»

Aerospace Engineering (http://catalog.ku.edu/engineering/aerospace-engineering)

- Bachelor of Science in Aerospace Engineering (http://catalog.ku.edu/engineering/aerospace-engineering/bs)
- Master of Engineering in Aerospace Engineering (http://catalog.ku.edu/engineering/aerospace-engineering/me)
- Master of Science in Aerospace Engineering (http://catalog.ku.edu/engineering/aerospace-engineering/ms)
- Doctor of Engineering in Aerospace Engineering (http://catalog.ku.edu/engineering/aerospace-engineering/de)
- Doctor of Philosophy in Aerospace Engineering (http://catalog.ku.edu/engineering/aerospace-engineering/phd)

Bioengineering (http://catalog.ku.edu/engineering/bioengineering)

- Master of Science in Bioengineering (http://catalog.ku.edu/engineering/bioengineering/ms)
- Doctor of Philosophy in Bioengineering (http://catalog.ku.edu/engineering/bioengineering/phd)

Chemical Petroleum Engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering)

- Bachelor of Science in Chemical Engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering/bs-chemical)
- Bachelor of Science in Petroleum Engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering/bs-petroleum)
- Master of Science in Chemical and Petroleum Engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering/ms)
- Doctor of Philosophy in Chemical and Petroleum Engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering/phd)
- Graduate Certificate in Petroleum Management (http://catalog.ku.edu/engineering/chemical-petroleum-engineering/gradcert)

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

- Bachelor of Science in Architectural Engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/bs-architectural-engineering)
- Bachelor of Science in Civil Engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/bs-civil-engineering)
- Master of Science in Architectural, Civil, and Environmental Enginering and Environmental Science (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/ms)
- Master of Civil Engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/master-civil-engineering)
- Master of Construction Management (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/master-construction-management)
- Doctor of Philosophy in Civil Engineering, Environmental Engineering, and Environmental Science (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering/phd)

Electrical Engineering and Computer Science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)	Bachelor of Science in Electrical Engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-electrical-engineering) Bachelor of Science in Computer Engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-computer-engineering) Bachelor of Science in Computer Science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-computer-science) Bachelor of Science in Information Technology (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-information-technology) Bachelor of Science in Interdisciplinary Computing (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/bs-interdisciplinary-computing) Master of Science in Electrical Engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-electrical-engineering) Master of Science in Computer Engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-computer-engineering) Master of Science in Computer Science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-computer-science) Master of Science in Information Technology (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/ms-information-technology) Graduate Certificate in Cybersecurity (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-cybersecurity) Graduate Certificate in Data Science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-data-science) Graduate Certificate in Software Engineering and Management (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-software-engineering-management) Doctor of Philosophy in Computer Science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/phd-computer-science) Doctor of Philosophy in Electrical Engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/phd-electrical-engineering)
Engineering (http://catalog.ku.edu/engineering/engineering)	
Engineering Management (http://catalog.ku.edu/engineering/engineering-management)	Master of Science in Engineering Management (http://catalog.ku.edu/engineering/engineering-management/ms) Master of Engineering in Project Management (http://catalog.ku.edu/engineering/engineering-management/project-management) Master of Science in Project Management (http://catalog.ku.edu/engineering/engineering-management/project-management) Graduate Certificate in Foundations of Engineering Management (http://catalog.ku.edu/engineering/engineering-management/foundations-engineering-management-gcert) Graduate Certificate in Foundations of Project Management (http://catalog.ku.edu/engineering/engineering-management/foundations-project-management-gcert)
Engineering Physics (http://catalog.ku.edu/engineering/engineering-physics)	Bachelor of Science in Engineering Physics (http://catalog.ku.edu/engineering/engineering-physics/bs)
Mechanical Engineering (http://catalog.ku.edu/engineering/mechanical-engineering)	Bachelor of Science in Mechanical Engineering (http://catalog.ku.edu/engineering/mechanical-engineering/bs) Master of Science in Mechanical Engineering (http://catalog.ku.edu/engineering/mechanical-engineering/ms) Doctor of Philosophy in Mechanical Engineering (http://catalog.ku.edu/engineering/mechanical-engineering/phd)

Introduction

From communication systems to bridges, from satellites to manufacturing—society depends 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, but 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.

Facilities

Engineering faculty members and graduate students are major users of the facilities and services of many research laboratories and centers across campus and among our research partners at other universities:

- Bioengineering Research Center (http://www.berc.ku.edu)
- Biomechanics Research Laboratory (http://ejbrl.res.ku.edu/ejbrl.html)
- Biotechnology Innovation and Optimization Center (http://www2.ku.edu/~biocenter)
- Center for Environmentally Beneficial Catalysis (http://cebc.ku.edu)
- Center for Remote Sensing of Ice Sheets (https://www.cresis.ku.edu)
- Energy Council (http://kuenergycouncil.ku.edu)
- Higuchi Biosciences Center (http://www.hbc.ku.edu)
- Information and Telecommunication Technology Center (http://www.ittc.ku.edu)
  - Bioinformatics and Computational Life Sciences Laboratory
  - Communications and Networking Systems Laboratory
  - Computer Systems Design Laboratory
  - e-Learning Design Laboratory
  - Intelligent Systems Laboratory
  - Radar Systems and Remote Sensing Laboratory
- Institute for Policy and Social Research (http://www.ipsr.ku.edu)
- Tertiary Oil Recovery Project (https://torp.ku.edu)
- Kansas Biological Survey (http://kbs.ku.edu)
- Kansas Geological Survey (http://www.kgs.ku.edu)

School of Engineering

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785-864-3881

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785-864-1952

Dawn Shew, Director, Undergraduate Student Academic Services
785-864-2927

Undergraduate Programs

The school offers 12 undergraduate degree programs:

- Aerospace engineering (http://catalog.ku.edu/engineering/aerospace-engineering)
- Architectural engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Chemical engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering)
- Civil engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Computer engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Computer science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Electrical engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Engineering physics (http://catalog.ku.edu/engineering/engineering-physics)
- Interdisciplinary computing (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Information technology (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Mechanical engineering (http://catalog.ku.edu/engineering/mechanical-engineering)
- Petroleum engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering)

Engineering and computer science degree programs are accredited by the Accreditation Board for Engineering and Technology (http://www.abet.org).

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 and at least one year of both chemistry and physics. 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 concentration. A strong college preparatory program provides a good background for the student who plans to major in engineering.

Honors Programs

The school encourages all qualified students to participate in the University Honors Program (http://www.honors.ku.edu). Students in engineering must meet with an engineering advisor every semester and should also meet with an honors program advisor.

Some engineering departments offer an option to graduate with departmental honors. Departments set these requirements.

Bachelor of Science in Engineering Degree Requirements

The B.S. degree is offered with majors in aerospace engineering, architectural engineering, chemical engineering, civil engineering, computer engineering, electrical engineering, engineering physics, mechanical engineering, and petroleum engineering. The school also offers the B.S. degree in computer science, interdisciplinary computing, and information technology.

First- and Second-Year Preparation

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 (communications, humanities, social sciences, diversity, ethics, etc.),
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 the KU Core is required in all majors. Each department recommends certain courses be used to fulfill the KU Core 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.

General Education Component

Students in all engineering curricula must take courses that complement the technical content. These must include courses applicable to the KU Core and course work that

- Fosters an understanding of professional and ethical responsibility.
- Promotes the ability to communicate effectively.
- Develops an understanding of the impact of engineering solutions.
- Advances the student's knowledge of contemporary issues.

Each engineering department specifies courses that fulfill these requirements.

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.

Credit for Foreign Language Courses

Some foreign language courses may be applied toward graduation in engineering programs. A foreign language that is similar to the native language is not acceptable. Information on use of foreign language courses is available in each engineering program listing.

Petitions for Exceptions

A student seeking an exception to the rules and practices of the school should first consult an advisor and then petition the school to consider the exception. All petitions are approved by the Engineering Dean's Office with the guidance of the student's advisor and department.

Minors

Engineering students may minor in many liberal arts (http://catalog.ku.edu/liberal-arts-sciences) areas or in the schools of Business (http://www.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 take at least 18 credit hours, 12 of which must be 300-level courses or above. If the department or program has additional requirements for the minor, students must meet those requirements also. Interested students should see an advisor in the department offering the minor and complete a minor declaration form as early as possible.

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.

Limitation on Enrollment in Engineering Courses

After the fifth day of classes, enrollment in a course offered by the school is permissible only with approval of the instructor and permission of the dean. The school reserves the right to deny admission to courses offered by the school to any student who is officially enrolled in another division of the university and does not meet the school's standards for admission or readmission and/or who does not have the proper prerequisite course work completed.

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

The **Master of Science (M.S.)** degree is offered in 13 areas:

- Aerospace engineering (http://catalog.ku.edu/engineering/aerospace-engineering)
- Architectural engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Bioengineering (http://catalog.ku.edu/engineering/bioengineering)
- Chemical engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering)
- Civil engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Computer science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Electrical and computer engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Engineering management (http://catalog.ku.edu/engineering/engineering-management)
- Environmental engineering or science (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Information technology (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Mechanical engineering (http://catalog.ku.edu/engineering/mechanical-engineering)
- Petroleum engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering)
- Project management (http://pmgt.ku.edu)

The **Master of Engineering (M.E.)** is offered in aerospace engineering (http://catalog.ku.edu/engineering/aerospace-engineering) and project management (http://pmgt.ku.edu).

The Department of Civil, Environmental, and Architectural Engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering) offers the **Master of Civil Engineering (M.C.E.)** and the **Master of Construction Management (M.C.M.).**

The school offers the **Doctor of Philosophy (Ph.D.)** degree in 8 areas:

- Aerospace engineering (http://catalog.ku.edu/engineering/aerospace-engineering)
- Bioengineering (http://catalog.ku.edu/engineering/bioengineering)
- Chemical and petroleum engineering (http://catalog.ku.edu/engineering/chemical-petroleum-engineering)
- Civil engineering (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Computer science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Electrical engineering (http://catalog.ku.edu/engineering/electrical-engineering-computer-science)
- Environmental engineering or science (http://catalog.ku.edu/engineering/civil-environmental-architectural-engineering)
- Mechanical engineering (http://catalog.ku.edu/engineering/mechanical-engineering)

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.

For aerospace students interested in careers in engineering design or engineering project management, the school offers programs leading to the **Doctor of Engineering (D.E.)** degree in Aerospace engineering. (http://catalog.ku.edu/engineering/aerospace-engineering)

Certificate Programs

The School of Engineering is excited to offer certificate programs in the following focus areas:

- Data Science (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-data-science)
- Cybersecurity (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-cybersecurity)
- Software Engineering and Management (http://catalog.ku.edu/engineering/electrical-engineering-computer-science/certificate-software-engineering-management)
- Petroleum Management (http://catalog.ku.edu/engineering/chemical-petroleum-engineering/gradcert)

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 (http://www.business.ku.edu).

Graduate Grade-Point Average (GPA) Requirement

In addition to completing a Plan of Study (https://gradplan.engr.ku.edu/accounts/login/?next=) 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://gradplan.engr.ku.edu/accounts/login/?next=) 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 faculty members. Students are assigned an advisor by their engineering departments.

Each entering student is encouraged to attend KU's summer Orientation (http://firstyear.ku.edu/orientation) during June and July. At the summer orientation program, students are advised on course selection for the fall semester and given the opportunity to enroll. Students who cannot attend the orientation program confer with their advisors and enroll a day or two before classes start.

Enrollment holds are placed on all Engineering students' accounts each semester before enrollment. Students see their faculty advisors to plan schedules and discuss academic and career interests. Once a student has met with an advisor, the enrollment hold is released. Students are encouraged to call on their advisors any time during the school year if they wish to change their schedules or discuss other matters. Consultation with an advisor is recommended before making schedule changes.

Undecided engineering majors are advised in the Engineering Student Success office, LEEP 2 room 1415, 785-864-3881.

Graduate Advising

Graduate advising generally is done at the department and program level. Graduate students should contact the Director of Graduate Studies or Graduate Assistant in their department or program if they have not yet chosen an advisor or have general questions. Students just entering the graduate program should plan to attend Orientation (http://engr.ku.edu/graduate-orientation) (each fall and spring semester during the week prior to the start of 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://gradplan.engr.ku.edu/accounts/login/?next=) 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 (http://affordability.ku.edu/steps/index.shtml) 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 (http://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 (Probation)

Good Academic Standing

Undergraduates must maintain both semester and cumulative grade-point averages of 2.0 or higher to remain in good standing. Students' academic standings are reviewed after each semester.

Probation

If a student's 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 (http://www.aec.ku.edu) or English courses until all AEC and the KU Core Written Communications requirements are met.

Dismissal

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

1. Any semester grade-point average is below 2.0 while the student is on probation.
2. The cumulative grade-point average is below 2.0 after two semesters on probation.
3. The student has failed to meet the other requirements stated in the probation letter.
4. The student on probation has failed to make progress toward an engineering degree or toward fulfilling all AEC and the KU Core Written Communications requirements.

Readmission

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 to the Engineering Student Success office in LEEP2, room 1415. 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). 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.

Change of School

To change from one school to another, KU students must submit a Change of School form in the dean's office of the school they plan to enter.

Admission is competitive and students are considered on a case-by-case basis. Students must have an overall college grade-point average of 2.5 or better, with grades of "C" or better in calculus I and any courses in mathematics, science, and engineering taken. Applications are due February 15 for summer or fall admission and September 15 for spring admission.

Credit/No Credit

A Credit/No Credit option is available to all degree-seeking undergraduates. You may enroll in one course a semester under the option, if the course is not in your major or minor. For more information, visit the KU Policy Library (https://documents.ku.edu/policies/governance/USRR.htm#art2sect2). **Always check with your advisor before electing C/NC, as policies vary from department to department.**

Credit/No Credit is allowed for courses used to fulfill KU Core GE 2.1 Written Communication, GE 2.2 Oral Communication, GE 3H Arts & Humanities, GE 3S Social Sciences, AE 4.1 Human Diversity, AE 4.2 Cultural & Global Awareness, and AE 5 Social Responsibility and Ethics requirements only. If an Engineering department recommends that certain course work be used to fulfill any of these requirements, those courses shall not be eligible for Credit/No Credit.

Credit/No Credit is **not an option** for any credits counting towards aerospace, civil, or architectural engineering degrees.

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 14 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 students' accounts prior to enrollment each term. Students must meet with their assigned Engineering 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 advisor and the Engineering Dean's Office. The No Drop Hold prevents students from withdrawing from essential classes without speaking with an advisor about the possible negative ramifications of a withdrawal.

Students voluntarily leaving the School of Engineering may have their Engineering Advising Hold or No Drop Hold released by signing an official Change of School form to leave the School of Engineering. Change of School forms are available in the Engineering Student Success office, LEEP2, room 1415.

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.

Maximum and Minimum Semester 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 12 credit hours during the summer session except with approval of the major advisor and the dean.

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

CredTran (http://admissions.ku.edu/apply/credits) 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.

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.

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 (http://catalog.ku.edu/regulations) Regulations (http://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 (http://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 will be returning 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 assistant, who will submit a Progress-to-Degree (PtD) form. You will need to provide the assistant 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 (by email).

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 who are 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 assistant 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 assistant, 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, 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 honers 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://www.engr.ku.edu/career_center) 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 1001 Eaton Hall; additional information is available from 785-864-3891.

Aerospace Engineering Courses

AE 211. Computing for Engineers. 3 Hours.
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 121 or MATH 125. LEC.

AE 221. Introduction to Global History of Aerospace Technologies. 1-3 Hours.
This History of Aerospace Technology starts in neolithic times with a description of a variety of flying implements being used for hunting and warfare. Their basic designs, mechanics, impact on human evolution, migration and societal development are brought forward to the development of gunpowder, ballistics and rocketry. Lighter than air flight innovations from 1783 forward show an intermingling of civil and military uses through WWI, shaping world events and the fortunes of nations. Heavier than air inhabited flight exploration begins with Cayley, includes the contributions of technologists Lilienthal, Chanute, visionaries and writers Mouillard and Verne, and concludes in a vertical exploration by region, nation and manufacturer, including: Douglas, Boeing, Lockheed, Fokker, Heinkel, Messerschmitt, Fairey, Handley Page, Piaggio, Tupelov, Mikoyan-Gurevich, Kamov, Mitsubishi, Hindustan Aeronautics, Sud Aviation and others. This course represents a very unique opportunity for students to study under one of the most important, famous and well published Aerospace Technologists and Historians ever to practice. LEC.

AE 241. Private Flight Course. 1 Hour.
One hour of academic credit is given upon the awarding of the private pilot's license by the Federal Aviation Administration. Required documentation includes a letter from the F.A.A. designated examiner giving the check ride and a copy of the private license. The Department of Aerospace Engineering provides no ground or flight instruction. Graded on a satisfactory/fail basis. Prerequisite: Aerospace Engineering students only, with consent of instructor. IND.

AE 242. Private Flight Aeronautics. 3 Hours.
Three hours of academic credit is given for the successful completion of the F.A.A. private pilot's written examination. Required documentation is a copy of the written score. Available only to Aerospace Engineering transfer students as a course substitute for AE 245. IND.

AE 245. Introduction to Aerospace Engineering. 3 Hours.
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 121 or MATH 125. LEC.

AE 290. Aerospace Colloquium. 0.25 Hours.
This is a required course for all aerospace engineering majors each fall semester. Topics of importance and new 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. Technical films. Open enrollment. LEC.

AE 292. Aerospace Industrial Internship. 1 Hour.
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 freshman year. FLD.

AE 345. Fluid Mechanics. 3 Hours.
Study of fundamental aspects of fluid motions and basic principles of gas dynamics with application to the design and analysis of aircraft. Prerequisite: Corequisite: CE 301 or MATH 220. LEC.

AE 360. Introduction to Astronautics. 3 Hours.
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 122 or MATH 126. Corequisite: A course in computer programming. LEC.

AE 390. Aerospace Industrial Internship. 1 Hour.
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 Sophomore year. FLD.

AE 421. Aerospace Computer Graphics. 3 Hours.
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. LEC.

AE 430. Aerospace Instrumentation Laboratory. 3 Hours.
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 and EECS 318. LAB.

AE 441. Advanced Flight Training. 1-3 Hours.
Academic credit is given for the successful completion of advanced flight training beyond the private pilot rating. One hour is given for each of the following: commercial, instrument rating, certified flight instructor. The Aerospace Engineering Department provides no ground or flight instruction. Graded on a satisfactory/fail basis. Open enrollment. Prerequisite: AE 241. IND.

AE 445. Aircraft Aerodynamics and Performance. 3 Hours.
Study of airfoil and wing aerodynamics, component drag, static and special performance, and maneuvers of aircraft. Open enrollment. Prerequisite: AE 345, CE 301. LEC.

AE 490. Aerospace Industrial Internship. 1 Hour.
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. FLD.

AE 507. Aerospace Structures I. 3 Hours.
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. LEC.

AE 508. Aerospace Structures II. 3 Hours.
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 507. LEC.

AE 509. Honors Aerospace Structures. 3 Hours.
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 507. LEC.

AE 510. Aerospace Materials and Processes. 4 Hours.
Properties and applications of aircraft materials, forming methods, and manufacturing processes. Ethics and social responsibility for engineers. Oral technical presentations. Prerequisite: AE 507 and CHEM 130 or CHEM 150. LEC.

AE 521. Aerospace Systems Design I. 4 Hours AE61.
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, AE 551, and AE 572. LEC.

AE 522. Aerospace Systems Design II. 4 Hours AE61.
Preliminary design project of a complete aircraft system. Technical written reports and oral presentations. Prerequisite: AE 521. LEC.

AE 523. Space Systems Design. 4 Hours AE61.
Preliminary design project of a complete space system. Technical written reports and oral presentations. Prerequisite: AE 521 and AE 560. LEC.

AE 524. Propulsion Systems Design I. 4 Hours AE61.
Preliminary design project of a complete propulsion system, including the airframe. Technical written reports and oral presentations. Prerequisite: AE 521. Enrollment only allowed by permission of instructor. LEC.

AE 545. Fundamentals of Aerodynamics. 4 Hours.
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: AE 445, ME 312, MATH 127 and MATH 220. LEC.

AE 546. Honors Aerodynamics. 5 Hours.
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 312, MATH 220 and MATH 290. LEC.

AE 550. Dynamics of Flight I. 4 Hours.
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: AE 445 and MATH 220. Corequisite: MATH 290. LEC.

AE 551. Dynamics of Flight II. 4 Hours.
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 550. LEC.

AE 552. Honors Dynamics of Flight II. 4 Hours.
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 550 and a course in differential equations (MATH 220 or MATH 320). LEC.

AE 560. Spacecraft Systems. 3 Hours.
Fundamentals of spacecraft systems and subsystems. Spacecraft systems engineering, space environment; basic astrodynamics; and the following spacecraft subsystems; attitude determination and control; electrical power; thermal; propulsion; structures and mechanisms; command, telemetry, and data handling; and communications. Prerequisite: AE 360, AE 507, EECS 318, and ME 312. LEC.

AE 571. Fundamentals of Airplane Reciprocating Propulsion Systems. 3 Hours.
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 312. LEC.

AE 572. Fundamentals of Jet Propulsion. 3 Hours.
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. LEC.

AE 573. Honors Propulsion. 3 Hours.
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 and AE 571. LEC.

AE 590. Aerospace Senior Seminar. 1 Hour.
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. LEC.

AE 592. Special Projects in Aerospace Engineering for Undergraduate Students. 1-5 Hours.
Directed design and research projects in aerospace engineering. Prerequisite: Consent of instructor. IND.

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

AE 600. Special Topics: _____. 1-3 Hours.
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. IND.

AE 621. Advanced Aircraft Design Techniques I. 3 Hours.
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. LEC.

AE 628. Wind Turbine Engineering. 3 Hours.
Course will cover the fundamentals of engineering wind-powered electric generators. Topics will include turbine configuration design, drive train engineering, composite rotor blade aerodynamic and structural design, characterizing the influence of the wind conditions on the operation, loads, and performance of a wind turbine, wind turbine controls systems engineering, and power electronic conversion. Prerequisite: AE 508, AE 545, and EECS 316 and EECS 318 or equivalent. LEC.

