Mechanical and Aerospace Engineering (MAE)

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The Department of Mechanical and Aerospace Engineering is a re-organization of the former Applied Mechanics and Engineering Sciences (AMES) Department. The MAE Department administers the interdepartmental Chemical Engineering Program (CENG). The Structural Engineering Department (SE) is a separate department. The aerospace program is shared between MAE and SE depending upon the student's major emphasis. Former AMES course numbers have been changed to an MAE, SE, or CENG prefix (i.e., MAE 5, SE 120, CENG 100). While most of the course content/number remain the same, some changes do exist (i.e., MAE 9 is the same as AMES 9 but MAE 107 is the same as AMES 154). Please refer to the course description section for further explanation.

Entering MAE freshmen will follow the new set of course work guidelines detailed in this section. Continuing students and transfer students will continue with their current set of course work guidelines outlined in previous general catalogs. The Student Affairs Office can provide the proper curriculum tables.

All MAE, CENG and AMES students are encouraged to visit the Student Affairs Office in EBU II for any clarification. SE students will refer to the SE section of the general catalog and should visit the Student Affairs Office located on the third floor of the Science and Engineering Research Facility (SERF).

Department Focus

The instructional and research programs are grouped into two major areas: mechanical engineering and aerospace engineering. Both the undergraduate and graduate programs are characterized by strong interdisciplinary relationships with the Departments of Physics, Mathematics, Bioengineering, Chemistry, Electrical and Computer Engineering, Computer Science and Engineering, Structural Engineering, the Materials Science Program, and associated campus institutes such as the UCSD Center for Energy Research, the Institute for Nonlinear Science, Institute of Geophysics and Planetary Physics, Institute for Pure and Applied Physical Sciences, Institute for Biomedical Engineering, Center for Magnetic Recording Research, Center of Excellence for Advanced Materials, California Space Institute, and Scripps Institution of Oceanography.

The educational mission of the department is to provide an excellent education to the next generation of mechanical and aerospace engineers as one of the nation's leading and most innovative mechanical and aerospace engineering departments.

This broad mission is supported by the following specific educational goals:

- To provide our students with a strong technical education that will enable them to have successful careers as professional mechanical aerospace and chemical engineers, as educators in academia, and as members of other professions.
- To prepare our students for rapid technological change with the core knowledge central to assuring that they are able to continuously improve their skills across a range of disciplines throughout their professional careers.
- To prepare our students to communicate effectively and to deal knowledgeably and ethically with the impact of technology in our society and on global issues.

The Undergraduate Program

Degree and Program Options

The Department of Mechanical and Aerospace Engineering (MAE) offers traditional ABET accredited engineering programs leading to the B.S. degree in mechanical engineering and chemical engineering. MAE also offers traditional nonaccredited engineering programs leading to the B.S. degree in aerospace engineering, engineering science, and environmental engineering. The EAC ABET (Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology) accreditation is currently being sought for the aerospace engineering program. The B.S. programs require a minimum of 196 units. The Chemical Engineering Program (CENG) is an interdepartmental program and is described more completely under the Chemical Engineering Program section in this catalog.

All MAE programs of study have strong components in laboratory experimentation, numerical computation, and engineering design. Design is emphasized throughout the curricula by open-ended homework problems, by laboratory and computer courses which include student-initiated projects, and finally by senior design project courses which often involve teams of students working to solve engineering design problems brought in from industry. The MAE programs are designed to prepare students receiving bachelor's degrees for professional careers or for graduate education in their area of specialization. In addition, the programs can also be taken by students who intend to use their undergraduate engineering education as preparation for postgraduate professional training in nontechnical fields such as business administration, law, or medicine.

Mechanical engineering is a traditional four-year curriculum in mechanics, vibrations, thermodynamics, fluid flow, heat transfer, materials, control theory, and mechanical design. Graduates find employment in the mechanical and aerospace industries as well as electro-mechanical or biomedical industries. Mechanical engineers are involved in material processing, manufacturing, assembling, and maintenance of life-line facilities such as power plants.

Mechanical design includes conceptual design, drafting with 3D CAD programs, stress, dynamics, heat transfer or fluid dynamics analyses, and the optimization of the total system for superior performance and customer satisfaction. In manufacturing, the objective is to enhance efficiency and economy by utilizing numerical control (NC) of machine tools, mechatronics, micro-machining, and rapid prototyping. Currently, engineers have available computers, process models, and sensors to improve the quality and productivity of the manufacturing lines. In preparation for this modern era, the mechanical engineering curriculum emphasizes CAD courses, computer courses, laboratory courses, and design courses in addition to providing a strong background in basic science.

The following educational objectives have been established for the mechanical engineering program:

1. To provide a sound introduction to the basic sciences that underlie the disciplines of mechanical and aerospace engineering
2. To provide a thorough training in methods of analysis, including problem formulation and the mathematical and computational skills required by mechanical engineers
3. To teach students the experimental and data analysis techniques required for engineering applications
4. To teach the fundamentals of the design process, including project management, the synthesis of information from different disciplinary areas, and innovation and creative problem solving in an engineering setting
5. To prepare students in the skills required for successful participation on teams and in leadership positions, including effective written and oral communication
6. To instill in our students an understanding of their professional and ethical responsibilities
7. To provide students with the opportunity to gain a range of experiences through classroom and extramural activities on campus and through partnerships and internships with industry, with primary and secondary schools, and with other organizations

Aerospace engineering is a four-year curriculum that prepares students for a career in the aeronautical and astronautical industries, related technology industries, or for graduate school. The degree is administered by the Aerospace Engineering Committee under the auspices of the Department of Mechanical and Aerospace Engineering (MAE) and the Department of Structural Engineering (SE). Students select either the MAE or the SE departments as their home department based upon their area of interest. Students interested in fluids, propulsion, controls, system design, or metallic materials typically select MAE, while students interested in structures, composite materials, or vehicle design select SE. Since the programs are identical in each department, students are allowed to change departments at any time. The EAC ABET (Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology) accreditation is currently being sought for this program.

The mission of the aerospace engineering program is to prepare students to be outstanding scientists and engineering leaders by emphasizing engineering fundamentals, principles of professional practices, and their integration into the design/development of advanced aeronautical and astronautical systems. The primary goals are:

- to provide our students with a strong technical education that will enable them to have successful careers as professional aerospace engineers, as educators in academia, and as members of other professions

- to prepare our students for rapid technological change with the core knowledge central to assuring that they are able to continuously improve their skills across a range of disciplines throughout their professional careers
- to prepare our students to communicate effectively and to deal knowledgeably and ethically with the impact of technology in our society and on global issues

The curriculum was developed to emphasize engineering fundamentals, aerospace topics, and the integration of these fundamentals and topics into the design of an aerospace system. Courses in engineering fundamentals include materials, solid and fluid mechanics, thermodynamics, computer modeling, computer-aided-design, numerical analysis, and controls. Courses covering the aerospace engineering topics include aerodynamics, aerospace structures, flight mechanics, dynamics and control of aerospace vehicles, and propulsion. Students complete the program by taking a two-quarter capstone design course that integrates all of their aerospace education into the design, development, and testing of an aeronautical or astronautical vehicle or component. Throughout the program, students take laboratory courses that expose them to modern testing techniques and enhance their understanding of complex engineering topics. The program's main objectives are:

1. to provide students with a strong foundation in engineering fundamentals; in-depth knowledge of key topics in aerospace engineering including aerodynamics, propulsion, flight mechanics, orbital mechanics, aerospace structures and materials, and design and control of aerospace systems; and an awareness of the value of life-long learning
2. to provide thorough training in methods of analysis and problem-solving including mathematical and computational skills and use of contemporary software and information technology tools
3. to teach students the experimental and data analysis techniques required for aerospace engineering applications
4. to teach the fundamentals of the open-ended design process, including project management, synthesis and integration of information from fundamental and interdisciplinary areas, manufacturing and incorporation of non-technical issues, and innovation and creative problem solving in an engineering environment
5. to prepare students with the skills required for successful participation on teams and for leadership positions, including effective written and oral communication skills and professionalism
6. to instill in our students an understanding of the role and importance of professional responsibility and engineering ethics
7. to provide students with the opportunity to gain a range of experiences through classroom and extramural activities on campus and through participation and internships with industry and other organizations

Further discussion of the degree requirements and policies are provided in the Aerospace Engineering Undergraduate Student Handbook.

The **engineering science** program resembles the Mechanical Engineering Program, except the amount of mechanical design is reduced and control theory is not required. In addition to core courses in dynamics, vibrations, structures, fluid mechanics, thermodynamics, heat transfer, and laboratory experimentation, a large number of technical electives are scheduled. This aspect of the curriculum allows flexibility by permitting specialization and in-depth study in one area of the engineering sciences or through a sequence of courses on various emerging technologies. Students must consult their advisers to develop a sound course of study to fulfill the technical elective of this program. Although a sequence in non-sciences may be permitted, the faculty advisers may insist on a substantial number of MAE or other science courses as technical electives.

Environmental engineering is a four-year curriculum that resembles the chemical engineering curriculum in its first two years, with fundamental engineering courses in mechanics, thermodynamics, physics, chemistry, and mathematics. In the third and fourth year, the programs diverge: an environmental engineering sequence is offered, as well as further specialization in fluid mechanics, and a wide choice of technical electives, both from within MAE and other departments. The environmental engineering major focuses on conveying an understanding and awareness of the fundamental processes associated with human industrial activity that have environmental implications, and on equipping the next generation of engineers with the tools to develop technologies that enable sustainable economic growth.