AE 670. Aerospace Propulsion III. 3 Hours.
Advanced theory of turbojet, fanjet (multi-spool), variable cycle engines, ramjet and bypass air breathing propulsion systems. Theory and design of inlets, compressors, burners and turbines. Component matching, cooling, regenerative systems, test methods and corrections. Prerequisite: AE 572. LEC.

AE 690. Professional Development for Graduate Studies. 0.25 Hours.
Professional development for graduate students. Presentation and discussion of graduate student research. Meets approximately monthly. Each meeting will include either a faculty-guided seminar on one of the core course topics or presentations by students on a research topic. Some class sessions will be devoted to 10-15 minute informal presentations on work in progress. Others will allow students to make informal presentations as a "dress rehearsal" for presentations to be given at a technical conference. Two semesters of enrollment required for all MS, ME PhD and DE aspirants and candidates. Graded on a satisfactory/unsatisfactory basis. LEC.

AE 701. Structural Design. 3 Hours.
Design and internal construction of major structural components: wing, fuselage, empennage, landing gear, engine pylons. Layout of major structures and system interfaces, internal geometry, material alternates, manufacturing alternates and design constraints. Certification and proof of design requirements. Prerequisite: AE 421, AE 508, and AE 510. LEC.

AE 704. Dynamics and Vibrations. 3 Hours.
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. LEC.

AE 705. Structural Vibrations and Modal Testing. 4 Hours.
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. LEC.

AE 707. Aerospace Structural Loads. 3 Hours.
Steady state spanwise and chordwise airloads, windshears, gusts, landing gear loads, bird strike, traumatic loads, special commercial and military load requirements. Prerequisite: AE 507 and AE 545. LEC.

AE 708. Aerospace Structures III. 3 Hours.
Modern methods in aircraft structural analysis. Computer solutions of linear problems of elastic structures. Orthotropic panels, effects of buckling non-linearity, structural optimization. Prerequisite: AE 508. LEC.

AE 709. Structural Composites. 3 Hours.
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: CHEM 184 or CHEM 150, CPE 121, AE 508 or CE 761; and AE 510 or ME 346 or CE 710. LEC.

AE 710. Advanced Structural Composites. 3 Hours.
The course objectives are to provide each student with a more in-depth understanding of and practical hands-on experiences with available fiber and matrix materials, manufacturing methods, and the mechanical behavior of composite materials and structures. Modern software tools and manufacturing methods are addressed, to include optimization techniques and design for manufacturability. Classical plate theory, bending, buckling, and vibration of anisotropic plates is addressed. Damage tolerance and repairability, as well as nondestructive evaluation techniques are also covered. Skills learned in previous composite courses will be utilized to design, analyze, and fabricate structures of current industrial relevance. Prerequisite: AE 508 or similar, AE 709 or similar, or consent of instructor. LEC.

AE 712. Techniques of Engineering Evaluation. 3 Hours.
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. LEC.

AE 713. Stochastic Systems, Estimation and Identification in Aerospace Engineering. 3 Hours.
Stochastic adaptive control theory is concerned with recursive estimation of unknown parameters and control for systems with uncertainties modeled as random variables or random processes. The theory is motivated by applications in such diverse areas as aerospace guidance and control, signal processing and communications, manufacturing processes, and financial economics. Mathematical theory of stochastic adaptive control for models based on stochastic difference equations such as autoregressive processes and stochastic differential equations as Markov diffusion processes have been developed and will be presented. This course focuses on filtering and system identification theory. Prerequisite: AE 430, AE 550, AE 551, AE 750, MATH 590 and MATH 627 or equivalent. LEC.

AE 721. Aircraft Design Laboratory I. 4 Hours.
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, AE 521, AE 545 , AE 551, and AE 571. AE 521 may be taken concurrently. LAB.

AE 722. Aircraft Design Laboratory II. 4 Hours.
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, AE 521, AE 545 , AE 551, and AE 571. AE 521 may be taken concurrently. LAB.

AE 724. Propulsion System Design and Integration. 3 Hours.
Theory and design of propulsion systems for both low and high speed aircraft and their integration into the overall configuration. Internal and external design and analysis of inlets and nozzles including their effect on the external aerodynamics of the aircraft. Engine/inlet compatibility and the problems of matching both steady state and dynamic characteristics to obtain peak, stable performance. Prerequisite: AE 572. LEC.

AE 725. Numerical Optimization and Structural Design. 3 Hours.
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: MATH 220 and MATH 290 or junior status. LEC.

AE 728. Wind Turbine Engineering. 3 Hours.
Course will cover the fundamentals of engineering wind-powered electric generators. Topics will include turbine configuration design, drive train engineering, composite rotor blade aerodynamic and structural design, characterizing the influence the wind conditions on the operation, loads, and performance of a wind turbine, wind turbine controls systems engineering, and power electronic conversion. Prerequisite: AE 507, AE 545, and EECS 316 and EECS 318 or consent of instructor. LEC.

AE 730. Advanced Experimental Fluid Dynamics. 3 Hours.
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 consent of instructor. LEC.

AE 731. Supersonic Aerodynamics Laboratory. 1 Hour.
Supersonic wind tunnel and shock tube operations, techniques, and instrumentation. Flow study and model testing. Prerequisite: AE 545. LAB.

AE 732. Introduction to Flight Test Engineering. 3 Hours.
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. LEC.

AE 743. Compressible Aerodynamics. 3 Hours.
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. LEC.

AE 744. Introduction to Turbulent Flow. 3 Hours.
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 equivalent. LEC.

AE 745. Applied Wing and Airfoil Theory. 3 Hours.
Applications of potential flow theory to aerodynamics of airfoil sections; wings and wing-body combinations. Introduction to high angle-of-attack and transonic aerodynamics. Prerequisite: AE 545. LEC.

AE 746. Computational Fluid Dynamics. 3 Hours.
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. LEC.

AE 747. Introduction to Transonic Aerodynamics. 3 Hours.
Review of Fundamental Equations, Transonic Similarity Laws, Shock-Expansion Theory, Method of Characteristics (MOC), Aerodynamics of Non-Lifting Bodies, Airfoil Aerodynamics and Aerodynamics of Swept Wings. Prerequisite: AE 545. LEC.

AE 748. Helicopter Aerodynamics. 3 Hours.
Helicopter components and their functioning: rotor aerodynamics, performance, stability and control, aeroelastic effects and vibrations. Prerequisite: AE 551. LEC.

AE 750. Applied Optimal Control. 3 Hours.
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 ME 682 or consent of instructor. LEC.

AE 751. Advanced Airplane Dynamics. 2 Hours.
Theory of elastic airplane stability and control using quasi-steady math models. Introduction to theory of nonlinear airplane stability and response behavior. Roll and pitch coupling phenomena. Lyapunov stability and approximate inverse Laplace transform methodology. Airplane response to atmospheric turbulence using power spectral density methods. Lagrangean dynamics. Prerequisite: AE 551. LEC.

AE 752. Linear Multivariable Control. 3 Hours.
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, state feedback controller design, LQR design, LQG design, cooperative controller design, etc. The successful completion of this course will prepare students for advanced studies in controls. Prerequisite: AE 551 or equivalent, or EECS 444 or equivalent; or by consent of instructor. LEC.

AE 753. Digital Flight Controls. 3 Hours.
Introduction to the classical Z-plane analysis and design tools useful for the design of control systems containing continuous dynamics and a digital computer. Mathematical modeling of the digital computer and design of digital compensators. Aerospace applications used to demonstrate the concepts. Prerequisite: AE 551 or ME 682 or consent of instructor. LEC.

AE 754. Missile Dynamics. 3 Hours.
Design of missile configurations. General equations of motion. Aerodynamics of missiles in subsonic through hypersonic flight regimes. Theory of missile trajectory. Linear and nonlinear theories of missile flight dynamics. Introduction to guidance and control. Launching problems and free flight dispersions. Prerequisite: AE 551. LEC.

AE 755. Robust and Nonlinear Control. 3 Hours.
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 550, AE 551, AE 750, MATH 590 or consent of instructor. LEC.

AE 756. Rule-Based Control Systems. 3 Hours.
Introduction to rule-based systems with an emphasis on a cognitive architecture. Realistic examples of using such systems will be covered in the context of unmanned aircraft control. A brief review of programming in LISP language, on which the cognitive architecture is based. Prerequisite: EECS 316 and EECS 318, AE 550, AE 551 or equivalent. LEC.

AE 757. Rule-Based UAV Control Lab. 1 Hour.
A guided experience on building an unmanned aircraft system. Uses and existing radio-controlled platform, and thus does not require an expertise in fabrication. Focuses on building the communication hardware and software that enables the use of a rule-based control system on a computer to control the aircraft remotely. Prerequisite: Corequisite: AE 756. LEC.

AE 758. Introduction to Robotics. 3 Hours.
An introduction to robotics covering spatial descriptions and transformations, manipulator kinematics, Jacobians, and dynamics and control of manipulators. The successful completion of this course will prepare students for advanced studies in robotics. Prerequisite: CE 301 or equivalent, AE 551 or equivalent, and MATH 290 or equivalent; or by consent of instructor. LEC.

AE 759. Estimation and Control of Unmanned Autonomous Systems. 3 Hours.
An introduction to the modeling, estimation and control of unmanned autonomous systems. Topics include model identification, complementary filters, Kalman filters, attitude estimation, position estimation, attitude keeping controller, path planning, etc. The successful completion of this course will prepare students for advanced studies in robotics controls. (Same as EECS 759.) Prerequisite: MATH 627 or EECS 461 or equivalent, AE 551 or EECS 444 or equivalent; or by consent of instructor. LEC.

AE 760. Spacecraft Systems. 3 Hours.
Fundamentals of spacecraft systems and subsystems. Spacecraft systems engineering, space environment; basic astrodynamics; and the following spacecraft subsystems; attitude determination and control; electrical power; thermal; propulsion; structures and mechanisms; command, telemetry, and data handling; and communications. Same as AE 560 with the addition of a research paper. Not available for students that have taken AE 560. Prerequisite: AE 507, EECS 318, MATH 124, and ME 312 or equivalents. LEC.

AE 765. Orbital Mechanics. 3 Hours.
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, MATH 290, and CE 301 or equivalent. LEC.

AE 766. Spacecraft Attitude Dynamics and Control. 3 Hours.
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 permission of instructor. LEC.

AE 767. Spacecraft Environments. 3 Hours.
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: PHSX 212 required, PHSX 313 or PHSX 351 recommended. LEC.

AE 768. Orbit Determination. 3 Hours.
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. Corequisite: AE 560 or AE 760. LEC.

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

AE 772. Fluid Mechanics of Turbomachinery. 3 Hours.
Fundamentals of two- and three-dimensional flows in turbomachinery. Study of secondary flows and losses. Flow instabilities in axial flow compressors (stall and surge). Aerodynamic design of a multistage axial flow compressor. Noise associated with a transonic axial flow compressor. Turbine blade cooling. Calculation of stresses and blade life estimation in axial flow turbines. Fundamentals of radial flow turbomachinery. Prerequisite: AE 572 or consent of instructor. LEC.

AE 781. Introduction to Adaptive Aerostructures. 3 Hours.
This course covers the basic material properties and modeling techniques for structures that are capable of changing some physical property in response to a command signal. The course will be useful for students from nearly every branch of engineering and includes a fabrication and testing practicum introducing basic post processing and integration techniques used with piezoelectric, shape memory alloy and magnetorheological materials. The course concludes with an overview of applications and examples of adaptive products. Prerequisite: ME 311 or equivalent. LEC.

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

AE 803. Aeroelasticity. 3 Hours.
Introduction to self-excited vibrations, wing flutter, panel flutter, unsteady aerodynamics, launch vehicle structural vibrations. Prerequisite: AE 508, AE 545, AE 551, and AE 704. LEC.

AE 821. Advanced Aircraft Design I. 3 Hours.
Aerodynamic design optimization. Aircraft cost prediction methods: development, manufacturing, and operating. Minimization of operation costs and implications to configuration design. Design to minimize life-cycle costs. Design decision making on the basis of cost. LEC.

AE 822. Advanced Aircraft Design II. 3 Hours.
Design of flight control systems, fuel systems, hydraulic systems, and electrical systems. Weapon system integration problems, design for low radar cross sections. The kinematics of landing gear retraction systems. LEC.

AE 830. Aerospace Graduate Internship. 1-12 Hours.
One credit hour per month of approved aerospace engineering internship satisfying one of the requirements for the MS or PhD program. Graded on a satisfactory/unsatisfactory basis. INT.

AE 840. Aerodynamics of Viscous Fluids. 3 Hours.
Concepts of boundary layer equations of viscous fluids. Various transformations for compressible boundary-layer equations. Approximate and exact finite-difference solutions, including effects of suction and blowing. Transitions. Concept of turbulent flow and solutions of turbulent boundary layer equations. Applications in aeronautics. Prerequisite: AE 545. LEC.

AE 845. Transonic Aerodynamics. 3 Hours.
Applications of potential flow, Euler and Navier-Stokes solvers to transonic and vortex-flow aerodynamics. Concept of rotated finite difference scheme. Convergence acceleration and multigrid techniques. Methods of flux vector splitting, upwind differencing, and approximate factorization. Turbulence modeling. Prerequisite: AE 746. LEC.

AE 846. Advanced Computational Fluid Dynamics and Heat Transfer. 3 Hours.
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. LEC.

AE 850. Advanced Control Seminar. 2 Hours.
Extension of AE 750 covering digital optimal control, optimal estimation, and advanced control topics. Combination of lecture, seminar, and project format. Review of current journal articles. Development of analysis and design computer programs. Prerequisite: AE 750 and consent of instructor. LEC.

AE 890. ME Internship. 1-6 Hours.
One credit per month of engineering internship. Prerequisite: Admission to Master of Engineering in Aerospace Engineering program and approved internship. INT.

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

AE 895. M.S. Thesis or Project. 1-6 Hours.
Original research or project which satisfies the requirements for the degree of Master of Science in Aerospace Engineering. Restricted to Aerospace MS students. THE.

AE 896. ME Project. 3-6 Hours.
A design problem or system study satisfying the project requirement for the Master of Engineering degree in Aerospace Engineering. Prerequisite: Admission to Master of Engineering in Aerospace Engineering program. THE.

AE 941. Hypersonic Aerodynamics I. 3 Hours.
The gasdynamics of aerospace vehicles operating in the speed range above Mach 5. Rarified and dissociated gas flows; magnetogasdynamic and heat transfer problems. Prerequisite: Consent of instructor. LEC.

AE 990. DE Internship. 1-12 Hours.
One credit per month of engineering internship. Prerequisite: Admission to DE program and approved internship. INT.

AE 996. Ph.D. Dissertation. 1-15 Hours.
Restricted to Aerospace Ph.D. candidates. Prerequisite: Successful completion of Comprehensive Oral Exam. THE.

AE 997. DE Project. 1-16 Hours.
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. Prerequisite: Successful completion of Comprehensive Oral Exam. THE.

Bioengineering Courses

BIOE 800. Bioengineering Colloquium. 0.5-1 Hours.
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. LEC.

BIOE 801. Responsible Conduct of Research in Engineering. 1 Hour.
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. LEC.

BIOE 802. Bioengineering Internship. 1-6 Hours.
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. INT.

BIOE 860. Advanced Bioengineering Problems. 1-3 Hours.
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. IND.

BIOE 899. Independent Investigation. 1-6 Hours.
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. THE.

BIOE 999. Independent Investigation. 1-12 Hours.
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. THE.

Chemical Petroleum Engr Courses

C&PE 111. Introduction to the Chemical Engineering Profession. 2 Hours.
An introduction to the University of Kansas and work done by professional engineers. Students are introduced to the resources available to them at KU, in the School of Engineering, and in the Chemical and petroleum Engineering Department. They are introduced to the curricula requirements and expectations of chemical engineering students. The career opportunities for chemical engineers are described. Students are introduced to engineering ethics, basic safety considerations, teamwork, and technical writing. The course includes fundamental calculations of material and energy balances and fluid flow. Prerequistie: Corequisite: CHEM 130 or CHEM 170 or CHEM 190. LEC.

C&PE 117. Energy in the Modern World. 1 Hour.
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. LEC.

C&PE 121. Introduction to Computers in Engineering. 3 Hours.
Formulation of engineering problems for machine computation with emphasis on good programming practices and the integration of appropriate computational and related tools. Solutions are computed using Excel, Visual Basic, and general purpose languages such as Mathcad and/or MATLAB. Computing methods are introduced as tools for developing solutions using elementary numerical techniques including linear interpolation, linear regression, numerical integration, and root finding. Microsoft Office is used with the computational tools to provide integrated report generation capability. Two lectures and weekly laboratory instruction. Prerequisite: MATH 121 or MATH 125 or MATH 145 or MATH 141. LEC.

C&PE 127. Introduction to Petroleum Engineering Profession. 1 Hour.
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. CPE 127 is required of all Petroleum Engineering freshmen but is optional for others. Transfer students who don't take the course must substitute CPE 127 with one hour of engineering science. LEC.

C&PE 211. Material and Energy Balances. 4 Hours.
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: CPE 121; and CHEM 135 or CHEM 175 or CHEM 195; or consent of instructor. LEC.

C&PE 217. Introduction to Petroleum Drilling Engineering. 2 Hours.
An introduction to modern rotary drilling. Topics covered include: rig systems/hardware, management practices, cost analysis, drilling fluid function formulations and testing, well control systems, cement formulation and placement, drilling bits. LEC.

C&PE 219. Drilling Fluids Laboratory. 1 Hour.
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: CPE 217. LAB.

C&PE 221. Chemical Engineering Thermodynamics. 3 Hours.
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 122 or MATH 142 or MATH 126 or MATH 146; CPE 121; and CPE 211. Prerequisite or Corequisite: PHSX 210, PHSX 211, or PHSX 213; or permission of instructor. LEC.

C&PE 325. Numerical Methods and Statistics for Engineers. 3 Hours.
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. MATH 126 or equivalent, CHEM 135 or CHEM 175 or equivalent. Corequisite: MATH 220, MATH 221, MATH 320 or MATH 321; MATH 290 or MATH 291 LEC.

C&PE 327. Reservoir Engineering. 4 Hours.
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. Prerequisite: CHEM 135 or CHEM 175. LEC.

C&PE 511. Momentum Transfer. 3 Hours.
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: CPE 221 or ME 312; CPE 121 (or equivalent), MATH 122 OR MATH 142 or MATH 127 or MATH 147, and a course in differential equations (MATH 220 or MATH 221 or MATH 320 or MATH 321). LEC.

C&PE 512. Chemical Engineering Thermodynamics II. 3 Hours.
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: CPE 121; CPE 211; CPE 221; and CHEM 330 or CHEM 380 or CHEM 624; or permission of instructor. LEC.

C&PE 521. Heat Transfer. 3 Hours.
An applied study of the various (conductive, convective, and radiative) heat transfer mechanisms in solid and fluid systems both transient and steady-state. Engineering applications include: conduction in solids and fluids, free and forced convection in fluids, radiation, boiling and condensing fluids, and design of heat exchangers. Prerequisite: CPE 121, Thermodynamics (CPE 221 or ME 312); CPE 511 or ME 510, MATH 122 or MATH 142, or MATH 127 or MATH 147; AND a course in differential equations (MATH 220 or MATH 221 or MATH 320 or MATH 321). LEC.

C&PE 522. Economic Appraisal of Chemical and Petroleum Projects. 2 Hours 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: MATH 122, or MATH 142; PHSX 210, PHSX 211, or PHSX 213; and CPE 121 or consent of instructor. LEC.

C&PE 523. Mass Transfer. 4 Hours.
Includes one credit hour of calculations laboratory. Treatment of mass transfer phenomena with application to analysis and design of unit operations equipment such as distillation, extraction, absorption, and adsorption. Prerequisite: CPE 211, CPE 511, and CPE 512. Corequisite: CPE 521. LEC.

C&PE 524. Chemical Engineering Kinetics and Reactor Design. 3 Hours.
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: CPE 511, CPE 512, and a course in differential equations. Corequisite: CPE 521. LEC.

C&PE 527. Reservoir Engineering II. 4 Hours.
Lectures on single phase flow and pressure distribution in reservoirs. Calculations in drawdown, buildup, multiple rate, fractured systems, gas and injection well testing. Material balance calculations for gas, gas-condensate, undersaturated, and saturated reservoirs. Prerequisite: CPE 327 or consent of instructor, a course in differential equations. LEC.

C&PE 528. Well Logging. 3 Hours.
Analysis of well logs to determine properties of reservoir rocks, fluid saturations and lithology, and production logging. Prerequisite: CPE 327 or consent of instructor. LEC.

C&PE 601. Undergraduate Topics in Chemical and Petroleum Engineering. 1-4 Hours.
Undergraduate study in various branches of Chemical and Petroleum Engineering on topics that may vary from year to year. Prerequisite: Varies. LEC.

C&PE 612. Environmental Assessment of Chemical Processes. 3 Hours.
A discussion and project-based survey of environmental issues in chemical engineering, including environmentally conscious design, environmental fate and transport, green chemistry, and life cycle analysis. Focus will be on the design, implementation and management of comprehensive environmental assessments for existing and new industrial facilities with an emphasis on the technical and economic impacts of catalytic systems on pollution control strategies. LEC.

C&PE 613. Chemical Engineering Design I. 4 Hours AE61.
Synthesis, design and economic analysis of petrochemical, and chemical plants. Applications in computer aided engineering applied to these topics. Prerequisite: CPE 511, CPE 512, CPE 521, CPE 522, CPE 523, and CPE 524. Corequisite: CPE 615. LEC.

C&PE 614. Reaction Engineering for Environmentally Benign Processes. 3 Hours.
Principles of reaction engineering and green chemistry applied to processes of the future. With a case-based introduction to the design and optimization of catalytic processes and reaction systems, focus will be on key reaction engineering concepts, including catalysis, mechanisms, reaction kinetics, heterogeneous reactions, reactor types and economic evaluation. Students will develop a multidisciplinary understanding of chemical, biological and molecular concepts and of the multiscale character of developing and designing processes from the micro level to the macro level. Prerequisite: Senior standing in engineering to the physical/biological sciences. LEC.