The following educational objectives have been established for the environmental engineering program:

1. to provide a sound introduction to the basic sciences that underlie the disciplines of environmental engineering
2. to provide a thorough training in methods of analysis, including problem formulation and the mathematical and computational skills required by environmental engineers
3. to teach students the experimental and data analysis techniques required for engineering applications
4. to teach the fundamentals of the design process, including project management, the synthesis of information from different disciplinary areas, and innovation and creative problem solving in an engineering setting
5. to prepare students in the skills required for successful participation on teams and in leadership positions, including effective written and oral communication
6. to instill in our students an understanding of their professional and ethical responsibilities
7. to provide students with the opportunity to gain a range of experiences through classroom and extramural activities on campus and through partnerships and internships with industry, with primary and secondary schools, and with other organizations

Other Undergraduate Programs of Study in MAE

The **engineering mechanics minor** involves successful completion of seven MAE courses, including at least five upper-division courses open to students who meet the course prerequisites: one must be MAE 130A (AMES 121A); one must be 101A (or 103A) or 131A (AMES 130A) (or both may be taken); and the balance must be selected from MAE 3 (AMES 15), 9 or 10, 20 (AMES 11), 107 (AMES 154), 110A, CENG 102, 130B (AMES 121B) and 160 (AMES 102). This set of courses provides a good introduction to engineering analysis and would be useful to nonengineering majors desiring a background that could be used in professional communication with engineers.

Other minor options are restricted. Students wishing to arrange a sequence of MAE courses to satisfy minor requirements, or to meet particular academic interests, must consult the MAE Student Affairs Office for referral to the appropriate MAE faculty member.

Program Accreditation

The B.S. programs in mechanical engineering are accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (ABET/EAC).

Major Requirements

Specific course requirements for each major program are outlined in tables in this section of the catalog. In addition to the required technical courses specifically indicated, a suggested scheduling of humanities and social science courses (HSS) are distributed in the curricula for students to use to meet college general-education requirements. To graduate, students must maintain an overall GPA of at least 2.0, and the department requires at least a C– grade in each course required for the major.

Deviations from these programs of study must be approved by the Undergraduate Affairs Committee prior to taking alternative courses. In addition, area of specialization (AS) course selections must have departmental approval *prior* to taking the courses. In the accredited programs, AS courses are restricted to meet ABET standards. Courses such as MAE 195, 197, and 198 are not allowed as an area of specialization in meeting the upper-division major requirements. MAE 199 can be used as an area of specialization only under restrictive conditions. Policy regarding these conditions may be obtained from the department's Student Affairs Office.

Students with different academic preparation may vary the scheduling of lower-division courses such as math, physics and chemistry, but should consult the department. Deviations in scheduling MAE upper-division courses is discouraged and requires prior approval. Most lower-division courses are offered more than once each year to permit students some flexibility in their program scheduling. However, most MAE upper-division courses are taught only once per year, and courses are scheduled to be consistent with the curricula as shown in the tables. When possible, MAE does offer large enrollment courses more than once each year. A tentative schedule of course offerings is available from the department each spring for the following academic year.

General-Education/ College Requirements

For graduation each student must satisfy general-education course requirements determined by the student's college as well as the major requirements determined by the department. The five colleges at UCSD require widely different general-education courses, and the number of such courses differs from one college to another. Each student should choose his or her college carefully, considering the special nature of the college and the breadth of general education.

Each MAE program allows for humanities and social science (HSS) courses so that students can fulfill their college requirements. In the ABET accredited programs, students must develop a program that includes a total of at least twenty-four units in the arts, humanities, and social sciences, not including subjects such as accounting, industrial management, finance, or personnel administration. It should be noted, however, that some colleges require more than the nine or ten HSS courses indicated in the curriculum tables. Accordingly, students in these colleges could take longer to graduate than the indicated four-year schedule. Students must consult with their college to determine which HSS courses to take.

Professional Licensing

After graduation, all students are encouraged to take the Fundamentals of Engineering (FE) examination as the first step in becoming licensed as a professional engineer (PE). Students graduating from an accredited program can take the PE examination after FE certification and two years of work experience; students graduating from a nonaccredited program can take the PE examination after FE certification and four years of work experience.

For further information please contact your local Board of Registration for Professional Engineers and Land Surveyors.

Four-Year Programs in Engineering

Two computer languages, C/C++ (MAE 9) and FORTRAN (MAE 10) are offered to MAE students but only one course is required. FORTRAN (MAE 10) is recommended for students interested in software development of large-scale computer codes for calculation of the response of structures and machines, and for the simulation of new products and manufacturing processes. C/C++ (MAE 9) is recommended for students who plan to be involved in data acquisition, parallel processing over the network, and use of CAD software for design and graphics.

Mechanical Engineering

The Mechanical Engineering Program has a traditional ABET accredited four-year curriculum involving mechanics, vibrations, thermodynamics, fluid flow, heat transfer, materials, control theory, and mechanical design. Graduates of this program are expected to have the following skills, knowledge, and abilities:

1. An ability to apply knowledge of mathematics, science, and engineering to mechanical engineering problems
2. An ability to design and conduct experiments, as well as to analyze and interpret data
3. An ability to design mechanical and thermal systems, components, or processes to meet desired needs
4. An ability to function on multi-disciplinary teams
5. An ability to identify, formulate, and solve engineering problems
6. An understanding of professional and ethical responsibility
7. An ability to communicate effectively with written, oral, and visual means
8. The broad education necessary to understand the impact of engineering solutions in a global and societal context
9. A recognition of the need for, and an ability to engage in life-long learning
10. A knowledge of contemporary issues
11. An ability to use modern engineering techniques, skills, and computing tools necessary for engineering practice.
12. A familiarity with chemistry, calculus-based physics, and advanced mathematics
13. Familiarity with probability theory, statistics, and linear algebra

Recommended Course Sequence—Mechanical Engineering for Students entering fall 1999 and later*

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 21C
MAE 1 (AMES 1)	Phys. 2A	Phys. 2B/2BL
Chem. 6A	Chem. 6B	MAE 3
HSS	HSS	(AMES 15)
		HSS
SOPHOMORE YEAR		
Math. 21D	Math. 20F	Math. 20E
Phys. 2C/2CL	MAE 9 or 10	MAE 130B
MAE 20 (AMES 11)	(AMES 9 or 10)	(AMES 121B)
HSS	MAE 130A	or SE 101B
	(AMES 121A)	MAE 131A
	or SE 101A	(AMES 130A)
	HSS	HSS
JUNIOR YEAR		
MAE 110A	MAE 101A	MAE 101B
(AMES 110)	(AMES 101A)	(AMES 101B)
MAE 105	ECE 101 or	MAE 143B
(AMES 105)	MAE 143A	MAE 170
MAE 140	MAE 130C	(AMES 170)
(AMES 163)	(AMES 121C)	HSS
MAE 107	MAE 160	
	(AMES 102)	
SENIOR YEAR		
MAE 101C	MAE 171A	MAE 171B
(AMES 101C)	(AMES 171A)	(AMES 171B)
MAE 156A	MAE 156B	TE
(AMES 156A)	(AMES 156B)	HSS
MAE 150	TE	HSS
(AMES 158)	HSS	
TE		

* Students entering the mechanical engineering major prior to fall 1999 should see the MAE Student Affairs Office for the recommended course sequence.

- Chem. 6AH-6BH sequence may be taken in place of Chem. 6A-B.
- In fulfilling the humanities and social science requirements (HSS), students must take a total of at least twenty-four units in the arts, humanities, and social sciences, not including subjects such as accounting, industrial management, finance, or personnel administration. Ten HSS courses are listed here; individual college requirements may be higher.
- Technical electives (TE) must be an upper-division or graduate course in the engineering sciences, natural sciences or mathematics.
- MAE 141A has been re-numbered to MAE 143B.
- Students entering fall 2001 and later are required to take MAE 143A and should not take ECE 101.

See the MAE Student Affairs Office for a complete list of Technical Electives.

Engineering Science

The engineering science program resembles the mechanical engineering program, except that the course load of mechanical design is reduced, and control theory is not required. In addition to core courses in dynamics, vibrations structures, fluid mechanics, thermodynamics, heat transfer, and laboratory experimentation, a large number of technical electives are scheduled. This aspect of the curriculum allows flexibility, permitting specialization and in-depth study in one area of the engineering sciences or development of a sequence of courses emerging from the current research interests of the faculty of MAE and/or other departments, e.g., sequences in the earth sciences, transportation, or energy-related studies. Students intending to pursue postgraduate professional careers in non-technical fields such as business administration, law, or medicine may develop an appropriate sequence of courses. Although a sequence in the non-sciences may be permitted, the faculty adviser may insist on a substantial number of MAE or other science courses as technical electives. Students must consult their advisers to develop a balanced course of study to fulfill the technical elective requirements of this program. This curriculum also allows the highest number of humanities and social science courses (HSS) to meet college general-education requirements.

Recommended Course Sequence—Engineering Science for Students entering fall 1999 and later*

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 21C
MAE 1 (AMES 1)	Phys. 2A	Phys. 2B/2BL
Chem. 6A	Chem. 6B	MAE 3
HSS	HSS	HSS
SOPHOMORE YEAR		
Math. 21D	Math. 20F	Math. 20E
Phys. 2C/2CL	MAE 9 or 10	MAE 130B
MAE 20	(AMES 9 or 10)	(AMES 121B)
(AMES 11)	MAE 130A	or SE 101B
HSS	(AMES 121A)	MAE 131A
	or SE 101A	(AMES 130A)
	HSS	HSS
JUNIOR YEAR		
MAE 110A	MAE 101A	MAE 101B
(AMES 110)	(AMES 101A)	(AMES 101B)
MAE 105	MAE 160	MAE 170
(AMES 105)	(AMES 102)	(AMES 170)
MAE 140	MAE 130C	TE
(AMES 163)	(AMES 121C)	HSS
HSS	HSS	
SENIOR YEAR		
MAE 150	MAE 171A	MAE 171B
(AMES 158)	(AMES 171A)	(AMES 171B)
MAE 101C	TE	TE
(AMES 101C)	TE	HSS
TE	HSS	HSS
HSS		

* Students entering the engineering science major prior to fall 1999 should see the MAE Student Affairs Office for the recommended course sequence.

- Chem. 6AH-6BH sequence may be taken in place of Chem. 6A-B.
- Humanities and social science (HSS) courses should be selected to meet general-education requirements of the colleges. Individual college requirements may be higher or lower than what is listed here.
- Five technical elective (TE) courses must be upper-division or graduate courses in the engineering sciences, natural sciences or mathematics selected with prior approval of the department. A sequence of non-science courses may also be selected with prior approval (see program description).

See the Student Affairs Office for a complete list of Technical Electives.