C&PE 615. Introduction to Process Dynamics and Control. 3 Hours.
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: CPE 511, CPE 512, CPE 521, CPE 523 and CPE 524. LEC.

C&PE 616. Chemical Engineering Laboratory I. 3 Hours.
Laboratory study of chemical engineering concepts of thermodynamics, fluid flow, heat transfer, mass transfer, and reaction kinetics. Includes emphasis on technical communication skills. Prerequisite: CPE 511, CPE 512, CPE 521, CPE 523, CPE 524, and ENGL 102. LAB.

C&PE 617. Drilling and Well Completion. 3 Hours.
Design and analysis of rotary drilling and well completion systems; casing design, cementing, and perforating. Safety and ethical considerations in drilling and fluid disposal operations. Prerequisite: CPE 327 and CPE 511 or ME 510 and CPE 217 or consent of instructor. LEC.

C&PE 618. Secondary Recovery. 4 Hours.
Study of waterflooding based upon linear displacement theory. Extension to two and three dimensions through correlations and stream tube models. Design of waterfloods including preparation of a reservoir description for waterflood evaluation. Prerequisite: CPE 527. LEC.

C&PE 619. Petroleum Engineering Laboratory I. 3 Hours.
Laboratory study of methods to determine rock and fluid properties related to petroleum engineering including phase behavior, viscosity, permeability, porosity, capillary pressure, oil recovery, water/oil displacement, fluid flow, and heat transfer coefficients. Analysis of experimental uncertainty. Oral and written presentations are required. Prerequisite: ENGL 102 or ENGL 105; and CPE 511 or ME 510; and CPE 327; or consent of instructor. LAB.

C&PE 620. Enhanced Oil Recovery. 3 Hours.
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: CPE 527 and CPE 618 or consent of instructor. LEC.

C&PE 623. Chemical Engineering Design II. 2 Hours AE61.
A continuation of CPE 613 with emphasis on individual student process design development and analysis. Prerequisite: CPE 613, CPE 615. LEC.

C&PE 624. Process Safety and Sustainability. 3 Hours 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: CPE 511 (or ME 510); CPE 521 (or ME 612). LEC.

C&PE 625. Unconventional Reservoirs. 3 Hours.
Principles of unconventional reservoir engineering including properties and use of shale reservoirs, hydraulic fracturing, and relevant environmental and economic factors. Prerequisite: CPE 511, CPE 522, CPE 527, CPE 528, ME 211 or CE 201 and CE 310, and GEOL 331 or GEOL 591: Geology for Petroleum Engineers. LEC.

C&PE 626. Chemical Engineering Laboratory II. 3 Hours 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, CPE 511, CPE 512, CPE 521, CPE 523, CPE 524, CPE 615 and CPE 616. LAB.

C&PE 627. Petroleum Production. 3 Hours.
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. Treatment of ethics considerations in production contracts and leasing arrangements. Prerequisite: CPE 511 or ME 510, CPE 528; and CPE 327. LEC.

C&PE 628. Petroleum Engineering Design. 3 Hours AE61.
Design problems related to petroleum reservoir development such as selection of optimum well spacing for a specified reservoir, evaluation of a producing property or installation of a waterflood. Designs consider economic, uncertainty analysis, as well as conservation, environmental, and professional ethics factors. Prerequisite: CPE 522, CPE 527, CPE 528, GEOL 535, CPE 618 and CPE 619. LEC.

C&PE 651. Undergraduate Problems. 1-6 Hours.
Investigation of a particular problem in the field of chemical or petroleum engineering. IND.

C&PE 654. Biocatalysis. 3 Hours.
Introductory and advanced topics in biocatalysis with focus on enzymatic reactions. Enzymology will provide the fundamental basis for discussion of kinetics and bio-process development. Advanced topics include: enzymes in non-aqueous solvents, immobilization techniques, whole-cell transformations, bio-reactors. LEC.

C&PE 655. Introduction to Semiconductor Processing. 3 Hours.
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: Senior standing in CPE or EE or consent of instructor. LEC.

C&PE 656. Introduction to Biomedical Engineering. 3 Hours.
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 instructor. LEC.

C&PE 657. Polymer Science and Technology. 3 Hours.
Polymer Science and Technology is a 3-hour introductory course to polymer chemistry, science, technology, and processing. The course targets junior, senior, and graduate chemical engineers and chemistry majors and is intended to provide a background which would allow young professionals to understand polymer chemistry and processes to which they would be exposed to in industry and literature. The course would also assist them in selecting polymers and polymer specifications. Prerequisite: Senior or graduate student standing in chemical or petroleum engineering, or consent of instructor. LEC.

C&PE 661. Undergraduate Honors Research. 1-3 Hours.
This course involves the investigation of a particular problem in the field of chemical or petroleum engineering. CPE 661 should be taken, rather than CPE 651, for students seeking Departmental Honors in Chemical Petroleum Engineering. CPE 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: Completion of CPE 121, CPE 211, CPE 511, CPE 512, CPE 522, overall GPA >3.5, and engineering GPA >3.5, or permission of the department. IND.

C&PE 671. Senior Thesis. 3 Hours.
This course involves the investigation of a particular problem in the field of chemical or petroleum engineering as a continuation for students with previous research experience, by invitation. The design or research topic is identified jointly by the student and faculty research supervisor and faculty committee. Students will present periodically and receive instruction and feedback on their presentations. A written thesis and public oral defense with committee are also required. Prerequisite: CPE 651 or CPE 661; and invitation and permission of instructor, open to seniors only. THE.

C&PE 678. Applied Optimization Methods. 3 Hours.
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 methods, penalty functions, linear programming, nonlinear and integer programming, stochastic optimization approaches, and treatment of constrained problems. A semester project is required. Prerequisite: Senior standing. LEC.

C&PE 701. Methods of Chemical and Petroleum Calculations. 3 Hours.
The utilization of advanced mathematical methods and computing techniques in the solution of problems in these fields. LEC.

C&PE 710. Subsurface Methods in Formation Evaluation. 3 Hours.
Study of subsurface methods and their applications to exploration, evaluation, and production of hydrocarbon reservoirs. Emphasis is on fundamentals of quantitative well log interpretations and the use of well log data in solving geologic and reservoir engineering problems, e.g., porosity, hydrocarbon saturation, permeable bed thickness, permeability, correlation, structural mapping, and stratigraphic and paleoenvironmental studies. Laboratory. Prerequisite: GEOL 535 or CPE 517 or consent of instructor. LEC.

C&PE 712. Environmental Assessment of Chemical Processes. 3 Hours.
A discussion and project-based survey of environmental issues in chemical engineering, including environmental conscious design, environmental fate and transport, green chemistry, and life cycle analysis. Focus will be on the design, implementation and management of comprehensive environmental assessments for existing and new industrial facilities with in-depth analysis of the technical and economic impacts of catalytic systems on pollution control strategies. A comprehensive research paper is required as a final project. LEC.

C&PE 714. Reaction Engineering for Environmentally Benign Processes. 3 Hours.
Principles of reaction engineering and green chemistry applied to processes of the future. With a case-based introduction to the design and optimization of catalytic processes and reaction systems, focus will be on key reaction engineering concepts, including catalysis, mechanisms, reaction kinetics, heterogeneous reactions, reactor types and economic evaluation. Students will develop a multidisciplinary understanding of chemical, biological and molecular concepts, and will develop and design processes from the micro level to the macro level. A final research paper is required. LEC.

C&PE 715. Topics in Chemical and Petroleum Engineering: _____. 1-4 Hours.
Study in various branches of Chemical and Petroleum Engineering on topics that may vary from year to year. LEC.

C&PE 721. Chemical Engineering Thermodynamics. 3 Hours.
Chemical engineering applications of advanced thermodynamics and physical chemistry. Prerequisite: CPE 512. LEC.

C&PE 722. Kinetics and Catalysis. 3 Hours.
Modeling and analysis of chemical reactors with emphasis on heterogenous catalytic reaction systems. Prerequisite: CPE 524. LEC.

C&PE 725. Molecular Cell Biology. 3 Hours.
Fundamentals and advanced concepts in cell biology and the molecular interactions responsible for cell functions, homeostasis and disease will be presented. Current analytical methods for examining cells and their molecular components will be discussed. Emphasis will be place on the chemical and physical properties of individual proteins, nucleic acids and lipids and their assembly into cellular and subcellular structures. (Same as PHCH 725) Prerequisite: Graduate standing or consent of instructor. LEC.

C&PE 731. Convective Heat and Momentum Transfer. 3 Hours.
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: ME 610/CPE 511 and ME 612/CPE 521 or equivalent. A concurrent course in partial differential equations is helpful. LEC.

C&PE 732. Advanced Transport Phenomena II. 3 Hours.
The formulation and solution of steady- and unsteady-state mass transfer problems (including those complicated by momentum and heat transfer). This course is the sequel to CPE 731 and relies upon much of the material treated there. The mathematical approach predominates and the methods available for determining suitable mass transfer coefficients are covered. LEC.

C&PE 751. Basic Rheology. 3 Hours.
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: CPE 511 or an equivalent course in fluid mechanics. LEC.

C&PE 752. Tissue Engineering. 3 Hours.
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 instructor. LEC.

C&PE 753. Introduction to Electrochemical Engineering. 3 Hours.
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; CPE 511, CPE 512, CPE 524 or equivalent; knowledge of a programming language. LEC.

C&PE 754. Biocatalysis. 3 Hours.
Introductory and advanced topics in biocatalysis with focus on enzymatic reactions. Enzymology will provide the fundamental basis for discussion of kinetics and bio-process development. Advanced topics include: enzymes in non-aqueous solvents, immobilization techniques, whole-cell transformations, bio-reactors. Knowledge of the theoretical basis for these techniques and processes will be demonstrated within a class project. LEC.

C&PE 755. Introduction to Semiconductor Processing. 3 Hours.
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. LEC.

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

C&PE 765. Corrosion Engineering. 3 Hours.
Electrochemical basis of corrosion. Types of corrosion and corrosive atmospheres. Corrosion control measures and industrial problems. Prerequisite: ME 306 or CHEM 188. LEC.

C&PE 771. Advanced Reservoir Engineering. 2-3 Hours.
Physical principles of petroleum production; gas drive performance; partial water drive performance; pressure maintenance through gas and water injection. Prerequisite: CPE 527. LEC.

C&PE 778. Applied Optimization Methods. 3 Hours.
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. LEC.

C&PE 790. Introduction to Flow in Porous Media. 3 Hours.
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: CPE 527. LEC.

C&PE 795. Enhanced Petroleum Recovery. 3 Hours.
A study of improved oil recovery processes such as miscible displacement, microemulsion displacement, and thermal methods. Prerequisite: CPE 618 or permission of instructor. LEC.

C&PE 798. Phase Equilibrium. 3 Hours.
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. LEC.

C&PE 800. Seminar. 0.5-1 Hours.
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 year, the seminar will involve presentation of current research and other topics of interest to chemical and petroleum engineers. These presentations will be made by invited guests, faculty, and advanced graduate students. Student attendance is required. Graded on a satisfactory/unsatisfactory basis. LEC.

C&PE 801. Introduction to Research. 1 Hour.
One hour per week in which the staff introduces entering graduate students to research. Topics include discussion of research methods, methods of effectively tapping library resources, preparation of literature surveys, and presentation of results. Faculty members of the department will make presentations of their current research interests. Offered fall only. Prerequisite: Corequisite: CPE 800. LEC.

C&PE 802. CEBC Colloquium. 0.5-1 Hours.
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. LEC.

C&PE 803. Research. 1-6 Hours.
For M.S. candidates. THE.

C&PE 804. Petroleum Management Seminar. 1 Hour.
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. LEC.

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

C&PE 902. Preparation for the Ph.D. Comprehensive Examination. 3 Hours.
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. RSH.

C&PE 904. Research. 1-12 Hours.
For Ph.D. candidates. THE.

C&PE 910. Industrial Development of Catalytic Processes. 3 Hours.
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. LEC.

C&PE 911. Industrial Practicum. 1-3 Hours.
Graduate students engage in an industrial research internship experience with collaborators in industry. FLD.

C&PE 912. Teaching College Level Engineering and Science Practicum. 1 Hour.
Future university instructors learn how to critically examine course content and teaching strategies, and prepare courses that will address the learning needs of the diverse student populations of the future. Students participate in weekly in-class workshops and symposia, as well as a teaching practicum experience during this course. LEC.

C&PE 919. Advanced Topics in Process Modeling Simulation or Control: _____. 1-4 Hours.
Advanced study in process modeling, simulation or control on topics which may vary from year to year. LEC.

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

C&PE 933. Heat and Mass Transport in Porous Media. 3 Hours.
A study of industrial problems involving heat and mass transport in porous media such as packed columns, catalyst beds, chemical reactors, and petroleum reservoirs. Mechanisms of interphase and intraphase transport, diffusion, and dispersion. Included are methods of solution of the describing differential equations. LEC.

C&PE 934. Heat Transport with Phase Change. 3 Hours.
A fundamental treatment of heat transfer occurring during boiling and condensation. Included are nucleate and film boiling, film and dropwise condensation, and two-phase flow. LEC.

C&PE 936. Industrial Separation Processes. 3 Hours.
Determination and treatment of vapor-liquid separations, including methods for obtaining and treating equilibrium data, procedures for calculating multi-component separations by distillation, absorption, extraction, and adsorption. LEC.

C&PE 937. Applied Rheology. 3 Hours.
Industrial applications of fluid mechanics including compressible flow, flow of non-Newtonian fluids, flow of drag reducing systems all to be considered in laminar and turbulent flow regimes, and within conduits, and porous media. LEC.

C&PE 939. Advanced Topics in the Transport Phenomena: _____. 1-4 Hours.
Advanced study in various branches of transport phenomena on topics which may vary from year to year. LEC.

C&PE 940. Data Analysis in Engineering and Natural Sciences. 3 Hours.
Statistical inference and data analysis, emphasizing interpretation of observations from areas of engineering and natural sciences where controlled experimentation is not possible. The basics of elementary statistics and matrix algebra are covered, followed by topics in time, series analysis, map analysis, including automatic contouring, and multivariate procedures such as principal components, discrimination and factor analysis. A suite of computer programs is provided. Students are encouraged to use data from their own graduate research in class projects. LEC.

Civil, Envr Arch Engineering Courses

ARCE 101. Introduction to Architectural Engineering. 2 Hours.
An introduction to the study of and careers in architectural engineering. 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. LEC.

ARCE 217. Computer-Assisted Building Design. 3 Hours.
Introduction to computer-aided design (CAD) tools for architectural engineering practice. The course covers building information modeling (BIM) including object-oriented 3D modeling, databases, virtual walkthroughs, basic customization, and creating BIM families. Prerequisite: ARCE 101 and MATH 104, or consent of instructor. LEC.

ARCE 350. Building Materials Science. 3 Hours.
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 and CHEM 130 or CHEM 150, or consent of instructor. LEC.

ARCE 390. Special Problems. 1-3 Hours.
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. IND.

ARCE 640. Power Systems Engineering I. 3 Hours.
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: EECS 315 or consent of instructor. LEC.

ARCE 641. Power Systems Engineering II. 3 Hours.
A continuation of ARCE 640 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 640, or EECS 212 and Upper-Level EECS Eligibility. LEC.

ARCE 642. Power System Protection. 3 Hours.
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 640 or EECS 212 or consent of instructor. LEC.

ARCE 644. Electric Machines and Drives. 3 Hours.
Introduction to electric machine theory, operation, and control. Electric machine covered include DC generators and motors, AC synchronous generators and motors, AC induction generators and motors, as well as fractional horsepower and special purpose motors. Motor starting and controls for both DC and AC machines are also covered including as introduction to power electronics and variable frequency drives (VFD). (Same as EECS 544.) Prerequisite: ARCE 640, or EECS 212 and Upper-Level EECS Eligibility. LEC.

ARCE 645. Electric Energy Production and Storage. 3 Hours.
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 640, or EECS 212 and Upper-Level EECS Eligibility. LEC.

ARCE 647. Power System Analysis I. 3 Hours.
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 640, or EECS 212 and Upper-Level EECS Eligibility. LEC.

ARCE 648. Power System Analysis II. 3 Hours.
Continuation of ARCE 647 that uses power system modeling developed in ARCE 647 to analyze power system load flow, operation and economic dispatch, stability, and transient response. The impact of alternative energy sources, energy storage, DC transmission and interties, and other emerging technologies on power system operation and reliability will be addressed throughout the course. (Same as EECS 548.) Prerequisite: ARCE 647 or consent of instructor. LEC.

ARCE 650. Illumination Engineering. 3 Hours.
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 consent of instructor. LEC.

ARCE 660. Building Thermal Science. 3 Hours.
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: ARCE 217, ME 312, and either ME 510, AE 345, CE 330, or CPE 511, or consent of instructor. LEC.

ARCE 661. HVAC&R Systems Design. 3 Hours.
Analysis and design of heating, ventilating, air-conditioning, and refrigeration equipment and systems. Prerequisite: ARCE 660 or consent of the instructor. LEC.

ARCE 662. Water Systems Design. 3 Hours.
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 CPE 511, or consent of the instructor. LEC.

ARCE 663. Energy Management. 3 Hours.
Energy usage in commercial buildings and industry, energy auditing methodology, utility analysis, management measures, and economic evaluation are covered. Includes fieldwork. Prerequisite: Corequisite: ARCE 660, or consent of instructor. LEC.

ARCE 664. Fire Protection Engineering. 3 Hours.
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 312 or CPE 221, and ME 510, AE 345, CE 330, or CPE 511, or consent of instructor. LEC.

ARCE 665. Solar Energy Systems Design. 3 Hours.
A quantitative and qualitative study of active, passive, wind, and photovoltaic energy conversion systems for buildings. Solar radiation and system performance prediction. Prerequisite: ME 312 or CPE 221, or consent of instructor. LEC.

ARCE 675. Sound and Vibration Control. 3 Hours.
An introduction to the physics and measurement of sound, wave phenomena, acoustics, and methods of noise and excessive vibration control for various applications. Prerequisite: PHSX 212 and MATH 220 or MATH 320, or consent of instructor. LEC.

ARCE 680. Architectural Engineering Design I. 6 Hours.
Capstone engineering design course that includes the analysis, design, and integration of structural, mechanical, electrical, and lighting systems for a commercial, industrial, or institutional building. Prerequisite: CMGT 500, ARCE 640, ARCE 650, ARCE 661, CE 562, and CE 563, or consent of instructors. Fifth year senior standing in architectural engineering. LAB.

ARCE 681. Architectural Engineering Design II. 6 Hours.
Comprehensive architectural engineering design project in a specific area of professional practice. Prerequisite: ARCE 680 or consent of instructor. Fifth year senior standing in architectural engineering. LAB.

ARCE 690. Special Problems. 1-3 Hours.
The study of a particular problem in architectural engineering involving individual research and presentation. Prerequisite: Student 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 instructor. IND.

ARCE 691. Honors Research. 3 Hours.
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. LEC.

ARCE 698. Comprehensive Design Project. 3 Hours.
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 357, CMGT 500, ARCE 640, ARCE 650, ARCE 661, and CE 562. LAB.

ARCE 700. Directed Readings in Architectural Engineering. 1-3 Hours.
Individual study of special topics and problems. May be repeated for credit. Prerequisite: Student must submit, in writing, a proposal including a statement of the problem the student wishes to pursue and a bibliography of the articles and books required to complete the project. The student must also have a signed agreement with the faculty member proposed as instructor for the course. Consent of instructor. RSH.

ARCE 750. Daylighting. 3 Hours.
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 ARCH 531, or consent of instructor LEC.

ARCE 751. Advanced Lighting Design. 3 Hours.
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. LEC.

ARCE 752. Lighting Measurement and Design. 3 Hours.
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 LEC.

ARCE 760. Automatic Controls for Building Mechanical Systems. 3 Hours.
An introduction to controls for building mechanical systems. Discussions of the theory, design, and equipment used for control systems. The benefits of pneumatic, electrical, and electronic (DDC) controls will be examined. Prerequisite: ARCE 660 or consent of instructor. LEC.

ARCE 764. Advanced Thermal Analysis of Buildings. 3 Hours.
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 consent of instructor. LEC.

ARCE 890. Architectural Engineering Seminar: _____. 1-3 Hours.
Individual or group studies in building engineered systems or construction engineering. Prerequisite: Graduate standing in Architectural Engineering and consent of instructor. RSH.

ARCE 895. Master's Project. 1-3 Hours.
Directed study and reporting of a specialized topic of interest to the architectural engineering profession. Prerequisite: Consent of instructor. RSH.

ARCE 899. Master's Thesis. 1-6 Hours.
Directed research and reporting of a specialized topic of interest to the architectural engineering profession. Prerequisite: Consent of instructor. THE.

Civil, Envr Arch Engineering Courses

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

CE 192. Civil Engineering Graphics. 3 Hours.
Introduction to computer-aided design (CAD) tools for civil and environmental engineering practice. This course covers 2D drafting and 3D modeling. Prerequisite: MATH 104. LEC.

CE 201. Statics. 2 Hours.
The principles of statics, with particular attention to engineering applications. Prerequisite: PHSX 210 or PHSX 211 or PHSX 201, and MATH 121 or MATH 125. LEC.

CE 240. Geomatics. 3 Hours.
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 121 or MATH 125, CE 192 or ARCE 217 or consent of instructor. LEC.

CE 300. Dynamics. 3 Hours.
The principles of kinematics and kinetics, with particular attention to engineering applications. Prerequisite: CE 201 or ME 201 or ME 211, and MATH 122 or MATH 126. LEC.

CE 301. Statics and Dynamics. 5 Hours.
A combination of statics and dynamics covered in CE 201 and CE 300. This course must be taken as a five-hour unit. Prerequisite: PHSX 210 or PHSX 211, and MATH 122 or MATH 126. LEC.

CE 310. Strength of Materials. 4 Hours.
Three one-hour lectures and one two-hour laboratory. Principles of stress and deformation in structures and machines. Prerequisite: CE 201 or ME 201 or ME 211 or CE 301, ENGL 102 or ENGL 105 or consent of instructor. Corequisite: MATH 220. LEC.