Aerospace Engineering

Aerospace engineering is a four-year curriculum that begins with fundamental engineering courses in mechanics, thermodynamics, materials, solid mechanics, fluid mechanics, and heat transfer. Additional courses are required in aerospace structures, aerodynamics, flight mechanics, propulsion, controls, and aerospace design. Graduates of this program enter graduate school or enter the aerospace industry to develop aircraft and spacecraft, but also they find employment in other areas that use similar technologies, such as mechanical and energy-related fields. Examples include automobile, naval, and sporting equipment manufacturing.

Graduates of this program are expected to have the following skills, knowledge, and abilities:

1. an ability to apply knowledge of mathematics, science, and engineering to aerospace engineering problems
2. an ability to design and conduct experiments, as well as to analyze and interpret data
3. an ability to design a system, component, or process to meet desired needs
4. an ability to function on multi-disciplinary teams
5. an ability to identify, formulate, and solve engineering problems
6. an understanding of professional and ethical responsibility.
7. an ability to communicate effectively with written, oral, and visual means
8. the broad education necessary to understand the impact of engineering solutions in a global and societal context
9. a recognition of the need for, and an ability to engage in life-long learning

10. a knowledge of contemporary issues
11. an ability to use modern engineering techniques, skills, and computing tools necessary for engineering practice
12. knowledge of key topics in aeronautical engineering including aerodynamics, aerospace materials, structures, propsion, flight mechanics, and stability and control
13. knowledge of topics in astronautical engineering including attitude determination and control, space structures, orbital mechanics, and rocket propulsion
14. an ability to integrate knowledge of the fundamental topics in the design of an aerospace system

Recommended Course Sequence—Aerospace Engineering for Students entering fall 1999 and later*

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 21C
MAE 1	Phys. 2A	Phys. 2B/2BL
Chem. 6A	Chem. 6B	MAE 3
HSS	HSS	HSS
SOPHOMORE YEAR		
Math. 21D	Math. 20F	Math. 20E
Phys. 2C/2CL	MAE 9 or 10	MAE 130B or SE 101B
HSS	MAE 130A or SE 101A	MAE 131A
HSS	HSS	SE 2
JUNIOR YEAR		
MAE 105	MAE 101A	MAE 101B
MAE 110A	MAE 130C	MAE 143B
MAE 140	ECE 101	MAE 170
HSS	HSS	SE 160A
SENIOR YEAR		
MAE 101C	MAE 142	MAE 113
MAE 104	MAE 155A	MAE 155B
MAE 150	MAE 175A	TE
SE 160B	HSS	HSS

* Students entering the aerospace major prior to fall 1999 should see the MAE or SE Student Affairs Office for the recommended course sequence.

- Chem. 6AH-6BH sequence may be taken in place of Chem. 6A-B.
- In fulfilling the humanities and social science (HSS) requirements, students must take a total of at least twenty-four units in the arts, humanities, and social sciences, not including subjects such as accounting, industrial management, finance, or personnel administration. Ten HSS courses are listed here; individual college requirements may be higher.
- Technical elective (TE) courses must be upper-division or graduate courses in the engineering sciences, natural sciences or mathematics selected with prior approval of the department. See Student Affairs in MAE or SE for a current list of approved TE's.

Environmental Engineering

The **environmental engineering** program resembles the chemical engineering program for the first two years. In the third and fourth year, the programs diverge: an environmental engineering sequence is offered, as well as further specialization in fluid mechanics, and a wide choice of technical elective (TE) courses, both from within MAE and in other departments.

FALL	WINTER	SPRING
FRESHMAN YEAR		
Math. 20A	Math. 20B	Math. 21C
MAE 9 or 10	Phys. 2A	Phys. 2B/2BL
Chem. 6A	Chem. 6B/BL	Chem. 6C
HSS	HSS	HSS
SOPHOMORE YEAR		
Math. 21D	Math. 20F	Math. 20E
Phys. 2C/2CL	CENG 100	CENG 102
Chem. 126 or 131	Chem. 127 or 132	Chem. 140A or 141A
HSS	HSS	HSS
JUNIOR YEAR		
MAE 105	MAE 101A	MAE 101B
CENG 120	MAE 107	MAE 170
TE	TE	MAE 124
HSS	HSS	HSS
SENIOR YEAR		
MAE 101C	MAE 126A	MAE 126B
MAE 125A	MAE 125B	TE
TE	TE	TE
HSS	HSS	HSS

- Humanities and social science (HSS) courses should be selected to meet general-education requirements of the colleges. Individual college requirements may be higher or lower than what is listed here.
- Technical electives (6): at least 2 must be from MAE and 2 must be upper-division courses.
- See MAE Student Affairs Office for a complete list of TE's.

Policies and Procedures for MAE Undergraduate Students

Application for Admission to the Major

Admission to the department as an MAE major or minor, or to fulfill a major in another department which requires MAE courses, is in accordance with the general requirements established by the Jacobs School of Engineering. The admission requirements and procedures are described in detail in the section on "Admission to the Jacobs School of Engineering" in this catalog. Applicants who have demonstrated excellent academic performance prior to being admitted to UCSD will be admitted directly to the engineering major of their choice. These directly admitted students and all students are expected to complete lower- and upper-division courses, as suggested in the curriculum tables, in a timely fashion in the sequences outlined.

Transfer Students

Requirements for admission as an MAE major or minor, or into MAE courses, are the same for transfer students as they are for continuing students (see section on "Admission to the Jacobs School of Engineering" in this catalog). Accordingly, when planning their program, transfer students should be mindful of lower-division prerequisite course requirements, as well as for meeting collegiate requirements.

Students who have taken equivalent courses elsewhere may request to have transfer credit apply toward the department's major requirements. To receive transfer credit, complete a MAE Student Petition form and submit it to MAE Student Affairs. For mathematics, chemistry and physics, transfer equivalencies are *determined by the respective departments*. An Undergraduate Student Petition must be submitted to each department from which you are requesting tranfer credit.

Academic Advising

Upon admission to the major, students should consult the catalog or MAE Web site (http://maeweb.ucsd.edu) for their program of study or their undergraduate adviser if they have questions. The program plan may be revised in subsequent years, but revisions involving curricular requirements require approval by the undergraduate adviser or the Undergraduate Affairs Committee. Because some course and/or curricular changes may be made every year, it is imperative that students consult with the department's undergraduate adviser on an annual basis.

Many MAE courses are offered only once a year and therefore should be taken in the recommended sequence. If courses are taken out of sequence, it may not always be possible to enroll in courses as desired or needed. If this occurs, students should seek immediate departmental advice. When a student deviates from the sequence of courses specified for each curriculum in this catalog, it may be impossible to complete an MAE major within the normal four-year period.

In addition to the advising available through the Student Affairs Office, programmatic or technical advice may be obtained from MAE faculty members. A specific MAE faculty mentor is assigned to each MAE student. All MAE students are required to meet with their faculty mentor at least once a quarter.

Program Alterations/ Exceptions to Requirements

Variations from or exceptions to any program or course requirements are possible only if a petition is approved by the MAE Undergraduate Affairs Committee before the courses in question are taken. Petition forms may be obtained from the MAE Student Affairs Office and must be processed through this office.

Independent Study

MAE students may take MAE 199, Independent Study for Undergraduates, under the guidance of an MAE faculty member. This course is taken as an elective on a P/NP basis. Under very restrictive conditions, however, it may be used to satisfy upper-division technical elective course requirements for the major. Students interested in this alternative must identify a faculty member with whom they wish to work and propose a two-quarter research or study topic. After obtaining the faculty member's concurrence on the topic and scope of the study, the student must submit a Special Studies Course form (each quarter) and an MAE 199 as Technical Elective Contract form to the Undergraduate Affairs Committee. These forms must be completed, approved, and processed prior to the add/drop deadline. Detailed policy in this regard and the requisite forms may be obtained from the Student Affairs Office.

Teaching

Students interested in participating in the instructional activities of the department may take MAE 195, Undergraduate Teaching. Normally, this course is taken as an elective on a P/NP basis. Under very restrictive conditions, it may be used to satisfy upper-division technical elective course requirements for the major. Policy in this regard and the appropriate forms may be obtained from the Student Affairs Office.

Integrated Bachelor's/Master's Degree Program

An integrated program leading to a bachelor of science and a master of science degree in engineering is offered to undergraduate students who are enrolled in any of the major programs offered by the Department of MAE. Contact the MAE Graduate Student Affairs Office for details.

The program is open only to UCSD undergraduates. The Department of MAE does not have financial assistance available for students enrolled in this program.

The Graduate Program

The Department of Mechanical and Aerospace Engineering offers graduate instruction leading to the **M.S. and Ph.D. degrees in engineering sciences** with a designated specialization in each of the following areas: aerospace engineering, applied mechanics, applied ocean sciences, chemical engineering, engineering physics, and mechanical engineering.

Admission is in accordance with the general requirements of the graduate division, which requires a B.S. and/or M.S. degree in some branch of engineering, the physical sciences, or mathematics; an overall GPA of 3.0; and three letters of recommendation from individuals who can attest to the academic or professional competence and to the depth of their interest in pursuing graduate study. In addition, all applicants are required to submit GRE General Test scores. A minimum score of 550 on the Test of English as a Foreign Language (TOEFL) is required of all international applicants whose native language is not English and whose undergraduate education was conducted in a language other than English. Students who score below 600 on the TOEFL examination are strongly encouraged to enroll in an English as a second language program before beginning graduate work. (UCSD Extension offers an excellent English language program during the summer as well as the academic year.) Applicants are judged competitively. Based on the candidate's background, qualifications, and goals, admission to the program is in one of three categories: M.S. *only*, M.S., or Ph.D. Admission to the M.S. *only* category is reserved for students for whom the MS degree is likely to be the terminal graduate degree. The M.S. designation is reserved for students currently interested in obtaining an M.S. degree but who at a later time may wish to continue in the doctoral degree program. Admission to the Ph.D. program is reserved for qualified students whose final aim is a doctoral degree. Policies for possible changes in status are given under the "Master's Degree Program" below.

Non-matriculated students are welcome to seek enrollment in MAE courses via UC Extension's concurrent registration program, but an extension student's enrollment in an MAE graduate course must be approved by the instructor.