CE 311. Strength of Materials. 3 Hours.
A course that includes a basic treatment of stress and deformation in elastic bodies. Prerequisite: CE 201 or ME 201, MATH 220 and MATH 290 or consent of instructor. LEC.

CE 312. Strength of Materials, Honors. 4 Hours.
Three one-hour lectures and one two-hour laboratory. Principles of stress and strain in deformable bodies under load. Prerequisite: CE 201 or ME 201 or ME 211 or CE 301, ENGL 102 or ENGL 105 or consent of instructor. Corequisite: MATH 220. LEC.

CE 330. Fluid Mechanics. 3 Hours.
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, ENGL 102, CE 300 or CE 301. LEC.

CE 331. Fluid Mechanics Lab. 1 Hour.
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, ENGL 102, CE 300 or CE 301. Corequisite: CE 330. LAB.

CE 412. Structural Engineering Materials. 3 Hours.
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 consent of instructor and ENGL 102. LEC.

CE 413. Structural Engineering Materials, Honors. 3 Hours.
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 consent of instructor, and ENGL 102. Open only to students admitted to the University Honors Program or by consent of instructor. LEC.

CE 450. Sustainability: Population, Energy and Water. 3 Hours.
The course will examine the concepts regarding the continued advancement of humankind while maintaining our ecological niche on earth. Key topics include: population growth, poverty, and impacts of development; energy consumption, sources, storage, conservation and policy; water quality and quantity; materials and building; and policy implications. Prerequisite: Junior standing or participation in KU Honors Program. LEC.

CE 455. Hydrology. 3 Hours.
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, and CE 330. LEC.

CE 461. Structural Analysis. 4 Hours.
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. LEC.

CE 477. Introduction to Environmental Engineering and Science. 3 Hours.
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, MATH 101 or MATH 104, and CHEM 135 or CHEM 150. LEC.

CE 480. Introduction to Transportation Engineering. 3 Hours.
An introductory study of the various modes of transportation, emphasizing highways, railroads, and air transport. The planning, design and operations of these modes are discussed. There is a multimodal project included in this course. Prerequisite: CE 240. LEC.

CE 484. Material for Transportation Facilities. 3 Hours.
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. LEC.

CE 487. Soil Mechanics. 4 Hours.
Three lecture periods and one laboratory period. Fundamental theories of soil mechanics and their applications in engineering. Prerequisite: CE 310, CE 330 or concurrent enrollment. LEC.

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

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

CE 498. Engineering Honors Seminar. 3 Hours.
Prerequisite: Participation in or eligibility for the University Honors Program. Sophomore or higher standing. LEC.

CE 499. Seminar. 1 Hour.
Concepts of professional development. LEC.

CE 535. Engineering Applications of GIS. 3 Hours.
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. LEC.

CE 550. Life Cycle Assessment. 3 Hours.
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 CPE 211. LEC.

CE 552. Water Resources Engineering Design. 4 Hours.
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. LEC.

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

CE 563. Design of Reinforced Concrete Structures. 3 Hours.
Two one-hour lectures and one three-hour laboratory. Fundamentals of structural design with reinforced concrete. Prerequisite: CE 461; CE 412 or CE 484 or consent of the instructor. LEC.

CE 570. Concepts of Environmental Chemistry. 2 Hours.
The fundamentals of aquatic chemistry, with emphasis on application to water purification and wastewater treatment. Prerequisite: Undergraduate standing, CE 477, and MATH 115 or MATH 121 or MATH 125. LEC.

CE 571. Environmental Chemical Analysis. 1 Hour.
A laboratory introducing the basic chemical tests used in the water and wastewater fields of environmental engineering and science. Prerequisite: Undergraduate standing, and credit or co-enrollment in CE 570. LAB.

CE 573. Biological Principles of Environmental Engineering. 3 Hours.
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. (Two lecture hours and one three-hour laboratory per week.) Prerequisite: Undergraduate standing, CE 477 or equivalent, and MATH 115 or MATH 121 or MATH 125. LEC.

CE 574. Design of Air Pollution Control Systems. 3 Hours.
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, MATH 122, PHSX 212; or consent of instructor. LEC.

CE 576. Municipal Water Supply and Wastewater Treatment. 4 Hours AE61.
The principles of public water supply design, including source selection, collection, purification, and distribution; for municipal wastewater, collection, treatment, and disposal. Prerequisite: CE 330, CE 455, and CE 477. LEC.

CE 577. Industrial Water and Wastes. 3 Hours.
A review of the methods of industrial water treatment and the fundamentals of industrial water 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. Prerequisite: Undergraduate standing, and CE 477 or equivalent. LEC.

CE 580. Transportation Planning and Management. 3 Hours.
The course covers the major technical aspects of traditional planning methodologies, computer applications in transportation and the impact of technology on the management and planning processes. Topics discussed will include origin-destination surveys, demand analysis models, supply analysis, traffic impact studies, computer simulation and modeling, economics, management systems, intelligent transportation systems (ITS), and geographic information systems (GIS). Prerequisite: CE 390 and senior standing. LEC.

CE 582. Highway Engineering. 3 Hours.
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. LEC.

CE 588. Foundation Engineering. 3 Hours.
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. LEC.

CE 625. Applied Probability and Statistics. 3 Hours.
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. Prerequisite: MATH 121 or MATH 115 and MATH 116. LEC.

CE 684. Materials for Transportation Facilities. 3 Hours.
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 and CE 487. LEC.

CE 704. Dynamics and Vibrations. 3 Hours.
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 vibrational systems. (Same as AE 704.) LEC.

CE 710. Structural Mechanics. 3 Hours.
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. LEC.

CE 712. Structural Engineering Materials. 3 Hours.
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 equivalent, and ENGL 102 or equivalent, or consent of instructor. LEC.

CE 715. Corrosion Engineering. 3 Hours.
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. LEC.

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

CE 730. Intermediate Fluid Mechanics. 3 Hours.
Fall semester. Principles of steady and unsteady flows, theories of potential, viscous, and turbulent flows, and applications in water resources engineering. Prerequisite: CE 330 and MATH 320. LEC.

CE 735. Engineering Applications of GIS. 3 Hours.
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. LEC.

CE 746. Pavement Construction. 3 Hours.
Introduction to the equipment, materials, and construction practices employed in the construction of flexible and rigid highway and airfield pavements, and the relationship of each to pavement design and performance. The principles of statistical based quality control and quality assurance methods and specification writing will be introduced. Prerequisite: CE 484 or CE 412, CE 582, and CE 625 or equivalent. LEC.

CE 748. Asphalt Technology. 3 Hours.
An introduction to the production of asphalt cements and its use in pavement construction and maintenance applications. Pavement distress identification. Design and use of bituminous pavements and materials for other than highway applications. Prerequisite: CE 484 or consent of instructor. LEC.

CE 751. Physical Hydrology. 3 Hours.
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. LEC.

CE 752. Physical Hydrogeology. 3 Hours.
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.) LEC.

CE 753. Chemical and Microbial Hydrogeology. 4 Hours.
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. LEC.

CE 754. Contaminant Transport. 3 Hours.
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. LEC.

CE 755. Free Surface Flow I. 3 Hours.
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. LEC.

CE 756. Wetlands Hydrology and Introduction to Management. 3 Hours.
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. LEC.

CE 757. Pipe-Flow Systems. 3 Hours.
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. LEC.

CE 759. Water Quality Modeling. 3 Hours.
Analytical and numerical modeling of transport and transformation processes in the aquatic environment. Mass balance principles and transport phenomena. Eutrophication of lakes. Transport and fate of conventional pollutants and toxic organic chemicals in rivers, lakes, and estuaries. Prerequisite: CE 330 and CE 477 or equivalent. LEC.

CE 760. Stochastic Hydrology. 3 Hours.
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 equivalent. LEC.

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

CE 762. Plastic Analysis and Design of Structures. 3 Hours.
Investigate the inelastic behavior of materials and cross sections. Study plastic analysis methods and identify the fundamental assumption and theorems to study structures up to collapse. Design ductile structures for extreme loads using plastic design methods. Two lectures one hour and fifteen minute lectures per week. Prerequisite: CE 562 or consent of instructor. LEC.

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

CE 764. Advanced Design of Reinforced Concrete Structures. 3 Hours.
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. LEC.

CE 765. Advanced Steel Design - Building Structures. 3 Hours.
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. LEC.

CE 766. Advanced Steel Design - Bridge Structures. 3 Hours.
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. LEC.

CE 767. Introduction to Fracture Mechanics. 3 Hours.
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 311 plus a structural or mechanical design course. LEC.

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

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

CE 770. Concepts of Environmental Chemistry. 2 Hours.
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 equivalent, calculus, and five hours of chemistry. LEC.

CE 771. Environmental Chemical Analysis. 1 Hour.
A laboratory introducing the basic chemical tests used in the water and wastewater fields of environmental engineering and science. May not be taken for credit by students with credit in CE 571. Prerequisite: Credit or co-enrollment in CE 770. LAB.

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

CE 773. Biological Principles of Environmental Engineering. 3 Hours.
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. (Two lectures and one three-hour laboratory per week.) May not be taken for credit by students with credit in CE 573. Prerequisite: CE 477 or equivalent, calculus, and five hours of chemistry. LEC.

CE 774. Chemical Principles of Environmental Engineering Processes. 3 Hours.
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 equivalent, calculus, and credit or registration in CE 570 or CE 770. LEC.

CE 775. Stormwater Treatment Systems Design. 3 Hours.
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, either CE 455 or CPE 511 or consent of instructor. LEC.

CE 776. Water Reuse. 3 Hours.
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 equivalent. LEC.

CE 777. Industrial Water and Wastes. 3 Hours.
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 equivalent. LEC.

CE 778. Air Quality. 3 Hours.
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 equivalent, and MATH 115 or MATH 121. LEC.

CE 779. Water Quality. 3 Hours.
Examination of water quality principles, policy, processes, practices, computer programs, laws and regulations as they relate to the integrated planning and control of point and nonpoint sources of pollution. Prerequisite: MATH 121 or equivalent, CE 477, and CE 570 or CE 770. LEC.

CE 780. Environmental Instrumental Analysis. 3 Hours.
The course will provide a basis for theoretical understanding and practical experience with state-of-the-art environmental analytical methods organic and inorganic analytes in aqueous matrices. Methods to be covered include liquid, gas and ion chromatography; mass spectrometry; spectrophotometric, FID, EC, and conductivity detection; atomic absorption; spectrophotometic methods; and potentiometric analysis. Statistical methods for analytical methods development, validation and interpretation will also be covered. Prerequisite: General chemistry, and graduate standing. Senior level undergraduates may enroll with consent of instructor. LEC.

CE 781. Traffic Engineering Characteristics. 3 Hours.
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. LEC.

CE 782. Public Works Engineering. 3 Hours.
The functions of a public works director are presented. Topics discussed are concerns with the environment, solid waste, traffic drainage, maintenance of facilities, personnel, etc. LEC.

CE 783. Railroad Engineering. 3 Hours.
A comprehensive study of the railroad industry, including the development of the railway system, an overview of the railroad industry, basic track work, right-of-way and roadway concerns, drainage, track design, railroad structures, electrification, and rail passenger service. A final design project is required. Prerequisite: CE 240; CE 582 or equivalent. LEC.

CE 784. Airport Planning and Design. 3 Hours.
A comprehensive study of the planning design and operations of airports. Both ground side and air side capacity and design elements will be presented. Other topics covered are airport master planning, air traffic control passenger terminal design, and environmental impacts of airports. Prerequisite: CE 240, CE 582 or equivalent. LEC.

CE 785. Terrain Analysis. 3 Hours.
A study of the applications of the science of aerial-photographic interpretation as it pertains to the field of civil engineering including the recognition of soil types and classes, engineering materials surveys, route location, and the delineation of watersheds and estimates of runoff there from. Prerequisite: CE 487 or equivalent. LEC.

CE 786. Highway Safety. 3 Hours.
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. LEC.

CE 787. Advanced Soil Mechanics. 3 Hours.
Three lecture periods. A study of the strength and compression characteristics of cohesive and noncohesive soils under various loading conditions. Prerequisite: CE 487 or equivalent. LEC.

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

CE 789. Pavement Management Systems. 3 Hours.
Basic components of pavement management systems. Emphasis is given to pavement evaluation, planning pavement investment, rehabilitation design alternatives, and pavement management program implementation. Prerequisite: CE 487, CE 484 or equivalent. LEC.

CE 791. Waste Facility Siting and Design. 3 Hours.
A review of current site characterization and design methods for solid and hazardous waste facilities with particular emphasis on working within the modern regulatory environment. Prerequisite: CE 487 or equivalent. LEC.

CE 792. Knowledge Based/Expert Systems in Engineering. 3 Hours.
Introduction to the use of knowledge-based systems for engineering problem solving. These systems have a separation between the facts and concepts (the knowledge base) and the reasoning process used to draw conclusions (the inference mechanism). A wide variety of applications are addressed including civil, chemical and petroleum, computer, and aerospace engineering. Prerequisite: Computer literacy, bachelor's degree in engineering, or consent of instructor. LEC.

CE 793. Advanced Concepts in CADD. 3 Hours.
Advanced concepts related to the application of computer aided design and drafting to the practice of civil engineering are presented. This includes: developing macros, understanding CADD programming languages, and relating CADD and other civil engineering based programs. An engineering approach to Geographical Information Systems (GIS) will be presented. Prerequisite: Working knowledge of one computer aided design graphics software package. LEC.

CE 794. Environmental Graduate Student Orientation. 1 Hour.
An introductory graduate level course with emphasis on selecting a research topic and preparing a thesis or special problem report, technical reports, oral presentations, papers, and grant proposals. This course will also provide orientation information for new students and advice on preparing a plan of study. LEC.

CE 795. Scanning Electron Microscopy and X-Ray Microanalysis. 3 Hours.
The course covers electron optics, electron beam-specimen interaction, image formation, x-ray spectral measurement, qualitative and quantitative x-ray microanalysis, practical techniques of x-ray analysis and specimen preparation techniques. Emphasis is placed on materials, but most techniques apply to biological specimens as well. Prerequisite: PHSX 212. LEC.

CE 797. Environmental Engineering and Science in Developing Countries. 3 Hours.
This course begins with a focus on basic sanitation, including control of infectious diseases, water supply and treatment, and proper disposal of excreta, wastewater, and solid wastes. The course then delves into other environmental topics such as sustainability, wastewater reuse, project planning and implementation, air pollution, deforestation, hazardous waste disposal, and the roles of various governmental and non-governmental organizations in addressing environmental issues. The course topics are addressed by a combination of lectures, guest lectures, and student presentations, with each student choosing a presentation topic of personal or professional interest that is relevant to the course. Prerequisite: CE 477 or permission of instructor. LEC.

CE 800. Theory of Elasticity. 3 Hours.
The basic equations of the theory of elasticity; stress and strain transformation, strain-displacement, compatibility and stress-strain relations. Formulation of problems and exact solutions. Introduction to approximate solution methods based on energy methods and finite elements. LEC.

CE 801. Energy Methods. 3 Hours.
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 and MATH 320. LEC.

CE 802. Nondestructive Evaluation of Materials and Structures. 3 Hours.
This course covers nondestructive methods and their application to engineered structures and components. Methods covered include: ultrasonic testing, acoustic emission, vibration, impact-echo, visual inspection, and frequency response. LEC.

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

CE 815. Viscoelasticity of Solids. 3 Hours.
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 equivalent. LEC.

CE 848. Pavement Materials Characterization. 3 Hours.
Laboratory and field test methods for determining engineering properties of bituminous pavements. Asphalt mix design methods and the relationship between mix design and pavement structural design and performance. Prerequisite: CE 484 or consent of instructor. LEC.

CE 855. Free Surface Flow II. 3 Hours.
The course addresses computer modeling of open channel flow using HEC-RAS (Hydraulic Engineering Center - River Analysis System). 1D, 2D and mixed 1D-2D HEC-RAS models will be developed for steady and unsteady flow conditions. ArcGIS will be used to develop HEC-RAS geometric input files and to process model results. Other 2D programs will also be introduced. Topics addressed are flood delineation, bridge hydraulics, bridge scour, sediment transport and stable channel design. Some knowledge of ArcGIS is desirable. Prerequisite: CE 330 or equivalent. LEC.

CE 856. Wetland Design, Engineering, and Management. 3 Hours.
Introduction of design concepts in creating and restoring wetland systems. Review of wetland hydrology and hydraulics. Interaction of wetland hydrology, soils, and vegetation providing environmental benefits. Considerations in project planning, site selection and preparation, construction and operation, and maintenance. Use of state and local legal and management tools to protect and restore wetlands. Emerging concepts of mitigation and banking. Prerequisite: CE 756 or equivalent. LEC.

CE 857. Sediment Transport. 3 Hours.
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. LEC.

CE 858. Urban Hydrology and Stormwater Management. 3 Hours.
Hydrology of urban watersheds; floodplain management; hydrologic modeling; storm drainage; stormwater detention; water quality improvement; geomorphology of urban streams; stream corridor management and stream restoration. Prerequisite: CE 751. LEC.

CE 861. Finite Element Methods for Solid Mechanics. 3 Hours.
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. LEC.

CE 862. Behavior of Reinforced Concrete Members. 3 Hours.
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. LEC.

CE 864. Seismic Performance of Structures. 3 Hours.
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. LEC.

CE 865. Structural Design for Dynamic Loads. 3 Hours.
The behavior and design of structural systems subjected to dynamic forces such as blasts, earthquakes, and wind loads. Prerequisite: CE 704 or equivalent. LEC.

CE 869. Plates and Shells. 3 Hours.
The analysis and design of plates and shells including thin and thick plates, membrane theory of shells and bending theories of shells. LEC.

CE 870. Life Cycle Assessment. 3 Hours.
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. Not open to students with credit in CE 560. Prerequisite: CE 477 or CPE 211 or equivalent. LEC.

CE 871. Fundamentals of Bioremediation. 3 Hours.
A study of microbial ecology and physiology as they relate to the degradation of environmental contaminants. Emphasis is placed on the interrelationship between the physiological traits or microorganisms, and the physical and chemical properties of the contaminants and the treatment environments. Case studies involving in-situ bioremediation and reactor design are discussed. Prerequisite: CE 573 or CE 773 or equivalent, and five hours of chemistry. LEC.

CE 873. Environmental Monitoring. 2 Hours.
A lecture-laboratory course to familiarize students with environmental monitoring techniques, regulations, and systems. Dimensions of environmental monitoring will be considered for air, soil, and water measurements. The major emphasis will be on monitoring techniques and their principles, utility, and limitations. LEC.

CE 874. Air Pollution Control. 3 Hours.
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. LEC.

CE 875. Solid and Hazardous Wastes. 3 Hours.
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 770 and CE 773 are recommended. LEC.

CE 876. Wastewater Treatment Plant Design. 3 Hours.
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. LEC.

CE 877. Water Treatment Plant Design. 3 Hours.
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. LEC.

CE 878. Air Quality Modeling. 3 Hours.
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 121 or CE 625. LEC.

CE 879. Environmental Research Seminar. 1 Hour.
Discussion of current topics in environmental engineering and science and related fields by staff, students, and visiting lecturers. May be taken only once for credit. LEC.

CE 881. Traffic Engineering Operations. 3 Hours.
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. LEC.

CE 882. Geometric Design of Traffic Facilities. 3 Hours.
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. LEC.

CE 883. Urban Transportation Planning. 3 Hours.
A detailed study of the comprehensive transportation planning process which involves the determination of urban travel characteristics and needs from studies of traffic, social-economical, and environmental factors, as well as the applications of land use, trip generation, trip distribution, model split, and traffic assignment models. Prerequisite: CE 781 or equivalent. LEC.

CE 884. Principles of Pavement Design. 3 Hours.
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. LEC.

CE 885. Advanced Foundation Engineering. 3 Hours.
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. LEC.

CE 886. Engineering Rock Mechanics. 3 Hours.
Rock properties and behavior; theories of failure of brittle, jointed, and anisotropic rocks; rock support; laboratory and in-situ testing techniques. Prerequisite: A course in physical geology and CE 487 or equivalent. LEC.

CE 887. Earth Structures. 3 Hours.
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. LEC.

CE 888. Ground Improvement. 3 Hours.
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. LEC.

CE 889. Designing with Geosynthetics. 3 Hours.
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. LEC.

CE 890. Master's Project. 1-4 Hours.
Directed study and reporting of a specialized topic of interest in civil engineering or an allied field. Prerequisite: Consent of instructor. RSH.

CE 891. Advanced Special Problems. 1-3 Hours.
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. LEC.

CE 892. Structural Engineering and Mechanics Seminar. 1 Hour.
Presentation and discussion of current research and design in structural engineering and engineering mechanics. LEC.

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

CE 899. Master's Thesis. 1-10 Hours.
Directed research and reporting of a specialize topic of interest in civil engineering or an allied field. Prerequisite: Consent of instructor. THE.

CE 902. Advanced Vibrations. 3 Hours.
Vibrations of mechanical systems and structures. Nonlinear vibrations. Random vibration. Prerequisite: CE 704 or AE 704. LEC.

CE 912. Theory of Plasticity. 3 Hours.
Plastic stress-strain relationships. Stress and deformation in thick-walled shells, rotating discs, and bars subjected to torsion and bending for ideally plastic materials. Plastic flow of strain-hardening materials. Theory of metal-forming processes including problems in drawing and extruding. LEC.

CE 913. Advanced Fracture Mechanics. 3 Hours.
Development of Griffith-Irwin crack theory and plane strain-stress intensity factors. Advanced analytical and experimental aspects of fracture and fatigue. Development of fracture control plans. Prerequisite: CE 767 or consent of instructor. LEC.

CE 927. Advanced Mechanics. 3 Hours.
The mechanics of continuous media. A unified treatment of the fundamental principles and theories governing applications in solid and fluid mechanics. Topics covered are stress, strain and deformation, general physical principles for the continuum, and various constitutive equations. LEC.

CE 929. Advanced Topics in Solid Mechanics. 2-4 Hours.
Topics such as thermal stresses, vibrations in elastic continuum, dynamic instability, and other advanced topics. LEC.

CE 961. Finite Element Methods for Nonlinear and Dynamic Systems. 3 Hours.
Advanced treatment of finite element techniques for structural analysis including material and geometric non-linearity and the solution of large scale dynamics problems. Prerequisite: CE 861 or ME 761 or equivalent. LEC.

CE 983. Implementation of the Urban Transportation Planning System--UTPS. 3 Hours.
A study of the principles and implementation skills of the most up-to-date versions of several urban transportation planning software packages. The course involves a two-hour lecture and a three-hour laboratory period. Prerequisite: CE 883, or UBPL 750, or equivalent. LEC.

CE 991. Research. 1-15 Hours.
An investigation of a special problem directly related to civil engineering. RSH.

CE 999. Ph.D. Dissertation. 1-15 Hours.
Restricted to Ph.D. candidates. Before candidacy, aspirants performing their research should enroll in CE 991. Prerequisite: Consent of instructor. THE.

Civil, Envr Arch Engineering Courses

CMGT 357. Engineering Economics. 3 Hours.
Analysis of design alternatives and investment opportunities based on the time value of money. Topics include financial statements and accounting concepts related to economic analysis, time value of money and cash flow equivalence, cost of capital and minimum attractive rate of return (MARR), defining mutually exclusive alternatives, developing alternative after-tax cash flows, performing investment and replacement studies, and methods for addressing uncertainty and risk. Prerequisite: MATH 122 or MATH 126, or consent of the instructor. LEC.

CMGT 457. Construction Project Management. 3 Hours.
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 122 or MATH 126 or consent of the instructor. LEC.

CMGT 500. Construction Engineering. 3 Hours.
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. LEC.

CMGT 700. Construction Project Management. 3 Hours.
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. LEC.

CMGT 701. Construction Planning and Scheduling. 3 Hours.
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: CMGT 500 or CMGT 700, and MATH 526 or EMGT 802, or consent of instructor. LEC.

CMGT 702. Construction Equipment and Methods. 3 Hours.
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: CMGT 500 or CMGT 700, MATH 526 or EMGT 802, and CMGT 357 or EMGT 806, or consent of instructor. LEC.

CMGT 703. Construction Quality, Productivity, and Safety. 3 Hours.
Operations analysis for work improvement in construction using process charts, crew balancing, time-lapse photography, and planning techniques. Regulations, accident prevention, and safety management are covered. Prerequisite: CMGT 500 or CMGT 700, MATH 526 or EMGT 802, and CMGT 357 or EMGT 806, or consent of instructor. LEC.

CMGT 704. Construction Estimating and Bidding. 3 Hours.
A study of the quantity survey, cost estimating, scheduling and project controls; construction operations; and methods of building construction. Prerequisite: CMGT 500 or CMGT 700, MATH 526 or EMGT 802, and CMGT 357 or EMGT 806, or consent of instructor. LEC.

CMGT 705. Construction Contracts, Bonds, and Insurance. 3 Hours.
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: CMGT 500 or CMGT 700, or consent of instructor. LEC.

CMGT 707. Engineering Risk and Decision Analysis. 3 Hours.
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 or consent of instructor. LEC.

CMGT 708. Introduction to Sustainable Design and Construction. 3 Hours.
This course introduces students to Sustainable Design Concepts that are applicable to Civil and Architectural Engineering. Prerequisite: Senior or graduate standing in Architectural Engineering, Architecture, or Civil Engineering or consent of instructor. LEC.

CMGT 709. International Construction Management. 3 Hours.
An introduction to the management of international construction projects. This course focuses on areas where international construction project management differs from the management of domestic construction projects. Topics include project delivery systems including build-operate-transfer (BOT) and other systems unique to international construction contracts; the impact of the host country's language, demographics, laws, political structure, geography, economics, culture, and customs on project delivery; currency transfer and risk; procurement and expediting; designing construction means and methods that optimize available labor, material, and equipment; participant roles and responsibilities; among other topics. Prerequisite: CMGT 500 or CMGT 700, or consent of instructor. LEC.

CMGT 790. Construction Seminar:. 3 Hours.
Prerequisite: Varies with topic. LEC.

CMGT 801. Directed Readings in Construction Management. 1-3 Hours.
Graduate-level directed readings on a topic in construction management mutually agreed on by the student and instructor. Intended to build on one or more of the core course topics: project management; planning and scheduling; equipment and methods; quality; productivity and safety; estimating and bidding; contracts, bonds, and insurance. CMGT 801 may be repeated for credit to a maximum of three hours in the degree program. Mutually agreed course deliverable(s) required. Prerequisite: Approval of the course topic and deliverable(s) by the instructor, CMGT 500 or CMGT 700, CMGT 701, CMGT 702, CMGT 703, CMGT 704, and CMGT 705, or consent of instructor. IND.

CMGT 802. Special Problems in Construction Management. 1-3 Hours.
Graduate-level investigation requiring research of a topic in construction management mutually agreed on by the student and instructor. Intended to build on one or more of the core course topics: project management; planning and scheduling; equipment and methods; quality; productivity and safety; estimating and bidding; contracts, bonds, and insurance. CMGT 802 may be repeated for credit to a maximum of three hours in the degree program. Mutually agreed course deliverable such as a paper summarizing the results of the investigation required. Prerequisite: Approval of the course topic and deliverable by the instructor, CMGT 500 or CMGT 700, CMGT 701, CMGT 702, CMGT 703, CMGT 704, and CMGT 705, or consent of instructor. IND.

CMGT 805. Construction Accounting and Finance. 3 Hours.
Project level cost control concepts and structure, time and cost integration, data collection and reporting, equipment cost, job overhead cost, and cost control. Integrating construction project level cost with construction company financial accounting and financial management. Prerequisite: CMGT 702 and CMGT 704 or consent of instructor. LEC.

CMGT 890. Construction Seminar: _____. 3 Hours.
Prerequisite: Varies with topic. LEC.

CMGT 895. Construction Management Project. 1-3 Hours.
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. 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. IND.

Electrical Engr Computer Sci Courses

EECS 101. New Student Seminar. 1 Hour.
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. LEC.

EECS 137. Visual Basic for Engineers. 3 Hours.
Introduction of computer-based problem solving techniques for engineering practice with emphasis on good programming practices and the integration of appropriate computational and related tools. Solutions are computed using Visual Basic, specifically VBA within Excel. Elementary numerical and statistical methods are applied to the solution of sets of linear and nonlinear algebraic equations, linear regression, and root finding. Microsoft Office is used with the computational tools to provide integrated report generation capability. Two lectures and a weekly laboratory instruction. Prerequisite: MATH 104. LEC.

EECS 138. Introduction to Computing: _____. 3 Hours NM.
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. Prerequisite: MATH 101 or MATH 104, or meeting the requirements to enroll in MATH 115 or MATH 121 or MATH 125 or MATH 145. LEC.

EECS 140. Introduction to Digital Logic Design. 4 Hours.
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 125. LEC.

EECS 141. Introduction to Digital Logic: Honors. 4 Hours.
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: Co-requisite: MATH 121, or MATH 125 or MATH 145, plus either acceptance into the KU Honors Program or consent of instructor. LEC.

EECS 168. Programming I. 4 Hours.
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 125. LEC.

EECS 169. Programming I: Honors. 4 Hours.
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: Co-requisite: MATH 121 or MATH 125 or MATH 145, plus either acceptance into the KU Honors Program or consent of instructor. LEC.

EECS 210. Discrete Structures. 4 Hours.
Mathematical foundations including logic, sets and functions, general proof techniques, mathematical induction, sequences and summations, number theory, basic and advanced counting techniques, solution of recurrence relations, equivalence relations, partial order relations, lattices, graphs and trees, algorithmic complexity, and algorithm design and analysis. Throughout there will be an emphasis on the development of general problem solving skills including algorithmic specification of solutions and the use of discrete structures in a variety of applications. Prerequisite: EECS 168 or 169 (or equivalent) and MATH 122 or MATH 126 or MATH 146. LEC.

EECS 211. Circuits I. 3 Hours.
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; computer-aided analysis. Prerequisite: Co-requisite: Math 220 and MATH 290. LEC.

EECS 212. Circuits II. 4 Hours.
Continued study of electrical circuits: Steady-state power analysis, three-phase circuits, transformers, frequency response, and two-port network analysis. Prerequisite: EECS 211. LEC.

EECS 220. Electromagnetics I. 4 Hours.
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: MATH 220, MATH 290, PHSX 211, and EECS 211. LEC.

EECS 221. Electromagnetics I. 3 Hours.
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: MATH 127, MATH 220, EECS 211, and either PHSX 210 or PHSX 211. LEC.

EECS 268. Programming II. 4 Hours.
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: EECS 168 or EECS 169. LEC.

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

EECS 315. Electric Circuits and Machines. 3 Hours.
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. LEC.

EECS 316. Circuits, Electronics and Instrumentation. 3 Hours.
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. LEC.

EECS 317. Electronics and Instrumentation. 2 Hours.
Introduction to 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: EECS 315. LEC.

EECS 318. Circuits and Electronics Lab. 1 Hour.
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. LAB.

EECS 360. Signal and System Analysis. 4 Hours.
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 systems using MATLAB. Prerequisite: Upper level of EECS Eligibility, and EECS 212. LEC.

EECS 368. Programming Language Paradigms. 3 Hours.
The course is a survey of programming languages: their attributes, uses, advantages, and disadvantages. Topics include scopes, parameter passing, storage management, control flow, exception handling, encapsulation and modularization mechanism, reusability through genericity and inheritance, and type systems. In particular, several different languages will be studied which exemplify different language philosophies (e.g., procedural, functional, object-oriented, logic, scripting). Prerequisite: EECS 268 and upper-level EECS eligibility. LEC.

EECS 388. Embedded Systems. 4 Hours.
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: EECS 140 or EECS 141, EECS 168 or EECS 169, and upper-level EECS eligibility. LEC.

EECS 399. Projects. 1-5 Hours.
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. IND.

EECS 412. Electronic Circuits II. 4 Hours.
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. LEC.

EECS 420. Electromagnetics II. 4 Hours.
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: EECS 220 and upper-level EECS eligibility. LEC.

EECS 441. Power Systems Engineering II. 3 Hours.
A continuation of ARCE 640 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 641.) Prerequisite: Either ARCE 640 or EECS 212, and Upper-Level EECS Eligibility. LEC.

EECS 443. Digital Systems Design. 4 Hours.
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. LEC.

EECS 444. Control Systems. 3 Hours.
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 and EECS 360. LEC.

EECS 448. Software Engineering I. 4 Hours.
This course is an introduction to software engineering, and it covers the systematic development of software products. It outlines the scope of software engineering, including life-cycle models, software process, teams, tools, testing, planning, and estimating. It concentrates on requirements, analysis, design, implementation, and maintenance of software products. The laboratory covers CASE tools, configuration control tools, UML diagrams, integrated development environments, and project specific components. Prerequisite: EECS 268 and upper-level EECS eligibility. LEC.

EECS 461. Probability and Statistics. 3 Hours.
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: MATH 290, MATH 220 and upper-level EECS eligibility. LEC.

EECS 470. Electronic Devices and Properties of Materials. 3 Hours.
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. LEC.

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

EECS 501. Senior Design Laboratory I. 3 Hours.
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. Prerequisite: EECS 412. LEC.

EECS 502. Senior Design Laboratory II. 3 Hours AE61.
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. Prerequisite: EECS 501. LEC.

EECS 510. Introduction to the Theory of Computing. 3 Hours.
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. May be taken for graduate credit. (Same as MATH 510.) Prerequisite: EECS 210 and upper-level EECS eligibility. LEC.

EECS 512. Electronic Circuits III. 3 Hours.
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. LEC.

EECS 541. Computer Systems Design Laboratory I. 3 Hours.
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. Can be taken only during the senior year. Prerequisite: EECS 443 and EECS 448. LEC.

EECS 542. Computer Systems Design Laboratory II. 3 Hours AE61.
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. Can be taken only during the senior year. Prerequisite: EECS 541. LEC.

EECS 544. Electric Machines & Drives. 3 Hours.
Introduction to electric machine theory, operation, and control. Electric machines covered include DC generators and motors, AC synchronous generators and motors, AC induction generators and motors, as well as fractional horsepower and special purpose motors. Motor starting and controls for both DC and AC machines are also covered including an introduction to power electronics and variable frequency drives (VFD). (Same as ARCE 644). Prerequisite: Either ARCE 640 or EECS 212, and Upper-Level EECS Eligibility. LEC.

EECS 545. Electric Energy Production and Storage. 3 Hours.
An introduction to utility scale and small scale (distributed generation) electric energy production and storage systems. This course addresses the technical, operational, economic, environmental, and social 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 production systems covered include fuel cells, photovoltaics (PV), concentrated solar power (CSP), wind, geothermal, and other emerging technologies. (Same as ARCE 645.) Prerequisite: Either ARCE 640 or EECS 212, and Upper-Level EECS Eligibility. LEC.

EECS 547. Power System Analysis I. 3 Hours.
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 647.) Prerequisite: Either ARCE 640 or EECS 212, and Upper-Level EECS Eligibility. LEC.

EECS 548. Power System Analysis II. 3 Hours.
Continuation of EECS 547 that uses power system modeling developed in EECS 547 to analyze power system load flow, operation and economic dispatch, stability, and transient response. The impact of alternative energy sources, energy storage, DC transmission and interties, and other emerging technologies on power system operation and reliability will be addressed throughout the course. (Same as ARCE 648.) Prerequisite: ARCE 647 or EECS 547 or consent of instructor. LEC.

EECS 560. Data Structures. 4 Hours.
Data abstraction and abstract data types. Topics include the design and implementation of dictionary, priority queues, concatenated queue, disjoint set structures, graphs, and other advanced data structures based on balanced and unbalanced tree structures. Special emphasis will be placed on the implementations of these structures and their performance tradeoffs. Both asymptotic complexity analysis and experimental profiling techniques will be introduced. Labs will be used to provide students with hands-on experience in the implementations of various abstract data types and to perform experimental performance analysis. Prerequisite: EECS 210 and EECS 448. LEC.

EECS 562. Introduction to Communication Systems. 4 Hours.
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 and EECS 360. LEC.

EECS 563. Introduction to Communication Networks. 3 Hours.
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 and either EECS 461 or MATH 526. LEC.

EECS 565. Introduction to Information and Computer Security. 3 Hours.
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. Corequisite: EECS 678 and Prerequisite: Upper-Level EECS Eligibility. LEC.

EECS 581. Computer Science Design I. 3 Hours.
The background and planning phase of a two-semester, team-oriented lecture/laboratory course involving the specification, design, implementation, and documentation of a significant software system. The course includes the consideration of project management, ethics, economics, and technical writing. Can be taken only during the senior year. Prerequisite: EECS 448. Co-Requsite: EECS 510 and EECS 560. LEC.

EECS 582. Computer Science Design II. 3 Hours AE61.
The design and implementation phase of a two-semester, team-orientated lecture/laboratory course involving the specification, design, implementation, and documentation of a significant software system. The course includes the consideration of project management, ethics, economics, and technical writing. Can be taken only during the senior year. Prerequisite: EECS 581. LEC.

EECS 611. Electromagnetic Compatibility. 3 Hours.
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 and EECS 312. LEC.

EECS 622. Microwave and Radio Transmission Systems. 3 Hours.
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 EECS 461. LEC.

EECS 628. Fiber Optic Communication Systems. 3 Hours.
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 and PHSX 313 or equivalent and upper-level EECS eligibility. LEC.

EECS 638. Fundamentals of Expert Systems. 3 Hours.
Basic information about expert systems: architecture of an expert system, building expert systems, uncertainty in expert systems, taxonomy of expert systems. Knowledge representation: first order logic, production systems, semantic nets, frames. Uncertainty in expert systems, one-valued approaches: probability theory, systems using Bayes' rule, and systems using certainty theory; two-valued approaches: systems using Dempster-Shafer theory and system INFERNO; set-valued approaches: systems using fuzzy set theory and systems using rough set theory. Prerequisite: EECS 560 or consent of instructor. LEC.

EECS 639. Introduction to Scientific Computing. 3 Hours.
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. Students cannot receive credit for both EECS 639 and EECS 781 or MATH 781. Prerequisite: MATH 127, MATH 290, and EECS 168 or equivalent. LEC.

EECS 644. Introduction to Digital Signal Processing. 3 Hours.
Discrete time signal and systems theory, sampling theorem, z-transforms, digital filter design, discrete Fourier transform, FFT, and hardware considerations. Prerequisite: EECS 360. LEC.

EECS 645. Computer Architecture. 3 Hours.
The structure, design, analysis, and evaluation of computer processors and systems. The design of instruction sets. Principles and techniques of parallelism at the data transfer (memory hierarchy), data processing (pipelines), and concurrent instruction execution. Prerequisite: EECS 388. LEC.

EECS 647. Introduction to Database Systems. 3 Hours.
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. Emphasis on relational databases and retrieval languages SQL, QBE, and ones based on relational algebra and relational calculus; brief description of predicate calculus. Theory of databases, normal forms, normalization, candidates keys, decomposition, functional dependencies, multi-valued dependencies. Introduction to the design of a simple database structure and a data retrieval language. Student cannot receive credit for both EECS 647 and EECS 746. Prerequisite: EECS 448. LEC.

EECS 649. Introduction to Artificial Intelligence. 3 Hours.
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: Corequisite: EECS 368. LEC.

EECS 660. Fundamentals of Computer Algorithms. 3 Hours.
Basic concepts and techniques in the design and analysis of computer algorithms. Models of computations. Simple lower bound theory and optimality of algorithms. Computationally hard problems and the theory of NP-Completeness. Introduction to parallel algorithms. Prerequisite: EECS 560 and either EECS 461 or MATH 526. LEC.

EECS 662. Programming Languages. 3 Hours.
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 368 and EECS 388 and EECS 560. LEC.

EECS 664. Introduction to Digital Communication Systems. 3 Hours.
An introduction to building digital communication systems in discrete time, including lectures and integrated laboratory exercises. Topics covered include signal spaces, base-band modulation, bandpass modulation, phase-locked loops, carrier phase recovery, symbol timing recovery, and basic performance analysis. Prerequisite: EECS 360 and EECS 461. LAB.

EECS 665. Compiler Construction. 4 Hours.
Compilation of simple expressions and statements. 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 PASCAL or C. Programming assignments include using tools for lexer and parser generator, and intermediate , and object code generation techniques. Laboratory exercises will provide hands-on experience with the tools and concepts required for the programming assignments. Prerequisite: EECS 368, EECS 448, and EECS 510. LEC.

EECS 670. Introduction to Semiconductor Processing. 3 Hours.
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 CPE 655.) Prerequisite: Senior standing in CPE or EECS, or consent of instructor. LEC.

EECS 672. Introduction to Computer Graphics. 3 Hours.
Foundations of 2D and 3D computer graphics. Structured graphics application programming. Basic 2D and 3D graphics algorithms (modeling and viewing transformations, clipping, projects, visible line/surface determination, basic empirical lighting, and shading models), and aliasing. Prerequisite: EECS 448. LEC.

EECS 678. Introduction to Operating Systems. 4 Hours.
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 388 and EECS 448. LEC.

EECS 690. Special Topics: _____. 1-3 Hours.
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. LEC.

EECS 692. Directed Reading. 1-3 Hours.
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. IND.

EECS 700. Special Topics: _____. 1-5 Hours.
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. LEC.

EECS 711. Security Management and Audit. 3 Hours.
Administration and management of security of information systems and networks, intrusion detection systems, vulnerability analysis, anomaly detection, computer forensics, auditing and data management, risk management, contingency planning and incident handling, security planning, e-business and commerce security, privacy, traceability and cyber-evidence, human factors and usability issues, policy, legal issues in computer security. (Same as IT 711.) Prerequisite: Graduate standing in EECS, or permission of the instructor. LEC.

EECS 713. High-Speed Digital Circuit Design. 3 Hours.
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. LEC.

EECS 718. Graph Algorithms. 3 Hours.
This course introduces students to computational graph theory and various graph algorithms and their complexities. Algorithms and applications covered will include those related to graph searching, connectivity and distance in graphs, graph isomorphism, spanning trees, shortest paths, matching, flows in network, independent and dominating sets, coloring and covering, and Traveling Salesman and Postman problems. Prerequisite: EECS 560 or graduate standing with consent of instructor. LEC.

EECS 721. Antennas. 3 Hours.
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. LEC.

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

EECS 725. Introduction to Radar Systems. 3 Hours.
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. EECS 622 recommended. LEC.

EECS 728. Fiber-optic Measurement and Sensors. 3 Hours.
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. LEC.

EECS 730. Introduction to Bioinformatics. 3 Hours.
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 560, and Introduction to Biology equivalent to BIOL 150, or consent of instructor. LEC.

EECS 731. Introduction to Data Science. 3 Hours.
This course covers topics in data collection, data transmission, and data analysis, in support of discoveries and innovations based on massive amounts of data. EECS 731 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. EECS 731 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. LEC.

EECS 738. Machine Learning. 3 Hours.
"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. LEC.

EECS 739. Parallel Scientific Computing. 3 Hours.
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 122 or MATH 126; MATH 290; experience programming in C, C++, or Fortran; EECS 639 (or equivalent.) Highly recommended: MATH 127 or MATH 223. LEC.

EECS 740. Digital Image Processing. 3 Hours.
This course gives a hands-on introduction to the fundamentals of digital image processing. Topics include: image formation, image transforms, image enhancement, image restoration, image reconstruction, image compression, and image segmentation. Prerequisite: EECS 672 or EECS 744. LEC.

EECS 741. Computer Vision. 3 Hours.
This course gives a hands-on introduction to the fundamentals of computer vision. Topics include: image formation, edge detection, image segmentation, line-drawing interpretation, shape from shading, texture analysis, stereo imaging, motion analysis, shape representation, object recognition. Prerequisite: EECS 672 or EECS 744. LEC.

EECS 742. Static Analysis. 3 Hours.
This course presents an introduction to techniques for statically analyzing programs. Converge includes theoretical analysis, definition and implementation of data flow analysis, control flow analysis, abstract interpretation, and type and effects systems. The course presents both the underlying definitions and pragmatic implementation of these systems. Prerequisite: EECS 665 or EECS 662 or equivalent. LEC.