Master's Degree Program

The M.S. program is intended to extend and broaden an undergraduate background and/or equip practicing engineers with fundamental knowledge in their particular fields. The degree may be terminal, or obtained on the way to the Ph.D. The degree is offered under both the Thesis Plan I and the Comprehensive Examination Plan II (see "Graduate Studies: Master's Degree"). A strong effort is made to schedule M.S.-level course offerings so that students may obtain their M.S. degree in one year of full-time study or two years of part-time study.

M.S. Time Limit Policy: Full-time M.S. students are permitted seven quarters in which to complete all requirements. While there are no written time limits for part-time students, the department has the right to intervene and set individual deadlines if it becomes necessary.

Course requirements are flexible in the applied mechanics, chemical engineering, and engineering physics programs. Specific departmental requirements for the M.S. degree are as follows:

Thesis Plan I: This plan of study involves both course work and research, culminating in the preparation of a thesis. A total of forty-eight units of credit is required: thirty-six units (nine courses) must be in course work, and twelve units must be in research. The student's program is arranged, with prior approval of the faculty adviser, according to the following policies:

1. Course work must include sixteen units (four courses) of MAE 200-level courses.
2. Units obtained in MAE 205, 207, 259, or 299 may not be applied toward the course work requirement.
3. No more than a total of eight units of MAE 296 and 298 may be applied toward the course work requirement.
4. No more than twelve units of upper-division 100-level courses may be applied toward the course work requirement.
5. Twelve units of MAE 299 must be taken to fulfill the research requirement.

Students must maintain at least a B average in the courses taken to fulfill the degree requirements. A thesis based on the research is written and subsequently reviewed by the thesis adviser and two other faculty members appointed by the dean of Graduate Studies. The review is normally an oral defense of the thesis.

Comprehensive Examination Plan II: This plan of study involves course work only and culminates in a comprehensive examination. A total of forty-eight units of credit (twelve courses) is required. The student's program is arranged, with prior approval of the faculty adviser, according to the following policies:

1. At least sixteen units (four courses) must be MAE 200-level courses.
2. Units obtained in MAE 205, 207, 259, or 299 may not be applied toward the degree requirements.
3. No more than a total of eight units of MAE 296 and 298 may be applied toward the degree requirements.
4. No more than twelve units of upper-division 100-level courses may be applied toward the degree requirements.

Students must maintain at least a B average in the courses taken to fulfill the degree requirements. The comprehensive examination is conducted by the adviser and at least two other faculty members. The examination committee normally conducts an oral examination in two areas of specialization covered by course work taken by the student. A student working toward the Ph.D. degree who has successfully passed two areas of the department's Ph.D. examination need not take the comprehensive examination for the M.S. degree.

Change of Degree. Upon completion of the requirements for the M.S. degree, students admitted as M.S. *only* or M.S. candidates are not automatically eligible for admission to the Ph.D. program.

M.S. *only* candidates who subsequently wish to pursue a doctorate must submit an application for a change in status to their examining committee. If the recommendation is positive and the request approved, the student must submit a general petition for graduate students to effect the change of status. In addition, the examining committee may recommend that the examination satisfy one of the four topics required in the departmental qualifying examination for the doctorate.

M.S. candidates who subsequently wish to pursue a doctorate must also submit an application for a change in status to their examining committee. In this case, a special examination is not required. The application, however, must be approved and signed by an MAE faculty member who expects to serve as the student's Ph.D. adviser. When the request is approved, the student must submit a general petition for graduate students to effect the change of status. If the student elects the comprehensive examination plan for the M.S. degree, this examination may be used not only to fulfill the requirement for the M.S. degree but also to satisfy one of the four topics required in the departmental qualifying examination for the doctorate. In fact, the M.S. examination may be part of the doctoral examination.

M.S. Program

To complete an M.S. degree with specialization in aerospace engineering, chemical engineering, engineering physics, mechanical engineering, applied mechanics, or applied ocean sciences, students must complete a sequence of courses unique to their area. Students should consult with their faculty adviser, as well as the MAE Graduate Student Affairs Office, when choosing their courses.

Doctoral Degree Program

The MAE Ph.D. program is intended to prepare students for a variety of careers in research and teaching. Therefore, depending on the student's background and ability, research is initiated as soon as possible. In general, there are no formal course requirements for the Ph.D. All students, in consultation with their advisers, develop course programs that will prepare them for the MAE Departmental Qualifying Examination and for their dissertation research. However, these programs of study and research must be planned to meet the time limits established to advance to candidacy and to complete the requirements for the degree. Doctoral students who have passed the Departmental Examination may take any course for an S/U grade with the exception of any course that the student's Departmental or Ph.D. Qualifying Examination Committee stipulates must be taken in order to remove a deficiency. It is strongly recommended that all MAE graduate students take a minimum of two courses (other than research) per academic year after passing the Departmental Qualifying Examination. Specific details in this regard can be obtained from the MAE Student Affairs Office.

Doctoral Examinations: An MAE Ph.D. student is required to pass three examinations. The first is a **Departmental Qualifying Examination (DQE)** which is intended to determine the candidate's ability to successfully pursue a research project level appropriate for the doctorate. This first exam must be taken within the first six quarters of registration as a graduate student. The DQE is an oral examination by a committee of four persons (two of which must be in the MAE department) and is based on material taught over 36 units in three areas of study: a major area (four courses), a minor area (two introductory courses), and a study in mathematics or basic science (three courses). Students must submit a plan of study, approved by their adviser, to the Graduate Affairs Committee for final approval by the end of their second quarter of graduate study.

The Teaching Experience is required of all MAE Ph.D. students prior to taking the Ph.D. Qualifying Exam. The teaching experience is defined as lecturing one hour per week in either a problem-solving section or regular lecture for one quarter in a course designated by the department. The requirement can be fulfilled by teaching assistant service or taken as a course for academic credit (MAE 501). Students must contact the Student Affairs Office to plan for completion of this requirement.

The **Ph.D. Qualifying Examination** is the second examination required of MAE Ph.D. students. In preparation for the Ph.D. Qualifying Examination, students must have completed the Departmental Qualifying Examination and the Departmental Teaching Experience requirement, obtained a faculty research adviser, and have identified a topic for their dissertation research and have made initial progress. At the time of application for advancement to candidacy, a doctoral committee responsible for the remainder of the student's graduate program is appointed by the Graduate Council. The committee conducts the Ph.D. Qualifying Examination, during which students must demonstrate the ability to engage in dissertation research. This involves the presentation of a plan for the dissertation research project. The committee may ask questions directly or indirectly related to the project and general questions that it determines to be relevant. Upon successful completion of this examination, students are advanced to candidacy and are awarded the Candidate in Philosophy degree (see "Graduate Studies" section in this catalog).

The **Dissertation Defense** is the final Ph.D. examination. Upon completion of the dissertation research project, the student writes a dissertation that must be successfully defended in an oral examination and public presentation conducted by the doctoral committee. A complete copy of the student's dissertation must be submitted to each member of the doctoral committee approximately four weeks before the defense. It is understood that this copy of the dissertation given to committee members will not be the final copy, and that the committee members may suggest changes in the text at the time of the defense. This examination may not be conducted earlier than three quarters after the date of advancement to doctoral candidacy. Acceptance of the dissertation by the Office of Graduate Studies and Research and the university librarian represents the final step in completion of all requirements for the Ph.D.

There is no formal foreign language requirement for doctoral candidates. Students are expected to master whatever language is needed for the pursuit of their own research.

Ph.D. Time Limit Policy. Pre-candidacy status is limited to four years. Doctoral students are eligible for university support for six years (engineering physics, seven years). The defense and submission of the doctoral dissertation must be within seven years (engineering physics, eight years).

Evaluations. In the spring of each year, the faculty evaluate each doctoral student's overall performance in course work, research, and prospects for financial support for future years. A written assessment is given to the student after the evaluation. If a student's work is found to be inadequate, the faculty may determine that the student cannot continue in the graduate program.

Joint Doctoral Program with San Diego State University

The Department of Mechanical and Aerospace Engineering at UCSD participates in a joint doctoral program with the Graduate Group in Applied Mechanics at SDSU. The program leads to the degree of doctor of philosophy in engineering sciences (applied mechanics). Participants in the program are required to spend one year enrolled at UCSD; their dissertation research is carried out under the supervision of an SDSU faculty member.

Information regarding admission may be obtained from the departmental Student Affairs Office.

The Graduate Curriculum in Chemical Engineering

The Chemical Engineering (CENG) graduate program is an interdepartmental program and is described more completely under the Chemical Engineering Program in this catalog.

COURSES

All students enrolled in MAE courses or admitted to an MAE program are expected to meet prerequisite and performance standards, i.e., students may not enroll in any MAE courses or courses in another department which are required for the major prior to having satisfied prerequisite courses with a C– or better. (The department does not consider D or F grades as adequate preparation for subsequent material.) Additional details are given under the various program outlines, course descriptions, and admission procedures for the Jacobs School of Engineering in this catalog. Furthermore, the majority of MAE courses have enrollment restrictions which give priority to or are open only to declared pre-engineering students and/or to students who have been admitted to an MAE major. Where these restrictions apply, the registrar will not enroll other students except by department stamp on class enrollment cards. The department expects that students will adhere to these policies of their own volition and enroll in courses accordingly. Students are advised that they may be dropped at any time from course rosters if prerequisites and/or performance standards have not been met.

While most lower-division courses are offered more than once each year, most MAE upper-division courses are taught only once per year, and courses are scheduled to be consistent with the curricula as shown in the tables. When possible, MAE does offer selected large enrollment courses more than once each year.

LOWER-DIVISION

MAE 01. Introduction to Mechanical and Aerospace Engineering (4)
(Formerly AMES 01) A general introduction to the various specialties in mechanical engineering using analysis of a specified system. Performance prediction using engineering analysis. Performance testing and post-test evaluation. A discussion of the role of engineers in research, design and development, testing, management, teaching. Professional ethics. *Prerequisite: MAE premajors and majors only.*

MAE 03. Introduction to Engineering Graphics and Design (4)
(Formerly AMES 15) Introduction to design process through a hands-on design project performed in teams. Topics include problem identification, concept generation, project management, risk reduction. Engineering graphics and communication skills are introduced in the areas of: Computer-Aided Design (CAD), hand sketching, and technical communication. *Prerequisite: grade of C– or better in Physics 2A or 4A (or concurrent enrollment).* Priority enrollment given to engineering majors.