EECS 743. Advanced Computer Architecture. 3 Hours.
This course will focus on the emerging technologies to build high-performance, low-power, and resilient microprocessors. Topics include multiprocessing, reliability-and-variability-aware computer architecture designs, energy-efficient computer systems, on-chip networks, 3D microprocessor designs, general-purpose computation on graphics processing units, and non-volatile computer memory. The course responds to VLSI technologies ability to provide increasing numbers of transistors and clock speeds to allow computer architects to build powerful microprocessors and computer systems and the challenges (e.g. resilience, energy-efficiency) that the growth in microprocessor performance is facing from the aggressive technology scaling. Prerequisite: EECS 643 or EECS 645, or equivalent. A good understanding of C/C++ and having basic Unix/Linux skills is required. LEC.

EECS 744. Communications and Radar Digital Signal Processing. 3 Hours.
The application of DSP techniques to specialized communications and radar signal processing subsystems. Topics include A-D converters, specialized digital filters, software receiver systems, adaptive subsystems and timing. Prerequisite: An undergraduate course in DSP such as EECS 644. LEC.

EECS 745. Implementation of Networks. 3 Hours.
EECS 745 is a laboratory-focused implementation of networks. Topics include direct link networks (encoding, framing, error detection, reliable transmission, SONET, FDDL, network adapters, Ethernet, 802.11 wireless networks); packet and cell switching (ATM, switching hardware, bridges and extended LANs); internetworking (Internet concepts, IPv6, multicast, naming/DNS); end-to-end protocols (UDP, TCP, APIs and sockets, RPCs, performance); end-to-end data (presentation formatting, data compression, security); congestion control (queuing disciplines, TCP congestion control and congestion avoidance); high-speed networking (issues, services, experiences); voice over IP (peer-to-peer calling, call managers, call signalling, PBX and call attendant functionality). Prerequisite: EECS 563 or EECS 780. LEC.

EECS 750. Advanced Operating Systems. 3 Hours.
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. LEC.

EECS 753. Embedded and Real Time Computer Systems. 3 Hours.
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. LEC.

EECS 755. Software Modeling and Analysis. 3 Hours.
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. LEC.

EECS 759. Estimation and Control of Unmanned Autonomous Systems. 3 Hours.
An introduction to the modeling, estimation and control of unmanned autonomous systems. Topics include model identification, complementary filters, Kalman filters, attitude estimation, position estimation, attitude keeping controller, path planning, etc. The successful completion of this course will prepare students for advanced studies in robotics controls. (Same as AE 759.) Prerequisite: MATH 627 or EECS 461 or equivalent, AE 551 or EECS 444 or equivalent; or by consent of instructor. LEC.

EECS 762. Programming Language Foundation I. 3 Hours.
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. LEC.

EECS 764. Analysis of Algorithms. 3 Hours.
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 660 or equivalent. LEC.

EECS 765. Introduction to Cryptography and Computer Security. 3 Hours.
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. LEC.

EECS 767. Information Retrieval. 3 Hours.
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 647 or permission of instructor. LEC.

EECS 768. Virtual Machines. 3 Hours.
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. LEC.

EECS 769. Information Theory. 3 Hours.
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 an equivalent undergraduate probability course. LEC.

EECS 773. Advanced Graphics. 3 Hours.
Advanced topics in graphics and graphics systems. Topics at the state of the art are typically selected from: photorealistic rendering; physically-based lighting models; ray tracing; radiosity; physically-based modeling and rendering; animation; general texture mapping techniques; point-based graphics; collaborative techniques; and others. Prerequisite: EECS 672 or permission of instructor. LEC.

EECS 774. Geometric Modeling. 3 Hours.
Introduction to the representation, manipulation, and analysis of geometric models of objects. Implicit and parametric representations of curves and surfaces with an emphasis on parametric freeform curves and surfaces such as Bezier and Nonuniform Rational B-Splines (NURBS). Curve and surface design and rendering techniques. Introduction to solid modeling: representations and base algorithms. Projects in C/C++ using OpenGL. Prerequisite: EECS 672 or permission of instructor. LEC.

EECS 775. Visualization. 3 Hours.
Data representations, algorithms, and rendering techniques typically used in Visualization applications. The emphasis is on Scientific Visualization and generally includes topics such as contouring and volumetric rendering for scalar fields, glyph and stream (integral methods) for vector fields, and time animations. Multidimensional, multivariate (MDMV) visualization techniques; scattered data interpolation; perceptual issues. Prerequisite: General knowledge of 3D graphics programming or instructor’s permission. LEC.

EECS 776. Functional Programming and Domain Specific Languages. 3 Hours.
An introduction to functional programming. Topics include learning how to program in Haskell; IO and purity in software engineering; functional data structures and algorithms; monads and applicative functors; parsing combinators; Domain Specific Languages (DSLs) and DSL construction; advanced type systems; making assurance arguments; testing and debugging. Prerequisite: EECS 368 or equivalent or consent of instructor. LEC.

EECS 780. Communication Networks. 3 Hours.
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. (Same as IT 780.) Prerequisite: EECS 563 or equivalent or permission of instructor. LEC.

EECS 781. Numerical Analysis I. 3 Hours.
Finite and divided differences. Interpolation, numerical differentiation, and integration. Gaussian quadrature. Numerical integration of ordinary differential equations. Curve fitting. (Same as MATH 781.) Prerequisite: MATH 320 and knowledge of a programming language. LEC.

EECS 782. Numerical Analysis II. 3 Hours.
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. LEC.

EECS 784. Science of Communication Networks. 3 Hours.
Comprehensive introduction to the fundamental science that is the basis for the architecture, design, engineering, and analysis of computer networks. Topics covered will include foundations on: Structure of networks: graph theory, complex systems analysis, centrality, spectral analysis, network flows, and network topology; Identification of network entities: naming, addressing, indirection, translation, and location; Operation of protocols and information transfer: automata, control theory, Petri nets, layering and cross-layering, protocol data units; Policy and tussle: game theory, decision theory; Resilience: dependability (reliability, availability, and maintainability), performability, fault tolerance, and survivability. Open-source tools will be used for network modelling and analysis. Prerequisite: EECS upper-level eligibility, graduate standing, or permission of the instructor. LEC.

EECS 786. Digital Very-Large-Scale-Integration. 3 Hours.
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. LEC.

EECS 788. Analog Integrated Circuit Design. 3 Hours.
This course covers the analysis and design of analog and mixed signal integrated circuits, with an emphasis on design principles for realizing state-of-the-art analog circuits. Modern circuit design is a "mixed signal" endeavor thanks to the availability of sophisticated process technologies that allow bipolar and CMOS (Complementary Metal Oxide Semiconductor), power and signal, passive and active components on the same die. It is then up to the circuit designer's creativity and inclination to assemble these components into the analog and/or logic building blocks. The course will provide the critical concepts by giving physical and intuitive explanations in addition to the quantitative analysis of important analog building block circuits. First-order hand calculations and extensive computer simulations are utilized for performance evaluation and circuit design. Prerequisite: EECS 412. LEC.

EECS 800. Special Topics: _____. 1-5 Hours.
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. LEC.

EECS 801. Directed Graduate Readings. 1-3 Hours.
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. RSH.

EECS 802. Electrical Engineering and Computer Science Colloquium and Seminar on Professional Issues. 1 Hour.
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. LEC.

EECS 812. Software Requirements Engineering. 3 Hours.
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. LEC.

EECS 820. Advanced Electromagnetics. 3 Hours.
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. LEC.

EECS 823. Microwave Remote Sensing. 3 Hours.
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. LEC.

EECS 828. Advanced Fiber-Optic Communications. 3 Hours.
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. LEC.

EECS 830. Advanced Artificial Intelligence. 3 Hours.
A detailed examination of computer programs and techniques that manifest intelligent behavior, with examples drawn from current literature. The nature of intelligence and intelligent behavior. Development of, improvement to, extension of, and generalization from artificially intelligent systems, such as theorem-provers, pattern recognizers, language analyzers, problem-solvers, question answerers, decision-makers, planners, and learners. Prerequisite: Graduate standing in the EECS department or Cognitive Science or permission of the instructor. LEC.

EECS 831. Introduction to Systems Biology. 3 Hours.
This course provides an introduction to systems biology. It covers computational analysis of biological systems with a focus on computational tools and databases. Topics include: basic cell biology, cancer gene annotation, micro RNA identification, Single Nucleotide Polymorphism (SNP) analysis, genetic marker identification, protein-DNA interaction, computational Neurology, vaccine design, cancer drug development, and computational development biology. Prerequisite: Introduction to Bioinformatics equivalent to EECS 730, or consent of instructor. LEC.

EECS 837. Data Mining. 3 Hours.
Extracting data from data bases to data warehouses. Preprocessing of data: handling incomplete, uncertain, and vague data sets. Discretization methods. Methodology of learning from examples: rules of generalization, control strategies. Typical learning systems: ID3, AQ, C4.5, and LERS. Validation of knowledge. Visualization of knowledge bases. Data mining under uncertainty, using approaches based on probability theory, fuzzy set theory, and rough set theory. Prerequisite: Graduate standing in CS or CoE or consent of instructor. LEC.

EECS 838. Applications of Machine Learning in Bioinformatics. 3 Hours.
This course is introduction to the application of machine learning methods in bioinformatics. Major subjects include: biological sequence analysis, microarray interpretation, protein interaction analysis, and biological network analysis. Common biological and biomedical data types and related databases will also be introduced. Students will be asked to present some selected research papers. Prerequisite: EECS 730 and EECS 738. LEC.

EECS 839. Mining Special Data. 3 Hours.
Problems associated with mining incomplete and numerical data. The MLEM2 algorithm for rule induction directly from incomplete and numerical data. Association analysis and the Apriori algorithm. KNN and other statistical methods. Mining financial data sets. Problems associated with imbalanced data sets and temporal data. Mining medical and biological data sets. Induction of rule generations. Validation of data mining: sensitivity, specificity, and ROC analysis. Prerequisite: Graduate standing in CS or CoE or consent of instructor. LEC.

EECS 843. Programming Language Foundation II. 3 Hours.
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. LEC.

EECS 844. Adaptive Signal Processing. 3 Hours.
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. LEC.

EECS 861. Random Signals and Noise. 3 Hours.
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. LEC.

EECS 862. Principles of Digital Communication Systems. 3 Hours.
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. LEC.

EECS 863. Network Analysis, Simulation, and Measurements. 3 Hours.
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. LEC.

EECS 865. Wireless Communication Systems. 3 Hours.
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. LEC.

EECS 866. Network Security. 3 Hours.
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. LEC.

EECS 868. Mathematical Optimization with Applications. 3 Hours.
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. LEC.

EECS 869. Error Control Coding. 3 Hours.
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. LEC.

EECS 881. High-Performance Networking. 3 Hours.
Comprehensive coverage of the discipline of high-bandwidth low-latency networks and communication, including high bandwidth-×-delay products, with an emphasis on principles, architecture, protocols, and system design. Topics include high-performance network architecture, control, and signaling; high-speed wired, optical, and wireless links; fast packet, IP, and optical switching; IP lookup, classification, and scheduling; network processors, end system design and protocol optimization, network interfaces; storage networks; data-center networks, end-to-end protocols, mechanisms, and optimizations; high-bandwidth low-latency applications and cloud computing. Principles will be illustrated with many leading-edge and emerging protocols and architectures. Prerequisite: EECS 563 or EECS 780, or permission of the instructor. LEC.

EECS 882. Mobile Wireless Networking. 3 Hours.
Comprehensive coverage of the disciplines of mobile and wireless networking, with an emphasis on architecture and protocols. Topics include cellular telephony, MAC algorithms, wireless PANs, LANs, MANs, and WANs; wireless and mobile Internet; mobile ad hoc networking; mobility management, sensor networks; satellite networks; and ubiquitous computing. Prerequisite: EECS 563 or EECS 780, or permission of the instructor. LEC.

EECS 888. Internet Routing Architectures. 3 Hours.
A detailed study of routing in IP networks. Topics include evolution of the Internet architecture, IP services and network characteristics, an overview of routing protocols, the details of common interior routing protocols and interdomain routing protocols, and the relationship between routing protocols and the implementation of policy. Issues will be illustrated through laboratories based on common routing platforms. Prerequisite: EECS 745. LEC.

EECS 891. Graduate Problems. 1-5 Hours.
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. Prerequisite: Consent of instructor. RSH.

EECS 899. Master's Thesis or Report. 1-6 Hours.
THE.

EECS 900. Seminar. 0.5-3 Hours.
Group discussions of selected topics and reports on the progress of original investigations. Prerequisite: Consent of instructor. LEC.

EECS 940. Theoretic Foundation of Data Science. 3 Hours.
A review of statistical and mathematical principles that are utilized in data mining and machine learning research. Covered topics include asymptotic analysis of parameter estimation, sufficient statistics, model selection, information geometry, function approximation and Hilbert spaces. Prerequisite: EECS 738, EECS 837, EECS 844 or equivalent. LEC.

EECS 965. Detection and Estimation Theory. 3 Hours.
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. LEC.

EECS 983. Resilient and Survivable Networking. 3 Hours.
Graduate research seminar that provides an overview of the emerging field of resilient, survivable, disruption-tolerant, and challenged networks. These networks aim to remain operational and provide an acceptable level of service in the face of a number of challenges including: natural faults of network components; failures due to misconfiguration or operational errors; attacks against the network hardware, software, or protocol infrastructure; large-scale natural disasters; unpredictably long delay paths either due to length (e.g. satellite and interplanetary) or as a result of episodic connectivity; weak and episodic connectivity and asymmetry of wireless channels; high-mobility of nodes and subnetworks; unusual traffic load (e.g. flash crowds). Multi-level solutions that span all protocol layers, planes, and parts of the network will be systemically and systematically covered. In addition to lectures, students read and present summaries of research papers and execute a project. Prerequisite: EECS 780; previous experience in simulation desirable. LEC.

EECS 998. Post-Master's Research. 1-6 Hours.
RSH.

EECS 999. Doctoral Dissertation. 1-12 Hours.
THE.

Electrical Engr Computer Sci Courses

IT 310. Computer Organization and Platform Technologies. 3 Hours.
Machine-level representation of data, digital logic and digital systems, computer architecture and organization, computing infrastructure, introduction to multiprocessing systems, firmware, hardware and software integration , introduction to intersystems communications, enterprise deployment management introduction to virtual machine emulation, platform technologies. Prerequisite: Upper-level IT eligibility. LEC.

IT 320. System and Network Administration. 3 Hours.
This course introduces operating systems and network administration and presents topics related to selection, installation, configuration, and maintenance of operating systems and computer networks. Topics to be covered include: Unix and Windows operating systems installation, configuration, and maintenance, server administration and management, client and server services, user and group management and support, software systems installation and configuration, content management and deployment, security management, network administration, backup management and disaster recovery, resource management, automation management, operating systems and Web domain management, operating systems and application version control management. A laboratory component will provide hands-on experience with system and network administration. Prerequisite: Upper-level IT eligibility. Corequisite: IT 310. LEC.

IT 330. Web Systems and Technologies. 3 Hours.
The objective of this course is to discuss how the Web systems are programmed and maintained and how online pages are created and delivered by Web servers and used by clients. Topics to be covered include: Web systems and technologies, information architecture, digital media, Web development, Web standards, vulnerabilities, social network software, client-side programming, server-side programming, Web services and servers, XHTML, CSS, flash and CGI programming, CSS, Web systems security, JavaScript, PHP, and emerging technologies. Prerequisite: Upper-level IT eligibility. Corequisite: IT 310. LEC.

IT 340. Computer and Information Security. 3 Hours.
Fundamentals of computer security, security mechanisms, information states, security attacks, threat analysis models, vulnerability analysis models, introduction to cryptography, authentication, intrusion detection, intrusion prevention (firewalls), operating systems security, database security, software security, host hardening, incident and disaster response. Prerequisite: Upper-level IT eligibility. LEC.

IT 342. Information Security Management. 3 Hours.
The objective of this course is to present topics related to the administration and management of information security. Topics to be covered include: security fundamentals, operational issues, cost-benefit analysis, asset management, security risk management, security policies and enforcement, risk avoidance, risk prevention, risk transfer, security services, security forensics, contingency planning, security auditing. A laboratory component will provide hands-on experience with security management and administration. Prerequisite: IT 340 and upper-level IT eligibility. LEC.

IT 380. Managing IT Projects. 3 Hours.
The objectives of this course are to cover the fundamental concepts in managing IT projects. Topics include planning, executing, monitoring, controlling, and closing a project, designing a comprehensive project management plan, developing strategies in managing complexity in large projects, and understanding agility in project management. Project management concepts such as planning, scheduling, cost and effort estimation, risk analysis and mitigation, human resources management, communication management, and stakeholder management will be presented in detail. Prerequisite: Upper-level eligibility or consent of the instructor. LEC.

IT 399. Directed Reading in IT. 1-4 Hours.
Reading under the supervision of an instructor on a topic in Information Technology. The topic, expected outcome, evaluation criteria, and the number of credit hours must be mutually agreed on by the student and the instructor. Course may not be used to fulfill major elective requirements. Consent of the department required for enrollment. Prerequisite: Consent of instructor and upper-level IT eligibility. LEC.

IT 410. Software Engineering and Management. 3 Hours.
This course introduces the software development life cycle and key concepts related to software engineering. Topics include software process models, software project management, software requirements engineering, formal and informal modeling, software architecture, software design, coding and implementation, software testing and quality assurance, software deployment, and software evolution. Additional topics such as software metrics and measures, application domains, software engineering standards, and software configuration management will also be presented. This is a project-driven course. Prerequisite: IT 380 or BBA 410, and MATH 365, and upper-level IT eligibility. LEC.

IT 414. Database Design. 3 Hours.
The objective of this course is to present key concepts related to database design and implementation. Topics to be discussed include: database architecture, relational data model, SQL, database design life cycle, conceptual data modeling, relational database normalization, query processing, transaction processing, database security, and database administration. This is a project-driven course. Prerequisite: IT 310. LEC.

IT 416. System Integration and Architecture. 3 Hours.
This course introduces system integration and architecture. Key concepts to be presented include: system architecture, system requirements, organizational context, acquisition and sourcing, system and component integration, middleware platforms, design patterns, integrative coding, scripting coding, testing and quality assurance, system deployment. Prerequisite: IT 410. LEC.

IT 420. Operating Systems. 3 Hours.
This course introduces operating systems principles and associated key concepts. Topics to be discussed include: processes and threads, concurrency, scheduling and dispatch, memory management, processor management, device management, security and protection, file system, disk scheduling, real-time and embedded systems, fault tolerance, scripting, and an introduction to virtualization. Prerequisite: MATH 365, IT 320, and IT 342. LEC.

IT 422. Computer Networks. 3 Hours.
Foundations of computer networking with practical applications and network administration, with emphasis on the Internet and wireless public switched telephone network. Topics to be covered include routing and switching, routing algorithms, physical layer, data link layer, network layer, network security, network management, and application areas. Prerequisite: IT 320. LEC.

IT 424. Network Security. 3 Hours.
This course covers the fundamental concepts, principles, and mechanisms in network and distributed system security. The topics that will be covered include: network security primitives, distributed authentication, key management, secure communication protocols, firewalls, intrusion detection, traffic monitoring and analysis, email and Web security, etc. Prerequisite: IT 340 and IT 422. LEC.

IT 430. Human-Computer Interaction. 3 Hours.
This course introduces principles of human-computer interaction. Important topics to be presented include: human factors, human-centered design and evaluation, graphical user interfaces, multimedia system integration, interactive systems development, computer-supported cooperative work, human cognitive skills, accessibility, alternative input/output media, and emerging technologies. Prerequisite: Completion of nine credits of IT 300-level coursework or consent of the instructor. LEC.

IT 440. Cloud Computing. 3 Hours.
This course introduces principles of cloud computing and the business and computing technology trends that enable and necessitate its uses. Cloud computing and its engineering and delivery models, Software as a Service (SaaS), Platform as a Service (PaaS), and Infrastructure as a Service (IaaS), will be covered. Cloud-based and RESTful web services for developing new applications and offering new services will be discussed. Topics related to cloud computing security, identity, auditing, and authorization management will be presented. The course will be project based and an existing cloud computing platform (e.g., Amazon AWS) will used for projects. Prerequisite: IT 320 or consent of the instructor. LEC.

IT 450. Social and Professional Issues. 3 Hours AE51.
This course will provide an overview of the history of computing and presents key concepts related to the social and professional aspects of IT. Topics to be covered include: pervasive themes in IT, social context of computing, intellectual property, legal issues in computing, professional and ethical issues and responsibilities, privacy and civil liberties. Prerequisite: Completion of nine credits of IT 300-level coursework or consent of the instructor. LEC.

IT 452. Special Topics in IT: _____. 3 Hours.
This course introduces a special topic of current interest in information technology, offered as the need arises. May be repeated for additional credit. Prerequisite: Upper-level IT eligibility and consent of instructor. LEC.

IT 490. IT Capstone I. 3 Hours AE61.
Capstone is a senior level course designed to allow a student to review, analyze, integrate, and apply technical knowledge in a meaningful and practical manner. The student will be expected to complete an approved academic project in IT that may be in collaboration with an industrial partner. Prerequisite: Corequisite: IT 410. LEC.

IT 492. IT Capstone II. 3 Hours.
IT Capstone II is a continuation of IT Capstone, is a senior level course designed to allow a student to review, analyze, integrate, and apply technical knowledge in a meaningful and practical manner. The student will be expected to complete an approved academic project in IT that may be in collaboration with an industrial partner. Prerequisite: IT 490. LEC.

IT 710. Information Security and Assurance. 3 Hours.
This introductory security course covers a wide range of topics in the area of information and network security, privacy, and risk: the basic concepts: confidentiality, integrity and availability; introduction to cryptography; authentication; security models; information and database security; computer systems security; network security; Internet and web security; risk analysis; social engineering; computer forensics. Prerequisite: Graduate standing in EECS, or permission of the instructor. LEC.

IT 711. Security Management and Audit. 3 Hours.
Administration and management of security of information systems and networks, intrusion detection systems, vulnerability analysis, anomaly detection, computer forensics, auditing and data management, risk management, contingency planning and incident handling, security planning, e-business and commerce security, privacy, traceability and cyber-evidence, human factors and usability issues, policy, legal issues in computer security. (Same as EECS 711.) Prerequisite: Graduate standing in EECS, or permission of the instructor. LEC.