MAE 05. Quantitative Computer Skills (4)
(Formerly AMES 05) Introductory course for non-engineering majors. Use of computers in solving problems; applications from life sciences, physical sciences, and engineering. Students run existing computer programs and complete some programming in BASIC. *Prerequisite: none.*

MAE 09. C/C++ Programming (4)
(Formerly AMES 09) C/C++ computer programming under the UNIX environment with applications to numerical problems fundamental to computational mechanics. Arithmetic operations, branches, arrays, data structures, and use of pointers are introduced. Programming ethics are discussed. Priority enrollment given to engineering majors.

MAE 10. FORTRAN for Engineers (4)
(Formerly AMES 10) FORTRAN 90 computer programming under UNIX environment with applications to numerical problems relevant to engineering applications. Arithmetic operations, control constructs, subprograms, arrays and array processing. Input/Output handling and some advanced features of FORTRAN 90 are introduced. Programming ethics. Priority enrollment given to engineering majors.

MAE 20. Elements of Materials Science (4)
(Formerly AMES 11) The structure of materials: metals, ceramics, glasses, semiconductors, superconductors and polymers. Control of internal structure to produce desired properties. Mechanical, rheological, electrical, optical, superconducting and magnetic properties and classification. *Prerequisites: Phys. 2A or 4A, Chem. 6A, Math. 21C or 20D (or concurrent registration).*

MAE 90. Undergraduate Seminar (1)
(Formerly AMES 90) Selected topics of interest to the faculty will be used to introduce students to engineering science. *Prerequisite: none.* Not open to upper-division students.

UPPER-DIVISION

MAE 101A. Introductory Fluid Mechanics (4)
(Formerly AMES 101A) Fluid statics; fluid kinematics; integral and differential forms of the conservation laws for mass, momentum and energy; Bernoulli equation; potential flows; dimensial analysis and similitude. *Prerequisites: admission to the engineering major and grades of C– or better in Phys. 2A, Math. 21D or 20D, 20E.*

MAE 101B. Advanced Fluid Mechanics (4)
(Formerly AMES 101B) Laminar and turbulent flow. Pipe flow including friction factor. Boundary layers, separation, drag, and lift. Compressible flow including shock waves. Professional ethics will be discussed. *Prerequisite:*

admission to an engineering major and grade of C– or better in MAE 101A and MAE 110A.

MAE 101C. Heat Transfer (4)
(Formerly AMES 101C) Extension of fluid mechanics in MAE 101A-B to viscous, heat-conducting flows. Application of the energy conservation equation to heat transfer in ducts and external boundary layers. Heat conduction and radiation transfer. Heat transfer coefficients in forced and free convection. Design applications. *Prerequisite: admission to an engineering major and grade of C– or better in MAE 101A-B.*

MAE 104. Aerodynamics (4)
(Formerly AMES 104) Basic relations describing flow field around wings and bodies at subsonic and supersonic speed. Thin-wing theory. Slender-body theory. Formulation of theories for evaluating forces and moments on airplane geometries. Application to the design of high-speed airplanes. *Prerequisites: admission to the engineering major and grade of C– or better in MAE 101A-B.*

MAE 105. Introduction to Mathematical Physics (4)
(Formerly AMES 105) Fourier series, Sturm Liouville theory, elementary partial differential equations, integral transforms with applications to problems in vibration, wave motion, and heat conduction. *Prerequisites: admission to engineering major or and grades of C– or better in Phys. 2A-B and Math. 20D or Math. 21D.*

MAE 107. Computational Methods in Engineering (4)
Introduction to scientific computing and algorithms; iterative methods, systems of linear equations with applications; nonlinear algebraic equations; function interpolation and differentiation and optimal procedures; data fitting and least-squares; numerical solution of ordinary differential equations. *Prerequisites: engineering majors only and grades of C– or better in MAE 9 or MAE 10 and Math. 20F.*

MAE. 110A. Thermodynamics (4)
Fundamentals of engineering thermodynamics: energy, work, heat, properties of pure substances, first and second laws for closed systems and control volumes, gas mixtures. Application to engineering systems, power and refrigeration cycles, combustion. *Prerequisites: grades of C- or better in Phys. 2C and Chem 6A.* Enrollment restricted to engineering majors only.

MAE 110B. Thermodynamic Systems (4)
Thermodynamic analysis of power cycles with application to combustion driven engines: internal combustion, diesel, and gas turbines. Thermodynamics of mixtures and chemical and phase equilibrium. Computational methods for calculating chemical equilibrium. *Prerequisite: grade of C– or better in MAE 110A.*

MAE 113. Fundamentals of Propulsion (4)
(Formerly AMES 159—Fundamentals of Gas Turbines) Compressible flow, thermodynamics, and combustion relevant to aircraft propulsion as well as to stationary power plants. Analysis and design of components for gas turbines, including turbines, inlets, combustion chambers and nozzles. *Prerequisites: admission to engineering major and grades of C– or better in MAE 110A or CENG 102 and MAE 101A-B-C or CENG 103A-B-C (formerly CENG 101A-B-C) and MAE 171A.*

MAE 117A. Elementary Plasma Physics (4)
Particle motions, plasmas as fluids, waves, diffusion, equilibrium and stability, nonlinear effects, controlled fusion. Cross-listed with Physics 151. *Prerequisites: MAE 117A. Math. 21D or consent of instructor. Phys. 100B-C or ECE 107 are suggested.*

MAE 117B. Industrial Plasma Applications (4)
Charged particle motion in DC and RF electro-magnetic; atomic processes in plasmas; ionization, excitation, dissociation, rate constants, electron energy balance electric breakdown of the gases; debye length, plasmas quasi-neutrality, sheath; DC, capacitive, inductive, and wave-heated discharges; etching, deposition, and implantation. *Prerequisites: Phys. 100B-C or ECE 107 or consent of instructor; Math. 21D.*

MAE 117L. Elements of Experimental Plasma Physics (4)
Measurements of electron density and temperature with the lengmuire probes, emission spectroscopy measurements of neutrals and ions in plasmas; electric breakdown of the gases; plasmas etching of materials. *Prerequisites: none.*

MAE 118A. Energy: Non-Nuclear Energy Technologies (4)
(Formerly AMES 118A) Oil recovery from tar sands and oil shale. Coal production, gasification, liquefaction. The hydrogen economy. Energy storage systems. Techniques for direct energy conversion. Solar energy utilization. Hydroelectric power generation. Hydrothermal energy. Geothermal energy from hot rocks. Electrical power production, transmission, and distribution. *Prerequisite: consent of instructor.*

MAE 118B. Energy: Nuclear Energy Technologies (4)
(Formerly AMES 118B) A brief survey of energy demands and resources. Available nuclear energy, background in atomic and nuclear physics; fission and fusion processes, physics of fission reactions—engineering aspects—safety and environmental effects, fusion-including laser fusion and magnetic confinement, and nuclear power economics. *Prerequisite: consent of instructor.*

MAE 118C. Introduction to Fusion Science and Technologies (4)
(Formerly AMES 118C) Overview of basic fusion processes, high-temperature plasma characteristics, and fusion power plant features. Reaction rates and energy balance for burning fusion plasmas. Survey of the enabling technologies for practical fusion and related applications outside of fusion, such as plasma-material interactions, plasma heating, high heat flux engineering, superconductivity, advanced materials, and nuclear technology. *Prerequisites: MAE 101A or CENG 103A or CENG 101A and either Physics 100B, 100C, ECE 107, or their equivalent.*

MAE 120. Dynamics of Natural Flows (4)
Description of atmosphere and oceans; hydrological cycle. Dynamics of stratified and rotating flows. Surface and interfacial waves; the solitary wave, hydraulic flows. Flow over topography. Gravity currents. Stratified withdrawal. Applications to river flow, estuaries, atmosphere-ocean system, water treatment, reservoir management. *Prerequisites: MAE (AMES) 101B and MAE 105 with a grade of C– or better.*

MAE 121. Convective Flows in the Environment (4)
Convection and the Rayleigh number. Plumes and thermals relation to atmospheric boundary layer and ocean mixed layer. Effects of rotation. Katabatic flows. Fires and clouds. Double-diffusive convection with oceanographic and industrial applications; solar ponds. *Prerequisites: MAE (AMES) 101B and MAE 105 with a grade of C– or better.*

MAE 122. Air Pollution Modeling (4)
Fickian diffusion; advection-diffusion equation. Turbulent dispersion and eddy diffusivities. Gaussian plume models for passive scalars; entrainment. Concepts of buoyancy and momentum fluxes. Similarity theory of the atmospheric boundary layer. Current practices and regulations. Experience with air dispersion software. *Prerequisites: MAE 101B and MAE 105 with a grade of C– or better.*

MAE 123. Fluid-Solid Interactions in Environmental Engineering (4)
Fundamentals of adsorption and surface reactions, and processes in porous media and packed beds (diffusion/dispersion/flow coupled with adsorption/reaction). Examples include reactions on atmospheric particulates, reactions on ice crystals in the polar atmosphere and effect on ozone, transport of contaminant plumes in groundwater, and remediation processes such as catalytic destruction of air pollutants. *Prerequisite: consent of instructor.*

MAE 124. The Human Earth: An Introduction to Environmental Engineering and Policy (4)
This course explores the impacts of human social, economic, and industrial activity on the environment. It highlights the central roles in ensuring sustainable development played by market forces, technological innovation and governmental regulation on local, national, and global scales. *Prerequisites: grade of C– or better in Math. 20B or Math. 10A-C; Phys. 2B or Phys. 1A-C; and Chem. 6B or by consent of instructor.*

MAE 125A. Flow and Transport in the Environment (4)
Study of river flow and hydraulic control; surface waves; applications to reservoirs and estuaries. Introduction to stratification and buoyancy; applications to atmospheric surface layer and the ocean mixed layer. Ideas behind turbulent dispersion. Turbulent and scaling laws. Gravity currents and katabatic flows. *Prerequisites: engineering majors and students receiving a grade of C– or better in MAE 101A or CENG 103A or CENG 101A.*

MAE 125B. Fluid-Solid Interactions in Environment Engineering (4)
Introduction to groundwater flow. Pollution transport through the water table. Chemical processes in ozone hole. Fundamentals of flow. Darcy flow. Diffusion and dispersion. Gravity currents and plumes in porous media. Mushy layers. Chemistry of fluid-solid interactions. Fundamentals of adsorption and surface reactions. *Prerequisites: engineering majors and students receiving a grade of C– or better in MAE 125A.*

MAE 125C. Case Studies In Environmental Engineering (4)
This course is project-oriented. Students will conduct research in small groups, give oral presentations and write reports. Topics reflect material in MAE 125A and MAE 125B. Possible topics: air pollution modeling, building ventilation, wetland preservation. *Prerequisites: engineering majors and student receiving a grade of C– or better in MAE 125A-B.*

MAE 130A. Mechanics I: Statics (4)
(Formerly AMES 121A) (Cross-listed with SE 101A) Principles of statics using vectors; two and three-d equilibrium of statically determinate structures under discrete and distributed loading including hydrostatics; internal forces and concepts of stress; free body diagrams; moment, product of inertia; analysis of trusses and beams. *Prerequisites: Math. 21C and Phys. 2A with grades of C– or better.* Students cannot also receive credit for SE 101A.

MAE 130B. Mechanics II: Dynamics (4)
(Formerly AMES 121B) (Cross-listed with SE101B) Kinematics and kinetics of particles in 2-D and 3-D motion by using vector representation. Orbital mechanics. Work, energy, and power. Conservative forces, conservation principles. Momentum, impulsive motion and impact. Rigid body kinetics and kinematics; Coriolis acceleration, eulerian angles. Undamped vibrating systems. *Prerequisites: Math. 21D and MAE 130A or SE 101A with grades of C– or better.* Student cannot also receive credit for SE 101B.

MAE 130C. Mechanics III: Vibrations (4)
(Formerly AMES 121C) Free and forced vibrations of damped one-degree of freedom systems. Matrix representation of discrete multiple degree of freedom systems. Use of Matlab for both modal analyses and response analyses of systems subjected to impulse and step loading. Lagrange's equations. Modal superposition for analysis of continuous vibrating systems with applications to structures. *Prerequisites: admission to the engineering major and grades of C– or better in Math. 20F and MAE 130B or SE 101B.* Engineers only. Students cannot also receive credit for SE 101C.

MAE 131A. Fundamentals of Solid Mechanics I (4)
(Formerly AMES 130A) Stress and strain, generalized Hooke's law. Mechanics of deformable bodies under torsional, shearing and bending loads. Deflection of beams. Stability of columns. St. Venant's semi-inverse torsion analysis. Strain energy and energy principles. Design of statically indeterminate rods, shafts, beams and columns. Professional ethics. *Prerequisites: admission to the engineering major and Grades of C– or better in Math. 20D or 21D, 20F; and MAE 130A or SE 101A.*

MAE 131B. Fundamentals of Solid Mechanics II (4)
(Formerly AMES 130B) Continuum mechanics of solids and its application to the mechanical response of machine and structural elements. Stress and strain in indicial notation; field equations and constitutive relations. Linear elastic stress analysis in torsion, plane stress and plane strain; stress concentrations; fracture mechanics. Extremum principles and structural stability. Viscoelasticity, plasticity, and failure criteria. Theorems of plastic limit analysis. *Prerequisites: admission to the engineering major and grades of C– or better in MAE 131A, and MAE 105 (or concurrent enrollment).*

MAE 131C. Solid Mechanics III (4)
(Formerly AMES 130C) Small deflection theory of plates. Solutions for rectangular and circular plates. Buckling of rectangular plates. Large deflections and shear deformations. Energy methods and finite element method of analysis. *Prerequisites: admission to the engineering major and grade of C– or better in MAE 131B.*

MAE 133. Finite Element Methods in Mechanical and Aerospace Engineering (4)
(Formerly AMES 133) Development of stiffness and mass matrices based upon variational principles and application to static, dynamic, and stability design problems in structural and solid mechanics. Architecture of computer codes for linear and nonlinear finite element analysis and basic computer implementation. The use of general purpose finite element structural analysis computer codes. *Prerequisites: admission to the engineering major and grades of C– or better in MAE 131AB and MAE 107.*

MAE 135. Computational Mechanics (4)
Mathematical modeling in terms of systems of algebraic and differential equations. Overview of numerical methods. Problem statement, boundary, and initial conditions. Overview of commerical packages for solving the equations of Mathematical and Engineering Physics. Numerical solutions of selected examples drawn from real-life applications of fluid flow, solid mechanics, and heat transfer with emphasis on design. *Prerequisite: consent of instructor.*

MAE 137. Technical Writing for Engineers (2)
Writing techniques for clear and effective presentation of technical information and ideas. Fundamentals of editing through peer review under instructor guidance. Several short papers on technical topics will be assigned. Students must complete college writing requirement(s) prior to taking this course. *Prerequisites: Completion of College Writing Program with a grade of C– or better (HUM 5 or MCWP 50 or DOC 3 or WARR 10B or MMW 6 or 6H).*

MAE 139. Reliability of Engineering Systems (4)
(Formerly AMES 139) Introduction to probability and basic statistics. Analytical models for random phenomena and associated mathematical properties. Analysis and assessment of reliability. Probability-based design. Structural component and systems reliability. *Prerequisites: admission to the engineering major and grades of C– or better in Math. 21C or Math. 20D; Math. 20E, and SE 130A-B.*

MAE 140. Linear Circuits (4)
(Formerly AMES 163) Steady-state and dynamic behavior of linear, lumped-parameter electrical circuits. Kirchoff's laws. RLC circuits. Node and mesh analysis. Operational amplifiers. Signal acquisition and conditioning. Electric motors. Design applications in engineering. *Prerequisites: admission to the engineering major and grades of C– or better in Math. 21D or Math. 20D, and Phys. 2B.*

MAE 142. Dynamics and Control of Aerospace Vehicles (4)
(Formerly AMES 142—Flight Mechanics) The dynamics of vehicles in space or air are derived for analysis of the stability properties of spacecraft and aircraft. The theory of flight, lift, drag, dutch roll and phugoid modes of aircraft are discussed. Optimal state space control theory for the design of analog and digital controllers (autopilots). *Prerequisites: admission to the engineering major and grades of C– or better in MAE 104 and MAE 141A or MAE 143B or ECE 171A.*

MAE 143A. Signals and Systems (4)
First-order vector ordinary differential equations, concepts of state, input and output. Linearity and linearization concepts introduced with solutions. Laplace and Fourier transforms are defined for signals. Transfer functions and frequency responses for systems. Spectra and filtering for deterministic signals, probability and statistics of random signals and treatment. *Prerequisites: Admission to MAE or bioengineering major and grade of C– or better in Math. 20E, 20F, and 21D.*

MAE 143B. Linear Control (4)
(formerly MAE 141A) Analysis and design of feedback systems in the frequency domain. Transfer functions. Time response specifications. PID controllers and Ziegler-Nichols tuning. Stability via Routh-Hurwitz test. Root locus method. Frequence response: Bode and Nyquist diagrams. Dynamic compensators, phase-lead and phase-lag. Actuator saturation and integrator wind-up. *Prerequisite: grade of C– or better in MAE 143A*

MAE 143C. Digital Control Systems (4)
(formerly MAE 141B) Discrete time systems: sampling. aliasing, stability, Z-transform, discrete time signals, state space models; state equations, canonical forms, observability, controllability. Pole placement design, observer design, output feedback, linear quadratic regulator design. Implementation: digital approximation, computational and numerical issues. *Prerequisite: Grade of C– or better in MAE 143B*

MAE 150. Computer-Aided Design (4)
(Formerly AMES 158—Computer-Aided Analysis and Design) Design methodology, tolerance analysis, Monte Carlo analysis, kinematics and computer-aided design of linkages, numerical calculations of moments of inertia, design of cams and cam dynamics; finite element analysis, design using Pro-E, Mechanica Motion and Mechanica Structures. *Prerequisites: grade of C– or better in MAE 130A or SE 101A; BENG 110, and MAE 107.*

MAE 152. Computer Graphics for Engineers and Scientists (4)
(Formerly AMES 157) Computer graphics algorithms using C programming and Ironcad. Applications in engineering and science. Line-drawing algorithms. Area fill algorithms, color, CAD user interface, spline curves and surfaces, 2-D and 3-D transformations, wireframe and solid models. Hidden-surface elimination. *Prerequisities: grade of C– or better in MAE 3 and MAE 9 or 10.*

MAE 155A. Aerospace Engineering Design I (4)
(Formerly AMES 155A—Fundamental principles of aerospace design) Application of engineering mechanics to the design of aerospace components. Design and analysis of aerospace components and assemblies. *Prerequisite: grade of C– or better in MAE 130C, 150, and 160.*

MAE 155B. Aerospace Engineering Design II (4)
(Formerly AMES 155B) Fundamental principles of aerospace design. Application of engineering mechanics to the design of aerospace components. Design, manufacture and assemble projects involving preliminary design for a realistic engineering application. *Prerequisites: grade of C– or better in MAE 130C, 150, 155A, and 160.*

MAE 156A. Fundamental Principles of Mechanical Design I (4)
(Formerly AMES 156A) Fundamental principles of mechanical design and the design process. Application of engineering science to the design and analysis of mechanical components. Initiation of team design projects that culminate in MAE 156B with a working prototype designed for a real engineering application. *Prerequisite: grade of C– or better in MAE 101C, MAE 130C, MAE 131A, MAE 150, MAE 160, and MAE 170.*

MAE 156B. Fundamental Principles of Mechanical Design II (4)
(Formerly AMES 156B) Fundamental principles of mechanical design and the design process. Culmination of a team design project initiated in MAE 156A which results in a working prototype designed for a real engineering application. *Prerequisite: grade of C– or better in 156A in the immediately preceding quarter, MAE 101C, MAE 150.*