IT 712. Network Security and its Application. 3 Hours.
This course focuses on network-based information and communication systems, and examines network technologies and service applications to provide the students with a comprehensive introduction to the field of network security and its application. The course covers key concepts and critical network security services including authentication and access control, integrity and confidentiality of data, routing, firewalls, virtual private networks, web security, virus protection, and network security architecture and policy development. The students are expected to understand the technical vulnerabilities of networked systems and to develop methods to eliminate or mitigate those vulnerabilities. Prerequisite: IT 710 and one of the following: IT 422, EECS 563, or EECS 780. LEC.

IT 714. Information Security and Cyber Law. 3 Hours.
The objectives of this course is to present an introduction to the legal and ethical issues and challenges in the information age, to provide a survey of legal and ethical issues introduced by information security, and to discuss individual rights vs. national interests. A coverage of key cyber laws that impact information security and IT professionals and topics related to intellectual property, copyrights, digital forensics, e-surveillance, and e-discovery for legal evidence and lawsuits will be provided. A review of preventative legal management practices in the context of information security (including employee awareness training) will be presented. Prerequisite: IT 710 or instructor permission. LEC.

IT 746. Database Systems. 3 Hours.
Introduction to the concept of databases and their operations. Basic database concepts, architectures, and data storage structures and indexing. Though other architectures are discussed, focus is on relational databases and the SQL retrieval language. Normalization, functional dependencies, and multivalued dependencies also covered. Culminates in the design and implementation of a simple database with a web interface. Prerequisite: EECS 448 or consent of instructor. Students cannot receive credit for both EECS 647 and EECS 746. LEC.

IT 780. Communication Networks. 3 Hours.
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. (Same as EECS 780.) Prerequisite: EECS 563 or equivalent or permission of instructor. LEC.

IT 810. Software Engineering and Management. 3 Hours.
Principal concepts in software engineering with a focus on formalism as well as managerial issues; software development models; software process models; software configuration management; software development life cycle activities; project management; planning and estimation; requirements engineering, software architecture, software modular design; software reusability; implementation strategies; testing techniques; software quality assurance; software evolution; metrics and measurements, ethics and professionalism. Prerequisite: Programming experience, preferably in Java or C++. LEC.

IT 811. IT Project Management. 3 Hours.
Management issues in the creation, development, and maintenance of IT systems; effort and cost estimation techniques; project planning and scheduling; resource allocation; risk analysis and mitigation techniques; quality assurance; project administration; configuration management; organizational issues; software process modeling; process improvement; frameworks for quality software. LEC.

IT 814. Software Quality Assurance. 3 Hours.
Software quality engineering as an integral facet of development from requirements through delivery and maintenance; verification and validation techniques; manual and automated static analysis techniques; fundamental concepts in software testing; test case selection strategies such as black-box testing, white-box testing; formal verification; unit, integration, system, and acceptance testing; regression testing; designing for testability; models for quality assurance; reviews, inspection, documentation, and standards; industry and government standards for quality. Prerequisite: IT 810. LEC.

IT 818. Software Architecture. 3 Hours.
Designing architectures; software architectural styles and patterns; architectural components and connectors; architectural modeling and analysis, architectural deployment, designing for nonfunctional properties such as efficiency, scaleability, adaptability, and security; domainspecificsoftware architectures; architecture product lines; architecture description languages (ADLs); standards. Prerequisite: IT 810. LEC.

Engineering Management Courses

EMGT 608. Principles of Engineering Management. 3 Hours.
A study of the principles used by the engineer in managing a technology-based enterprise. Topics include planning, organizing, staffing, directing, and controlling. Prerequisite: Senior or graduate standing in an engineering curriculum or consent of the instructor. LEC.

EMGT 800. Special Topics in Engineering Management. 1-4 Hours.
Advanced or experimental work of a specialized nature representing unique or changing needs and resources in engineering management. RSH.

EMGT 801. Management Theory and Practice for Engineering Managers. 3 Hours.
This course is intended to introduce the student to the basic concepts of management and motivation for the engineering manager and general behavior of technical organizations. This course presents a history of the schools of management thought through the modern research that began the participative management movement. The course will investigate classical motivational theories and management style principles. The student will perform research to determine how their employer or clients apply these theories. LEC.

EMGT 802. Statistical Analysis and Prediction of Engineering Systems. 3 Hours.
Applied statistical methods to engineering systems will be introduced in this course for analyzing engineering and management systems. Emphasis will be given to applied regression analysis, analysis of variance, analysis of time dependence by smoothing, Bayes method, time series analysis, auto-regressive moving averages and forecasting model. Prerequisite: Skills in probability, statistics, and computer application. LEC.

EMGT 803. Technological Forecasting and Assessment. 3 Hours.
This course focuses on the impact of technology on society. Techniques of technology forecasting such as Delphi, cross-impact analysis, trend projection, decision trees, and scenarios are discussed. Case studies of technology assessments are presented. Each student is asked to conduct a preliminary technology assessment which is a systematic study of the effects on society which may occur when a technology is introduced or modified. Prerequisite: Elementary skills in statistics, computer programming, and linear algebra. LEC.

EMGT 804. Business Development and Marketing of Professional Services. 3 Hours.
Principles and theories of business development and marketing as applicable to professional engineering and architectural practices. LEC.

EMGT 805. Management of Innovation. 3 Hours.
Management of technology and technological change through innovation, imitation, and obsolescence; planning, organizing, motivation, and control for innovation; organizational climate and its effects on innovative ideas and entrepreneurship; project/product decisions and RD strategies in small and large companies; innovation in multinational corporations. LEC.

EMGT 806. Finance for Engineers. 3 Hours.
A study of finance including financial planning and management in technological based organizations. Topics covered include financial statement analysis, present value of financial markets, capital budgeting, taxes, investment decisions, replacement decisions, cash flow budgets, and sources of capital. LEC.

EMGT 807. Labor and Employee Relations for the Engineering Manager. 3 Hours.
This course is an introduction to labor relations and human resources, including employment practices in unionized and non-union organizations. The course will examine labor relations, human relations and collective bargaining with emphasis on the negotiation and administration of labor agreements. Included will be a survey of the historical, legal, and structural environments that influence the collective bargaining process. Research topics focus on some of the most important issues in the workplace: protecting jobs, increasing productivity, computerization, worker participation, expanding and declining labor markets, and new methods of decision making in the human resources field. LEC.

EMGT 808. Quality Management. 3 Hours.
The overwhelming challenge that faces the U.S. today is the need to regain its competitive position in the world marketplace. This course offers a broad view of Quality Management in that it focuses on the managerial aspects of quality, rather than just the technical. For example, students will learn the Malcolm Baldridge award criteria which focuses on leadership, data analysis, human resources, quality assurance, quality results, and customer satisfaction. In addition, a review of the theory and approaches of the major quality leaders such as Deming, Juran, and Crosby will be covered. Practical applications of TQM concepts in a technological environment will be stressed throughout the course. LEC.

EMGT 809. Personal Development for the Engineering Manager. 4 Hours.
Includes the study of theories, tests for, and objectives of engineering and management ethics. Explores personal values. Measures personality profile and preferred communication style for each student. Includes management of stress, time, and career. Each student prepares career and personal development plans. Managerial writing and communication skills are developed through weekly projects including report and proposal preparation, internal correspondence concerning praise and reprimand, and organizational policy preparation. Interpersonal and nonverbal communication styles are studied. Relies heavily on instructor-assisted peer mediation of topics after introduction of constructive techniques of interpersonal communication. LEC.

EMGT 810. Applications of Quantitative Analysis in Decision Making. 3 Hours.
This course emphasizes the use of general system theory, classical optimization and optimality conditions, model development, and theory and application of mathematical programming, to include: linear programming, dynamic programming, queuing models, integer and non-linear programming, and introduction to decision analysis. Prerequisite: Elementary skills in linear algebra, probability, calculus, and computer application. LEC.

EMGT 811. Engineering Systems Simulation. 3 Hours.
Methods of developing, implementing, and using computer simulations for management processes such as inventory control, waiting lines, project monitoring, and capital investment decisions are covered. Extensive use is made of simulation languages and interactive graphic-supported gaming and decision analysis. Engineering systems and chemical processes are studied under deterministic and stochastic conditions. Two hours lecture, three hours laboratory per week. LEC.

EMGT 812. Law and the Design Professional. 3 Hours.
This course covers: legal doctrines relating to owners, design professionals, and contractors; sources of law, forms of association, and agency; contracts, including formation, rights and duties, interpretation, performance problems, disputes, and claims; standards of care and the management of construction claims; duties and obligations of the design professional, the owner, and the contractor; surety bonds and insurance. Prerequisite: Admission to graduate study in engineering or architecture. LEC.

EMGT 813. Design Project Management in Professional Practice. 3 Hours.
Includes planning, organizing, staffing, directing, and controlling design projects. Treats those topics from viewpoints of profit, cost control, client satisfaction, and project team human relations. Also covers delegation, motivation, team building, performance reviews, conflict resolution, and group dynamics. Presents the project manager's job from an augmented model of the Blake-Mouton grid. Prerequisite: Admission to graduate study in engineering or architecture. LEC.

EMGT 814. Leadership Techniques and Methods for the Engineering Manager. 3 Hours.
Leadership is a balancing act. It requires communicating a compelling vision, convincing others to buy in to that vision, and marshaling resources and talent to make it happen. This course will help new leaders master the complex art of the leadership role by improving decision making and communications, earning trust and building momentum, and inspiring and enabling others to excel. Managers are under increasing pressure to deliver better results faster than the competition. But meeting today's tough challenges requires complete mastery of a full array of management skills, form communications and coaching to public speaking and managing people. LEC.

EMGT 815. Business Relationships and Selling Skills. 3 Hours.
This course will introduce students to the Fundamentals of Business Relationships and Professional Selling. It is suitable for any technical professional who would like to be more effective in "getting their message across" to external or internal customers. Students will learn and connect through class lectures on relationship management including ethical issues in business relationships, experimental exercises on conducting and evaluating dialogues/presentations with groups of Customers/Internal Audiences/Upper Management and through assignments via Blackboard. LEC.

EMGT 816. Energy Management. 3 Hours.
One of the most critical topics for an engineering manager is effective energy cost cutting. This class will be an introduction to the latest strategies for improving lighting, combustion processes, steam generation/distribution, and industrial waste re-utilization. Topics include distributed generation, energy auditing, rate structures, economic evaluation techniques, lighting efficiency improvement, HVAC optimization, combustion and use of industrial wastes, steam generation and distribution system performance, control systems and computers, energy systems maintenance, and renewable energy. LEC.

EMGT 817. Mathematics for the Engineering Manager. 3 Hours.
This comprehensive math course is designed for the needs of the Engineering Manager who may need a "refresher" or to gain greater understanding of math concepts and the relationship to Engineering Management decision-making. LEC.

EMGT 818. Advanced Mathematics for the Engineering Manager. 2 Hours.
This math course is designed to supplement Engineering Management students' math skill and knowledge that is relevant to both the program needs and career needs. This course begins with a higher level of trigonometry and ends with differential equations. LEC.

EMGT 821. Strategic Analysis of Technology Projects. 3 Hours.
A study of the economic feasibility of competing engineering projects including the application of break-even analysis, decisions under uncertainty, decision trees, stochastic models, risk vs. return, and forecasting. A study of the financial figures of merit used to evaluate competing engineering projects including the DuPont rate of return method, the accounting rate of return, the operating return method, return on equity, earnings per share, margin on sales, selling price of stock, corporate credit rating, total sales, market share, market entry, and proforma year-end statements. A study of the strategic evaluation of a project including the proposed product or service, the organization, the environment, and the venture in general. Prerequisite: Admission to the M.S. Engineering Management program or consent of instructor, EMGT 806, a course in applied statistics. LEC.

EMGT 823. Management of Internal Engineering Projects. 3 Hours.
The purpose of this course is to introduce the student to all aspects of managing a project within a company or organization. The entire project life cycle will be covered from inception to close-out, and many practical considerations will be discussed including material procurement, working with contractors and consultants, selecting software, and managing the project team. The course will focus on how to manage project scope, schedule budget, and resources using personal computer software. A semester project is required presenting an example of project management or investigating some aspect of project management in detail. LEC.

EMGT 824. Product Marketing for Engineering Managers. 3 Hours.
Basic principles of marketing as applicable to engineering managers in the production- or operations-based enterprise. Includes a broad overview of the major components of marketing (competition, product, price, promotion, and distribution). Also details the integration of those components into the marketing plan. The students will develop a group marketing plan for an agreed-upon product. Prerequisite: Admission to a graduate program in engineering or Pittsburgh State's technology management program. LEC.

EMGT 830. Case Studies in Engineering Management. 2-3 Hours.
A capstone course for the program which provides an integration of the material presented in the other courses through the utilization of several engineering management case studies. Note: Research paper and presentation are part of the 3 credit hour option. Prerequisite: Completion of a minimum of 21 credit hours in the Engineering Management program. LEC.

EMGT 835. Field Project (M.S.). 1-3 Hours.
A problem in engineering management, the satisfactory completion of which satisfies the project requirement for the degree of Master of Science in Engineering Management. THE.

EMGT 840. Systems Approach to Engineering. 3 Hours.
This is a first course at the graduate level introducing the formal methods and processes in bringing complex systems into being and improving existing systems. Systems include both products and services. Emphasis is placed on: the definition of customer needs, the entire life cycle of systems, and introduction to formal specification methods, the value to cost ratio and the management of the systems engineering process. LEC.

EMGT 844. Managing Software Development Projects. 3 Hours.
This course investigates the area of managing software development and presents the management process as a means of optimizing business considerations and project demands. Uncertainties in product/service specifications, technology risks, cost and delivery requirements impact the management functions. Cost and schedule estimation techniques are presented together with project planning, risk control and measurement technologies. The techniques presented in this course are directly applicable to management in other industry segments. Guest speakers are used to demonstrate applications in this course. LEC.

EMGT 848. Information Technology for Management. 3 Hours.
This course is intended to bring the student up to date on developments in the field of information technology (IT) and to prepare the student to apply those technologies in the workplace. To this end, the course is divided into two components. First, current hardware, software, and networking technologies will be presented. Topics include relational databases, object oriented design and programming, client-server technologies, the Internet, and emerging communication technologies. Second, approaches to evaluating and implementing the range of information technology alternatives available to business will be presented. Topics in this area include software development, management and evaluation, IT project management, information integrity and security, and the effects of IT on people and the organization. LEC.

EMGT 850. Environmental Issues for Engineering Managers. 3 Hours.
This course provides a survey of the environmental regulations, environmental problems, and environmental solutions that must be dealt with by engineering managers regardless of their function or industry. A historical perspective on the environment is presented followed by discussion of pollution generation (sources), transportation, fate, and effects. The quantity and quality of various types of pollutants emitted to various media and the risk posed by these pollutants is analyzed. The regulatory process is examined from the perspective of the legislator, the regulator, the regulated, the engineer, and the public. LEC.

EMGT 854. Management of Business Intelligence and Security for Strategic Planning. 3 Hours.
Management of competitive intelligence and security in business strategic planning is a first course at the graduate level that introduces the formal methods, concepts, and processes of competitive intelligence and security which are vital to both strategic business planning and day-to-day business operations. This course provides access to the tools used to identify what is happening in the business environment including legislation, economics, regulatory changes, competition, customers, etc. that affect a business' strategy and operations. Further, these tools are applied to determining what will likely happen in the future and how to use those forecasts to optimize strategic and operational plans. LEC.

EMGT 860. Special Problems in Engineering Management. 1-4 Hours.
Graduate-level investigation requiring original, independent research on problems or subjects of immediate interest to a student or faculty member. Intended to develop a student's capability in coordinating two or more of the following: technology, finance, economics, applied mathematics, and managerial communication. EMGT 860 may be repeated for credit to a maximum of four hours in the degree program. Prerequisite: Approval of an outline of the proposed project by the instructor and the program director. RSH.

EMGT 862. Manufacturing Systems Integration. 3 Hours.
This course develops the rationale and need for the integration of manufacturing systems, and deals with the multitude of practical problems involved with manufacturing systems integration. Topics covered include intelligent manufacturing subsystems and vendor-specific islands of automation, on-line and off-line information sources, and end users of information in the manufacturing enterprise. Engineering details covered include the types of communication links available between systems, communication standards, network and protocol alternatives, and hardware platform alternatives. Management concepts covered include the top-down design/bottom-up implementation approach to system integration, long-range planning and management of integration projects, reliability and security issues, and human factors. LEC.

EMGT 867. Advanced Operations Management. 3 Hours.
This course provides the student with up-to-date information of the management of manufacturing operations. Emphasis is on quantitative methods for designing and analyzing manufacturing processes, simulation of manufacturing processes, and recent paradigms in manufacturing including just-in-time production, synchronous manufacturing, and agile manufacturing. A semester project is required covering some aspect of operations management in detail. LEC.

Engineering Management Courses

PMGT 800. Special Topics: _____. 3 Hours.
Advanced or experimental work of specialized nature representing unique or changing needs and resources in project management. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 806. Finance for Project Manager. 3 Hours.
A study of finance including financial planning and management in technological based organizations. Topics covered include financial statement analysis, present value of financial markets, capital budgeting, taxes, investment decisions, replacement decisions, cash flow budgets and sources of capital. LEC.

PMGT 809. Personal Development for Project Managers. 4 Hours.
Concepts and skills development in the primary areas of communication methods, ethical behavior, conflict resolution, workforce diversity, and continuous learning, and secondary areas of basic project and project team contexts and related interpersonal relations. Career development is emphasized. LEC.

PMGT 816. Project Management Fundamentals I. 3 Hours.
Managerial concepts and skills development in relation to the project-oriented business environment, project lifecycle, integrated project management, project selection, and project initiation. Focus is on management of a single project. LEC.

PMGT 817. Project Managemnt Fundmntls II. 3 Hours.
Planning concepts and skills development in relation to developing needed information on project scope, time, cost, and risk, and making direct use of such information to develop key documentation such as the project schedule and budget. Examples of specific topics considered include project work content and change, documentation, and resource requirements. Planning content is complementary to that of PMGT 818. Prerequiste: PMGT 816. LEC.

PMGT 818. Project Management Fundamentals III. 3 Hours.
Concepts and skills development in relation to planning for management of communications, human resource aspects of project team formation and development, procurement, and quality. Examples of specific topics considered include information handling, reporting, and stakeholder relationships. Planning content is complementary to that of PMGT 817. Prerequisite: PMGT 817. LEC.

PMGT 819. Project Management Fundamentals IV. 3 Hours.
Concepts and skills development in relation to project execution, including processes monitoring and controlling, and project closure. Examples of specific topics considered include handling change requests, procurement, teamwork and team development, and cost management. Course content represents systematic treatment of all aspects of project management beyond plannig-but is, in project execution and closing phrases. Prerequisite: PMGT 818. LEC.

PMGT 820. Management of New Product Development Projects. 3 Hours.
This course discusses how to properly manage new product development processes using project management tools and techniques. New products are not projects until they are analyzed, planned, scheduled, budgeted, managed, and controlled by managers. It is not typically technical process issues that result in failed new product introductions, but rather a failure in their management and marketing. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, PMP Certified. LEC.

PMGT 821. Management of Consulting Projects. 3 Hours.
Application area course exposing students to specialized knowledge, standard, and regulations involved in managing consulting projects. Attention is directed to unique characteristics of consulting project environments, major project phases-from selection to closing-and related management processes. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 822. Management of Governmental Projects. 3 Hours.
Application area course exposing students to specialized knowledge, standards, and regulations involved in managing projects for governmental entities. Attention is directed to unique characteristics of the governmental project environments, major project phases-from selection to closing-and related management processes. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 823. Risk Management for Project Managers. 3 Hours.
Advanced study of risk management theory and practice as applied in managing projects. Basic concepts and methods of risk management are reviewed-such as qualitative and quantitative risk assessment-and details then examined. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 824. Project Cost Estimation, Analysis, and Control. 3 Hours.
Advanced study of cost estimation methodology, cost engineering, and cost control applicable in project management. Includes review of commonly used supportive software. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 825. Portfolio Analysis for Project Managers. 3 Hours.
Concepts and methods of intra-and inter-project finance including inter-organization funding, project evaluation and selection, project cost accounting, portfolio formulation and modification, and performance tracking. Introduces fundamentals of investment theory and real options analysis. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 826. Program Management. 3 Hours.
Examination of program definition, structuring, and management in the context of organizational strategy, and the critical resources and skills required in long-term program evolution and execution. Facilitation of efforts across multi-tiered organizations will be stressed. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 827. Project Team Management and Development. 3 Hours.
Concepts and methods of team and team member development, achieving higher-performance teams while satisfying organizational expectations. Specific topics include management concepts and practices, team dynamics, and interpersonal skills in negotiation and conflict resolution. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 828. Management of Global Projects. 3 Hours.
Survey of management challenges in conducting international projects, emphasizing cross-culture issues. Differences across world regions and selected key countries in relation to communication and interpersonal norms, business conventions, and legal systems will receive particular attention. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 829. Management of Distributed Project Teams. 3 Hours.
Concepts and methods of conducting high-performance, multi-site team operations, focusing on intra-team communication, coordination, and control. Incorporates review of practical technologies with emphasis on web-enabled approaches. Prerequisite: PMGT 816, Project Management-Master of Engineering plan code, or PMP Certified. LEC.

PMGT 830. Case Studies in Project Management. 2 Hours.
Reinforcement and demonstration of developing project management skills through case analysis and discussion. Goal is integration of learning across all core courses, and also drawing on content from general management, applications area, and advanced project management elective courses taken. Emphasis is on integrated project management. The students will document their project in a written report and present their project during the final oral examination to the Project Management faculty and student's employer or representative if practical. LEC.

PMGT 833. Management of Internal Projects for Scientists and Technical Professionals. 3 Hours.
The purpose of this course is to introduce the student to all aspects of managing a project within a company or organization. The entire project life cycle will be covered from inception to close-out, and many practical considerations will be discussed including material procurement, working with contractors and consultants, selecting software, and managing the project team. The course will focus on how to manage project scope, schedule budget, and resources using personal computer software. A semester project is required presenting an example of project management or investigating some aspect of project management in detail. LEC.

PMGT 835. Project Management Capstone. 3 Hours.
The capstone serves as a culminating experience for this degree. Students will develop an applied workforce project or benefit to in the student's place of employment for full time students. The students will document their project in a written report and present their project during the final oral examination to the Project Management facility and student's employer or representative if practical. Prerequisite: Must complete 21 credit hours. LEC.

Engineering Physics Courses

EPHX 400. Topics in Engineering Physics: _____. 1-3 Hours.
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. LEC.

EPHX 501. Honors Research. 1-4 Hours AE61 / N.
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 PHSX 501.) Prerequisite: Junior/Senior standing in Astronomy, Engineering Physics, or Physics, or permission of instructor. IND.

EPHX 503. Undergraduate Research. 1-4 Hours AE61.
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. IND.

EPHX 511. Introductory Quantum Mechanics. 3 Hours.
An introduction to quantum mechanics, emphasizing a physical overview. Topics should include the formalisms of non-relativistic quantum mechanics, the 3-dimensional Schrodinger equation with applications to the hydrogen atom; spin and angular momentum; multi-particle systems of Fermi-Dirac and Bose-Einstein particles; time-independent perturbation theory. (Same as PHSX 511.) Prerequisite: PHSX 313 and MATH 290. LEC.

EPHX 516. Physical Measurements. 4 Hours.
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. (Same as PHSX 516.) Prerequisite: PHSX 313, EPHX 316, and EPHX 521. (EPHX 521 may be taken concurrently.) LAB.

EPHX 518. Mathematical Physics. 3 Hours N.
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. Prerequisite: PHSX 313 and MATH 320 or permission of instructor. (Same as PHSX 518.) LEC.

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

EPHX 531. Electricity and Magnetism. 3 Hours.
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 special permission; MATH 127; MATH 290; and MATH 220 or MATH 320. LEC.

EPHX 536. Electronic Circuit Measurement and Design. 4 Hours.
A laboratory course that explores the theory and experimental techniques of analog and digital electronic circuit design and measurements. 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; and MATH 290. PHSX 313 and 316 recommended. LEC.

EPHX 600. Special Topics in Physics and Astrophysics: _____. 3 Hours.
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. LEC.

EPHX 601. Design of Physical and Electronic Systems. 4 Hours AE61.
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. LEC.

EPHX 615. Numerical and Computational Methods in Physics. 3 Hours.
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. LEC.

EPHX 621. Mechanics II. 3 Hours.
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. LEC.

EPHX 623. Physics of Fluids. 3 Hours.
An introduction to basic fluid mechanics in which fundamental concepts and equations are covered. Topics include hydrostatics, hydrodynamics, wave propagation in fluids, and applications in the areas such as astrophysics, atmospheric physics, and geophysics. (Same as PHSX 623.) Prerequisite: MATH 127; MATH 290; PHSX 212 and PHSX 236 (or PHSX 214 can replace PHSX 212 and PHSX 236.) LEC.

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

EPHX 641. Introduction to Nuclear Physics. 3 Hours.
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 511. LEC.

EPHX 655. Optics. 3 Hours.
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 313 and PHSX 316. LEC.

EPHX 661. Introduction to Elementary Particle Physics. 3 Hours.
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 511 and MATH 320. LEC.

EPHX 671. Thermal Physics. 3 Hours.
Development of thermodynamics from statistical considerations. Elementary techniques of calculating thermodynamic properties of systems. Application to classical problems of thermodynamics. Elementary kinetic theory of transport processes. Fermi-Dirac and Bose-Einstein systems. (Same as PHSX 671.) Prerequisite: PHSX 511. LEC.

EPHX 681. Concepts in Solids. 3 Hours.
Properties of common types of crystals and amorphous solids. Lattice vibrations and thermal properties of solids. Electrons and holes in energy bands of metals, semiconductors, superconductors, and insulators. (Same as PHSX 681.) Prerequisite: PHSX 313 and PHSX 511. LEC.

EPHX 691. Astrophysics I. 3 Hours.
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 or consent of instructor. LEC.

EPHX 693. Gravitation and Cosmology. 3 Hours.
An overview of topics relevant to gravitation and modern cosmology: special relativity, tensor notation, the equivalence principle, the Schwarzchild 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 and MATH 320. LEC.

Engineering Courses

ENGR 101. Engineering Academic Success Seminar. 0-1 Hours.
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. Prerequisite: Eligible students must have fewer than thirty credit hours from the University of Kansas. LEC.

ENGR 102. Engineering Academic Recovery Program. 0 Hours.
The Engineering Academic Recovery Program is a mandatory course for freshman engineering students who are placed on academic probation (

ENGR 108. Introduction to Engineering. 2 Hours.
An introductory level course with emphasis on engineering problem definition, methods simulation, and solution, including approaches to engineering design; engineering units and terminology; engineering disciplines and career areas, and engineering code of ethics. LEC.

ENGR 111. Freshman Self Seminar. 0-1 Hours.
This 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. Prerequisite: Students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow. LEC.

ENGR 112. Sophomore Self Seminar. 0-1 Hours.
This 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. Prerequisite: Students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow. LEC.

ENGR 113. Junior Self Seminar. 0-1 Hours.
This 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. Prerequisite: Students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow. LEC.

ENGR 114. Senior Self Seminar. 0-1 Hours.
This 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. Prerequisite: Students must have applied, interviewed, and been accepted as a Self Engineering Leadership Fellow. LEC.

ENGR 177. First Year Seminar: _____. 3 Hours GE11.
A limited-enrollment, seminar course for first-time freshmen, organized around current issues in mechanical engineering. May not contribute to major requirements for School of Engineering students. First year seminar topics are coordinated and approved through the Office of First Year Experiences. Prerequisite: First-time freshman status. LEC.

ENGR 180. Introduction to Naval Ships Systems I. 3 Hours.
The concept of weapons systems and the systems approach are explored. The techniques of linear analysis of ballistics and weapons are introduced. The dynamics of the basic components of weapons control systems are investigated and stated as transfer functions. This course provides the tools for the future development in the student's understanding of the basic principles that underlie all modern naval weapons systems. Approved for degree credit in the College of Liberal Arts and Sciences effective fall 1971. Such courses count within the limit of 25 hours accepted from other schools and divisions. (Same as NAVY 180.) Prerequisite: MATH 002. LEC.

ENGR 184. Introduction to Naval Ships Systems II. 3 Hours.
The concept of weapons systems and the systems approach are explored. The techniques of linear analysis of ballistics and weapons are introduced. The dynamics of the basic components of weapons control systems are investigated and stated as transfer functions. This course provides the tools for the future development in the student's understanding of the basic principles that underlie all modern naval weapons systems. Approved for degree credit in the College of Liberal Arts and Sciences effective Fall 1971. Such courses count within the limit of 25 hours accepted from other schools and divisions. (Same as NAVY 184.) LEC.

ENGR 300. Cooperative Engineering Education Experience. 1 Hour.
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. Prerequisite: Permission of major department. FLD.

ENGR 301. Navigation and Operations I. 3 Hours.
First semester juniors. Three hours classroom and two and one-half hours laboratory per week. A comprehensive study of the theory, principles, and procedures of ship navigation in coastal and open ocean environment. Includes piloting, triangulation, ocean and tidal currents, navigational astronomy, spherical trigonometry, sight reduction, publications and logs; an introduction to electronic navigation, including theory of wave propagation, hyperbolic and azimuthal systems, doppler, inertial, and satellite systems. (Same as NAVY 300.) LEC.

ENGR 304. Technology: Its Past and Its Future. 3 Hours.
An examination of the role of technology and its influence on society. The historical development of technology will be traced up to modern times with an emphasis on its relations to the humanities. Attention will be given to the future of different branches of technology and alternative programs for their implementation. (Same as HIST 404.) LEC.

ENGR 305. Navigation and Operations II. 3 Hours.
A study of the laws for the prevention of collisions at sea; tactical formations and dispositions, relative motion, and the maneuvering board. A portion of the semester is devoted to an analysis of naval operations utilizing formal decision making theory, particularly as applied to command and control. Numerous case studies are used to examine the application of the above topics. Approved for degree credit in the College of Liberal Arts and Sciences effective fall 1971. Such courses count within the limit of 25 hours accepted from other schools and divisions. (Same as NAVY 304.) Prerequisite: MATH 111 or higher. NAVY 300 or ENGR 301. LEC.

ENGR 360. Special Topics: _____. 1-5 Hours.
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. FLD.

ENGR 490. Engineering Internship. 1-6 Hours.
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. INT.

ENGR 504. Technical Writing for Engineers. 1-3 Hours.
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. Graded on satisfactory/unsatisfactory basis. Prerequisite: ENGL 102. FLD.

ENGR 515. Verbal Communications in Engineering. 1 Hour.
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. FLD.

ENGR 600. Engineering Applications in India: Technical, Business, and implementation Issues. 3 Hours.
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. LEC.

ENGR 835. Project (ME). 3-6 Hours.
A design problem or system study satisfying the project requirement for the Master of Engineering degree. THE.

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

Mechanical Engineering Courses

ME 201. Statics. 2 Hours.
The principles of statics, with particular attention to engineering applications. Prerequisite: PHSX 210 or PHSX 211. LEC.

ME 208. Introduction to Digital Computational Methods in Mechanical Engineering. 3 Hours.
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. One lecture and lab meets with ME 228, therefore ME 208 cannot be taken concurrently with ME 228, but should be taken in back-to-back semesters. Prerequisite: Corequisite: MATH 116 or MATH 121 or MATH 125. LEC.

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

ME 211. Statics and Intrduction to Mechanics. 3 Hours.
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: PHSX 210 or PHSX 211. LEC.

ME 228. Computer Graphics. 3 Hours.
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. One lecture and lab meets with ME 208, therefore ME 228 cannot be taken concurrently with ME 208, but should be taken in back-to-back semesters. LEC.

ME 306. Science of Materials. 3 Hours.
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 170 or consent of instructor. LEC.

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

ME 309. Introduction to Mechanical Design. 1 Hour.
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. LEC.

ME 311. Mechanics of Materials. 3 Hours.
The principles of mechanics of materials with particular emphasis on mechanical systems including theories of failure. Prerequisite: ME 211 or ME 210. Corequisite: MATH 220. LEC.

ME 312. Basic Engineering Thermodynamics. 3 Hours.
An introduction to the concepts of heat, work, the first and second laws of thermodynamics and equations of state. These concepts are applied to flow and nonflow systems including power and refrigeration cycles. Prerequisite: PHSX 210 or PHSX 211 or (Corequisite: PHSX 211 and CHEM 135 or CHEM 175). Corequisite: MATH 122 or MATH 127. LEC.

ME 320. Dynamics. 3 Hours.
Kinematics and kinetics of particles and of rigid bodies as applied to mechanical engineering problems. Prerequisite: ME 201 or ME 211, MATH 220, and MATH 290. LEC.

ME 321. Dynamics Simulations. 1 Hour.
Introduction to dynamics simulations on the computer. Prerequisite: Corequisite: ME 320. LEC.

ME 360. Mechanical Engineering Problems. 1-3 Hours.
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. IND.

ME 361. Undergraduate Honors Research. 1-3 Hours.
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. IND.

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

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

ME 420. Mechanisms. 3 Hours.
Design and analysis of mechanisms composed of linkages, cams, and gears. Mechanical vibration. Prerequisite: PHSX 211 and MATH 220. LEC.

ME 455. Mechanical Engineering Measurements and Experimentation. 4 Hours.
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 and ME 311. Corequisite: EECS 318, ME 510, ME 320, ME 612, and MATH 365 or MATH 526 (or DSCI 202.) LEC.

ME 501. Mechanical Engineering Design Process. 2 Hours.
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 311 and ME 312. Corequisite: ME 228 and ME 307. LEC.

ME 508. Numerical Analysis of Mechanical Engineering Problems. 3 Hours.
Introduction to numerical methods for solution of mechanical engineering problems by use of digital computers. Prerequisite: ME 208 or equivalent, MATH 220 and MATH 290. LEC.

ME 510. Fluid Mechanics. 3 Hours.
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, or CE 201 and MATH 122 or MATH 127 and ME 312. Corequisite: MATH 220. LEC.

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

ME 612. Heat Transfer. 3 Hours.
An applied study of conductive, convective, and radiative heat transfer mechanisms in solid and fluid systems. Engineering applications include solid conduction, free and forced convection in fluids, thermal radiation and heat exchangers, evaporators, and furnaces. Prerequisite: MATH 220 and ME 312. Corequisite: ME 510 or CPE 511. LEC.

ME 627. Automotive Design. 3 Hours.
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: Permission of instructor. LEC.

ME 628. Mechanical Design. 3 Hours.
Design of mechanical components and systems. Prerequisite: ME 311. LEC.

ME 633. Basic Biomechanics. 3 Hours.
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 and ME 320 or equivalent. LEC.

ME 636. Internal Combustion Engines. 3 Hours.
Study and analysis of internal combustion engine physical phenomena dynamic function, 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 lubrication, and mechanical design. Prerequisite: ME 412. LEC.

ME 637. Steam Power Plants. 3 Hours.
A study of steam power plant equipment including thermodynamic analysis, design and performance of modern steam generators, prime movers, and auxiliaries. Prerequisite: ME 412 or permission of instructor. LEC.

ME 639. Alternative Energy Systems. 3 Hours.
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 CPE 511 and (ME 412 or ME 612 or CPE 521). LEC.

ME 640. Design Project. 2 Hours AE61.
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: Approval of instructor. LEC.

ME 641. Design Project Option A. 2-3 Hours AE61.
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 501, ME 510, ME 628 and ME 640. Corequisite: ME 412 and ME 455. LEC.

ME 642. Design Project Option B. 4 Hours AE61.
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 627, ME 501 and ME 628. Corequisite: ME 412 and ME 455. LEC.

ME 643. Design Project Option C. 2 Hours AE61.
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 501, ME 628, ME 633 and ME 640. Corequisite: ME 455. LEC.

ME 644. Design Project Option D. 2-3 Hours AE61.
Design and development of a thermal or fluid system. A group report that includes design, 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 412, ME 455, and ME 501. Corequisite: ME 628. LEC.

ME 645. Design Project Option E. 2-3 Hours AE61.
Design and development of a mechanical, electrical or thermal/fluid system related to a sustainable approach to automobiles and energy infrastructure. This may include, but is not limited to alternative fuels, biomass, batteries and advanced vehicle powertrains along with solar/wind energy at various scales. 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 501, ME 510, and ME 628. Corequisite: ME 412 and ME 455. LEC.

ME 661. The Finite Element Method. 3 Hours.
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, MATH 220, and MATH 290. LEC.

ME 682. System Dynamics and Control Systems. 3 Hours.
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. LEC.

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

ME 702. Mechanical Engineering Analysis. 3 Hours.
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. LEC.

ME 708. Microcomputer Applications in Mechanical Engineering. 3 Hours.
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: Permission of instructor. LEC.

ME 711. Bearings and Bearing Lubrication. 3 Hours.
Theoretical aspects of lubrication, determination of pressure distribution in bearings from viscous flow theory, application of hydrodynamic and hydrostatic bearing theories to the design of bearings, high speed bearing design problems, properties of lubricants, methods of testing. Prerequisite: ME 510 and a course in differential equations. LEC.

ME 712. Advanced Engineering Thermodynamics. 3 Hours.
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 508 and ME 412. LEC.

ME 714. Thin Film Flow. 3 Hours.
In thin film theory, the lubrication approximation (also called the long-wave approximation) is used to simplify the Navier-Stokes equations to study the flow of thin films. Even with this simplification, the thin film equation is still a challenging nonlinear PDE, and numerical and analytical methods are used to solve and analyze the equation. Similarity solutions, linear stability analysis, and travelling waves are useful tools for analysis. This course will focus on coating flows of thin films so the students can learn these techniques and discover the current knowledge gaps at the frontiers of this research area. Thin film flows are found in many applications, such as microchip production or biomedical applications, and experiments with thin film flows often yield stunning photos and videos. Prerequisite: ME 510, MATH 290, ME 508 or equivalents. LEC.

ME 718. Fundamentals of Fuel Cells. 3 Hours.
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.) LEC.

ME 720. Advanced Dynamics of Machinery. 3 Hours.
Dynamics of particles and of rigid bodies with advanced engineering applications; generalized coordinates; Hamilton's principles; Lagrange's equations; Hamilton-Jacobi theory. Prerequisite: ME 320 or equivalent. LEC.

ME 722. Modeling Dynamics of Mechanical Systems. 3 Hours.
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. LEC.

ME 733. Gas Dynamics. 3 Hours.
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. LEC.

ME 736. Catalytic Exhaust Aftertreatment Modeling. 3 Hours.
Fundamental concepts behind catalytic exhaust aftertreatment devices for automobiles including both monolithic catalysts and particulate filters. Studies of other catalytic devices intended for applications in the mechanical and chemical engineering fields. Topics covered are the development of governing equations based on conservation laws and their numerical solutions using finite difference methods. Studies will include a monolithic catalyst. Project assignments will be included. Prerequisite: ME 412 and ME 510 or permission of instructor. LEC.

ME 750. Biomechanics of Human Motion. 3 Hours.
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. LEC.

ME 751. Experimental Methods in Biomechanics. 3 Hours.
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. LEC.

ME 752. Acoustics. 3 Hours.
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. LEC.

ME 753. Bone Biomechanics. 3 Hours.
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. LEC.

ME 754. Biomedical Optics. 3 Hours.
This course will cover the fundamentals of photon transport in biological tissues, including explanations of Rayleigh and Mie scattering, Monte Carlo simulations, the radiative transport equations and more. Also, the basic physics and engineering of various optical imaging techniques for biological tissues, including ballistic or quasi-ballistic imaging (such as confocal microscopy, and optical coherence tomography), diffuse imaging, photoacoustic imaging, will be introduced. Prerequisite: ME 508 or permission of instructor. LEC.

ME 755. Computer Simulation in Biomechanics. 3 Hours.
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. LEC.

ME 756. Biofluid Dynamics. 3 Hours.
An introduction to the fundamentals of biofluid dynamics, and the application of these principles to a variety of biological flows. Fluid flows in physiology, drug delivery, and biotechnology are investigated at a variety of scales, ranging from subcellular to organ groups. Topics include non-Newtonian constitutive equations, solution techniques, and principles of modeling and simulating. Prerequisite: ME 208 and ME 510 or equivalents. LEC.

ME 757. Biomechanical Systems. 3 Hours.
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. LEC.

ME 758. Physiological System Dynamics. 3 Hours.
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. LEC.

ME 760. Biomedical Product Development. 3 Hours.
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. LEC.

ME 765. Biomaterials. 3 Hours.
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. LEC.

ME 767. Molecular Biomimetics. 3 Hours.
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.) LEC.

ME 770. Conductive Heat Transfer. 3 Hours.
The formulation of steady- and unsteady-state conduction heat transfer problems and their solution by analytical and numerical methods. Prerequisite: ME 612 or equivalent. LEC.

ME 774. Radiative Heat Transfer. 3 Hours.
The formulation of steady and unsteady radiation heat transfer problems and their solution by analytical and numerical methods. Prerequisite: ME 612 or equivalent. LEC.

ME 788. Optimal Estimation. 3 Hours.
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.) LEC.

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

ME 797. Materials for Energy Applications. 3 Hours.
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. LEC.

ME 801. Responsible Conduct of Research in Engineering. 1 Hour.
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. LEC.

ME 808. Advanced Microprocessor Applications. 3 Hours.
Advanced design and development of microprocessor based mechanical systems. Individual and team projects involving the development and integration of hardware and software into a "smart" system which includes the sensing, processing, and controlling functions are accomplished. Emphasis is on the use of the latest sensors and development tools. Prerequisite: Permission of instructor. LEC.

ME 810. Advanced Fluid Mechanics. 3 Hours.
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. LEC.

ME 831. Convective Heat and Momentum Transfer. 3 Hours.
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. LEC.

ME 832. Computational Fluid Dynamics and Heat Transfer. 3 Hours.
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. LEC.

ME 836. Hybrid and Electric Vehicles. 3 Hours.
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. LEC.

ME 840. Continuum Mechanics I. 3 Hours.
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. LEC.

ME 841. Continuum Mechanics II. 3 Hours.
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. LEC.

ME 854. Continuum Mechanics for Soft Tissues. 3 Hours.
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. LEC.

ME 860. Advanced Mechanical Engineering Problems. 1-3 Hours.
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 departmental chairperson. Prerequisite: Approval of instructor. RSH.

ME 861. Theory of the Finite Element Method. 3 Hours.
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. LEC.

ME 862. Finite Element Method for Transient Analysis. 3 Hours.
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. LEC.

ME 864. Mesh Generation and Adaptivity for Finite Element Simulations in Engineering. 3 Hours.
The generation of Finite Element meshes in the analysis and simulation of engineering systems. Important topics are treated such as initial mesh generation and refinements (i.e. geometric modeling and mesh adaptivity or grading), choice of type of element, and assessment of solution accuracy (i.e. error estimation). Assignments include solving problems using FE software. Prerequisite: ME 661, ME 861, or equivalent. LEC.

ME 882. Advanced Control Systems. 3 Hours.
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. LEC.

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

ME 899. Independent Investigation. 1-6 Hours.
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.) THE.

ME 961. Finite Element Method for Nonlinear Problems in Solid Mechanics. 3 Hours.
Advanced treatment of finite element techniques for structural analysis including material and geometric non-linearity as well as large strain deformation. Prerequisite: ME 861 or equivalent. LEC.

ME 962. p-Approximation, Error Estimation, and Other Advanced Topics in the Finite Element Method. 3 Hours.
Advanced treatment of p-Approximation, error estimation, and other advanced topics in the finite element method. Prerequisite: ME 861 or equivalent. LEC.

ME 965. Mathematical Modeling and Computational Method in Multi-Scale Processes. 3 Hours.
An overview of classical averaging and homogenization methods, as well as current multi-scale modeling techniques for the analysis of the micro- and nano-mechanics of materials. Models and numerical techniques are introduced based on continuum as well as particle descriptions. Assignments include the simulation of micro- and nano-mechanics problems by using existing finite element software and molecular dynamics packages. Prerequisite: ME 861 and ME 840. LEC.

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

ME 999. Independent Investigation. 1-16 Hours.
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. THE.