MAE 160. Mechanical Behavior of Materials (4)
Elasticity and anelasticity, dislocations and plasticity of crystals, creep, and strengthening mechanisms. Mechanical behavior of ceramics, composites, and polymers. Fracture: mechanical and microstructural. Fatigue. Laboratory demonstrations of selected topics. *Prerequisites: grades of C– or better in MAE 20, MAE 130A (or SE 101A) and MAE 131A.*

MAE 162. Advanced Materials: Processing, Selection and Design (4)
(Formerly AMES 160) Introduction to various techniques used in fabricating useful bodies with optimal structural, magnetic, optical, or electronic properties. Influence of the type of raw material, densification techniques and methods to tailor composition and microstructure. Ceramics, metals, semiconductors, and composites will be discussed. *Prerequisite: MAE 160 or consent of instructor.*

MAE 163. Mechanics of Porous Materials (4)
Powder packing structures. Fundamentals of the continuum mechanics of powder deformation, plasticity of porous materials. Micromechanical models. Review of main methods of powder shaping, synthesis an manufacturing of high density structures: cold consolidation, forging, rolling, sintering, uniaxial hot pressing, hot isostatic compaction (HIP), extrusion, injection molding. *Prerequisite: consent of instructor.*

MAE 165. Fatigue and Failure Analysis of Engineering Components (4)
The engineering and scientific aspects of crack nucleation, slow crack growth, and unstable fracture in crystalline and amorphous solids. Microstructural effects on crack initiation, fatigue crack growth and fracture toughness. Methods of fatigue testing and fracture toughness testing. Fractography and microfractography. Design safe methodologies and failure prevention. Failure analysis of real engineering structures. *Prerequisite: consent of instructor.*

MAE 167. Wave Dynamics in Materials (4)
Pressure and shear waves in infinite solids. Reflection and diffraction. Rayleigh and Love waves in semi-infinite space. Impulse load on a half space. Waveguides and group velocity. *Prerequisite: consent of instructor.*

MAE 170. Experimental Techniques (4)
(Formerly AMES 170) Principles and practice of measurement and control and the design and conduct of experiments. Technical report writing. Lectures relate to dimensional analysis, error analysis, signal-to-noise problems, filtering, data acquisition and data reduction, as well as background of experiments and statistical analysis. Experiments relate to the use of electronic devices and sensors. *Prerequisite: admission to the MAE or Bioengineering major and grade of C– or better in Phys. 2CL.*

MAE 171A. Mechanical Engineering Laboratory I (4)
Design and analysis of experiments in fluid mechanics, solid mechanics, and control engineering. Experiments in wind tunnel, water tunnel, vibration table and material testing machines, and refined electromechanical systems. Laboratory report writing; error analysis; engineering ethics. *Prerequisites: Grade of C– or better in MAE 101C (or CENG 103C); MAE 160, MAE 141, MAE 170, and senior standing in engineering major.*

MAE 171B. Mechanical Engineering Laboratory II (4)
(Formerly AMES 171B) Design and analysis of original experiments in mechanical engineering. Students research projects using experimental facilities in undergraduate laboratories: wind tunnel, water channel, vibration table, and testing machine and control systems. Students propose and design experiments, obtain data, complete engineering analysis and write a major report. *Prerequisite: requires a grade of C– or better in MAE 171A.*

MAE 175A. Aerospace Engineering Laboratory I (4)
(Formerly AMES 175A) Analysis of aerospace engineering systems using experimental facilities in undergraduate laboratories: wind tunnel, water channel, vibration table, and testing machine. Students operate facilities, obtain data, complete engineering analysis and write major reports. *Prerequisites: senior standing in engineering major and grade of C– or better in MAE 101C or CENG 103C or CENG 101C; MAE 160, MAE 141A or MAE 143B, MAE 170.*

MAE 175B. Aerospace Engineering Laboratory II (4)
(Formerly AMES 175B) Design and analysis of original experiments in aerospace engineering. Students research projects using experimental facilities in undergraduate laboratories: wind tunnel, water channel, vibration table, testing machine and control systems. Students propose and design experiments, obtain data, complete engineering analysis and write a major report. *Prerequisite: requires a grade of C– or better in MAE 175A.*

MAE 180A. Space Science and Engineering I (4)
(Formerly AMES 144A) Introduction to space science. Earth, planetary atmospheres, especially upper atmospheres. Magnetospheres, energetic particles. Electromagnetic spectrum. Atmospheric attenuation, windows. Detection methods, instruments. Imaging systems, image processing. Observations from space. Newtonian mechanics of bound orbits. Science on manned, unmanned missions. *Prerequisite: upper-division standing in physics, chemistry, or engineering department.*

MAE 180B. Space Science and Engineering II (4)
(Formerly AMES 144B) Introduction to space engineering. Kinematics of rockets. Types of rocket engines. Relation of engine performance and rocket characteristics to mission phases—takeoff, on-orbit maneuvers, reentry, and landing. Space structures and materials, with emphasis on new developments. Fabrication of structures from materials obtained in space. Communication systems: design characteristics, requirements, performance. Robotics and control. Tethers. Astrodynamics. *Prerequisite: upper-division standing in physics, chemistry or engineering department.*

MAE 191. Topics in Engineering Science (4)
(Formerly AMES 151A) course to be given at the discretion of the faculty in which topics of current interest in engineering will be presented by visiting or resident faculty members. *Prerequisite: consent of instructor.*

MAE 195. Teaching (2-4)
(Formerly AMES 195) Teaching and tutorial assistance in an MAE course under supervision of instructor. Not more than four units may be used to satisfy graduation requirements. P/NP grades only. *Prerequisites: junior status and a B average in major and consent of department chair.*

MAE 197. Engineering Internship (1-4)
(Formerly AMES 197) Coordinated through UCSD Academic Internship Program, this course provides work experience through industry, government offices, hospitals and their practices. Students will work in local industry or hospital under faculty supervision. Units may not be applied toward major graduation requirements. Internship is unsalaried. *Prerequisites: completion of ninety units with 2.5 GPA and consent of faculty adviser.*

MAE 198. Directed Group Study (1-4)
(Formerly AMES 198) Directed group study on a topic or in a field not included in the regular department curriculum, by special arrangement with a faculty member. May be taken P/NP only. *Prerequisite: consent of instructor.*

MAE 199. Independent Study for Undergraduates (4)
(Formerly AMES 199) Independent reading or research on a problem by special arrangement with a faculty member. P/NP grades only. *Prerequisite: consent of instructor.*

GRADUATE COURSES

205. Graduate Seminar (1)
Each graduate student in MAE is expected to attend one seminar per quarter, of his or her choice, dealing with current topics in fluid mechanics, solid mechanics, applied plasma physics and fusion, chemical engineering, applied ocean sciences, energy and combustion, environmental engineering, or materials science, and dynamics and controls. Topics will vary. (S/U grades only)

207. Topics in Engineering Science (4)
A course to be given at the discretion of the faculty in which topics of current interest in engineering will be presented. *Prerequisite: consent of instructor.*

210A. Fluid Mechanics I (4)
Basic conservation laws. Flow kinematics. The Navier-Stokes equations and some of its exact solutions. Nondimensional parameters and different flow regimes, vorticity dynamics. Cross-listed with CENG 210A. *Prerequisites: MAE 101A-B and MAE 110A, or consent of instructor.*

210B. Fluid Mechanics II (4)
Potential flows, boundary layers, low-Reynolds number flows. *Prerequisites: MAE 210A, MAE 101A-B, and MAE 110A, or consent of instructor.*

210C. Fluid Mechanics III (4)
Flow instabilities, linear stability theory; introduction to turbulent flows. *Prerequisites: MAE 210A-B, MAE 101A-B, and MAE 110A, or consent of instructor.*

211. Introduction to Combustion (4)
Fundamental aspects of flows of reactive gases, with emphasis on processes of combustion, including the relevant thermodynamics, chemical kinetics, fluid mechanics, and transport processes. Topics may include deflagrations, detonations, diffusion flames, ignition, extinction, and propellant combustion. *Prerequisites: MAE 101A-B-C or CENG 103A-B-C, MAE 110A, or consent of instructor.*

212. Introductory Compressible Flow (4)
Equations of motion for compressible fluids; one-dimensional gas dynamics and wave motion, waves in supersonic flow, including oblique shock waves; flow in ducts, nozzles, and wind tunnels; methods of characteristics. *Prerequisites: MAE 101A-B-C or CHE 103A-B-C, MAE 110A, or consent of instructor.*

213. Mechanics of Propulsion (4)
Fluid mechanics, thermodynamics and combustion processes involved in propulsion of aircraft and rockets by air breathing engines, and solid and liquid propellant rocket engines characteristics and matching of engine components; diffusers, compressors, combustors, turbines, pumps, nozzles. *Prerequisites: MAE 101A-B-C, MAE 110A, or consent of instructor.*

214A. Introduction to Turbulence and Turbulent Mixing (4)
Basic features of turbulent flows. Analytical description of turbulence: random variables, correlations, spectra,

Reynolds-averaging, coherent structures. Length and time scales. Kolomogorov similarity theory. Turbulence transport equations. Free shear flows. Homogeneous turbulence. Wall-bounded flows. Mixing of velocity and scalar fields. *Prerequisites: MAE 210A, MAE 101A,B or equivalent or consent of instructor.*

214B. Ocean Turbulence and Mixing (4)
(Cross-listed with SIO 213) Mixing mechanisms, their identification, description and modeling. Introduction to turbulence, semi-empirical theories, importance of coherent structures, effects of stratification and rotation on turbulent structure, entrainment and mixing. S/U grades permitted.

215. Hydrodynamic Stability (4)
Kelvin-Helmholtz instability of shear layers, the Orr-Sommerfeld equation and its solution for inviscid and viscous flows. Taylor instability of circular Couette flows; finite amplitude stability; chaos; transition to turbulence. *Prerequisite: MAE 210A-C or equivalent.*

217. Introduction to Plasma Equilibria, Waves, and Instabilities (4)
Plasma kinetic theory. Two fluid and MHD descriptions of plasmas. Plasma equilibrium configurations and macroscopic stability. Waves in plasmas, collisional and landau damping. Microscopic plasma instabilities. Amomalous cross field plasma transport. Nonlinear wave processes; parametric instabilities, self focusing, solitons. *Prerequisite: none*

218A. Physics of Gas Discharge Plasmas and Appplications (4)
Charged particle motion in electro-magnetic field. Atomic processes in plasmas. Electric breakdown of the gases, plasma quasineutrality, weakly ionized plasma particle and energy fluxes, sheath. Electron kinetics, DC and RF driven discharges, plasma instabilities. Etching, deposition, implantation, and surface modification. *Prerequisite: Physics 100 (B-C) or ECE 107 or equivalent.*

220A. Physics of Gases (4)
Thermodynamics of gases for use in gasdynamics. Derivation of thermodynamic functions from statistical mechanics. Applications of classical and quantum statistical mechanics to chemical, thermal, and radiative properties of gases. Equilibrium and nonequilibrium radiation, chemical equilibrium, and elements of chemical kinetics. Laser and reacting-flow applications. *Prerequisite: MAE 110A or consent of instructor.*

220B. Physical Gasdynamics (4)
Velocity distribution functions, the Boltzmann equation, moment equations and the Navier-Stokes equations. The dynamics of molecular collisions. The Chapman-Enskog expansion and transport coefficients: shear and bulk viscosity, heat conduction, molecular and thermal diffusion. Linearizations about equilibrium: applications to acoustics and supersonic flows with relaxation. *Prerequisite: MAE 101A-B-C or CENG 103A-B-C, MAE 220A, or consent of instructor.*

220C. Nonequilibrium Gasdynamics (4)
Applications of thermodynamics, statistical mechanics, kinetic theory of gases and fluid mechanics to nonequilibrium flow problems. Shock structure. Chemical relaxation. Chemically reacting boundary layers. Ionized gases. Radiative heat transfer. *Prerequisite: MAE 220B or consent of instructor.*

221A. Heat Transfer (4)
Conduction, convection, and radiation heat transfer. Development of energy conservation equations. Analytical and numerical solutions to transport problems. Specific topics and applications vary. *Prerequisite: MAE 101A-B-C or CENG 103A-B-C or CENG 101A-B-C, or consent of instructor. Cross listed with CENG 221A*

221B. Mass Transfer (4)
Fundamentals of diffusive and convective mass transfer and mass transfer with chemical reaction. Development of mass conservation equations. Analytical and numerical solutions to mass transport problems. Specific topics and applications will vary. Cross-listed with CENG 221B. *Prerequisitie: MAE 101A-B-C or CENG 103A-B-C or CENG 101A-B-C, or consent of instructor.*

222A-B-C. Advanced Fluid Mechanics (4-4-4)
Contemporary problems in broad areas of fluid mechanics, e.g., turbulent flows, hydrodynamic stability, geophysical fluid dynamics, transport phenomena, acoustics, boundary layers, etc. (Not necessarily taught as a sequence nor offered every quarter.) *Prerequisite: MAE 210A-B-C or consent of instructor.*

223. Computational Fluid Dynamics (4)
Numerical methods in fluid dynamics and convective transport processes. Numerical solution of the Euler and Navier-Stokes equation. Additional topics will vary according to instructor. Examples include eigenvalue problems in hydrodynamic stability, vortex methods, spectral and panel methods. *Prerequisite: MAE 210A, 290A-B or equivalent, MAE 107, or consent of instructor.*

224. Environmental Fluid Dynamics (4)
Single-layer flows with a free surface, two layer flows including exchange flows in harbors, estuaries, seas, and buildings. Continuously stratified flows with meteorological and oceanographic applications. Topographic effects, plumes, jets, and thermals. Planetary boundary layers. Cross-listed with SIO 214B. *Prerequisites: introductory level graduate course in fluid mechanics*.

227A. Fundamentals of Fusion Plasma Physics (4)
Magnetic and inertial confinement fusion concepts. Magnetic equilibrium configurations and limitations. Classical and anomalous transport of magnetically confined plasmas. Plasma-wall interactions. Rayleigh-Taylor and Richter-Meshkov instabilities. Direct and indirect drive, laser and particle beams. Emerging and alternative concepts. *Prerequisite: none*

227B. Fundamentals of Modern Plasma Physics (4)
Fusion plasma turbulence, magnetic reconnection, strong electromagnetic wave/plasma I interactions, numerical simulations of nonlinear plasma phenomena, issues of plasma astrophysics and space plasmas, plasma based propulsion, plasma boundary layers in fusion devices, plasma chemistry. *Prerequisite: MAE 227A or consent of instructor*

229A. Mechanical Properties (4)
Review of basic concepts in mechanics of deformation: elasticity, plasticity, viscoelasticity and creep; effects of temperature and strain-rate on inelastic flow; microstructure and mehanical perperties; application of basic concepts to selected advanced materials.Cross-listed with MATS 211A. *Prerequisite: consent of instructor.*

229B. Advanced Mechanical Behavior (4)
Rate mechanisms in crystaline solids, kinetics and dynamics of plastic flow by slip at low and high strain rates. Mechanisms of inelasticity in non-metals, metals, and polymeric materials. Mechanisms of failure and effects of strain rates. Cross-listed with MATS 211B. *Prerequisite: MAE 229A or consent of instructor.*

231A. Foundations of Solid Mechanics (4)
Specification of stress and strain; infinitesimal and finite deformation; conservation equations; typical constitutive equations; minimum potential energy principle. *Prerequisite: MAE 131B or consent of instructor.*

231B. Elasticity (4)
Basic field equations. Typical boundary value problems of classical linear elasticity. Problems of plane stress and plane strain. Variational principles. *Prerequisite: MAE 231A or consent of instructor.*

231C. Anelasticity (4)
Mechanical models of viscoelastic, plastic, and viscoplastic behavior in simple shear or uniaxial stress. Constitutive relations for three-dimensional states of stress and strain. Application to selected technological problems. *Prerequisite: MAE 231B or consent of instructor.* (S)

232A. Finite Element Methods in Solid Mechanics I (4)
Finite element methods for linear problems in solid mechanics. Emphasis on the principle of virtual work, finite element stiffness matrices, various finite element formulations and their accuracy and the numerical implementation required to solve problems in small strain, isotropic elasticity in solid mechanics. *Prerequisite: graduate standing.*

232B. Finite Element Methods in Solid Mechanics II (4)
Finite element methods for linear problems in structural dynamics. Beam, plate, and doubly curved shell elements are derived. Strategies for eliminating shear locking problems are introducted. Formulation and numerical solution of the equations of motion for structural dynamics are introduced and the effect of different mass matrix formulations on the solution accuracy is explored. *Prerequisites: graduate standing and MAE 230 or MAE 232A.*

232C. Finite Element Methods in Solid Mechanics III (4)
Finite element methods for problems with both material and geometrical (large deformations) nonlinearities. The total Lagrangian and the updated Lagrangian formulations are introduced. Basic solution methods for the nonlinear equations are developed and applied to problems in plasticity and hyperplasticity. *Prerequisites: graduate standing and MAE 230 or MAE 232A and MAE 231A.*

233A. Fracture Mechanics (4)
Theoretical strength; stress concentration. Linear and nonlinear fracture mechanics: stress singularity, fracture modes, crack tip plastic zone, Dugdale model, the R-curve; power-law materials, the J-integral; fatigue. Special topics. *Prerequisite: MAE 231A-B or consent of instructor.*

233B. Micromechanics (4)
General theory of transformation strains and corresponding elastic fields; Green's functions and other solution methods; dislocations; inclusions and inhomogeneities; micromechanics of plastic flow, microcracking, cavitation, and damage in crystalline and other solids. *Prerequisite: MAE 231A-B-C or consent of instructor.*

233C. Advanced Mechanics of Composite Materials (4)
Three-dimensional anisotropic constitutive theories, anisotropic fracture mechanics, composite micromechanics, edge effects and interlaminar shear stresses, impact damage and energy absorbing mechanisms, and surface wave. *Prerequisite: MAE 131A-B-C, 231A-B or consent of instructor.*

235A. Theory of Shells (4)
General mathematical formulation of the theory of thin elastic shells; linear membrane and bending theories; finite strain and rotation theories; shells of revolution; shallow shells; selected static and dynamic problems; survey of recent advances. *Prerequisite: MAE 131A-B-C or consent of instructor.*

236. Structural Stability (4)
Static, dynamic, and energy-based techniques and predicting elastic stability. Linear and nonlinear analysis of classical and shear deformable beams and plates. Ritz, Galerkin, and finite element approaches for frames and reinforced shells. Nonconservative aerodynamic (divergence flutter) and follower forces. *Prerequisite: MAE 131B or consent of instructor.*

237. Structural Dynamics (4)
Matrix analysis of the free and forced vibrations of discrete linear systems; response to periodic and transient excitations. Frequency response and generalized normal mode methods. Dynamics of continuous systems. *Prerequisite: MAE 231A-B or consent of instructor.*

238. Stress Waves in Solids (4)
Linear wave propagation; plane waves; reflection and refraction; dispersion induced by geometry and by material properties. Application of integral transform methods. Selected topics in nonlinear elastic, anelastic, and anisotropic wave propagation. *Prerequisite: MAE 231A-B-C or consent of instructor.*

241. Advances in Control Applications (4)
Study of problems of control design, identification, and optimization for flexible and smart structures, fluid flows, propulsion, power generation, vehicle dynamics (aerospace, ocean, and automotive), magnetic recording, semiconductor manufacturing, biological systems, robot manipulations, and other applications. *Prerequisites: MAE 141A or equivalent.*

243. Advances in Two-Phase Flow (4)
Modern developments in understanding of two-phase flows will be reviewed. New experimental methods and new theoretical concepts will be covered, as will potential future practical applications. *Prerequisites: MAE 210A-B-C.*

244. Advanced Simulation and Modeling of Turbulent Flows (4)
Progress in the area of simulation and modeling of turbulent flows will be reviewed. Methods to be covered include: direct simulations, large-eddy simulation, and Reynolds averaged turbulence models. *Prerequisites: MAE 210ABC; MAE 214; MAE 290AB.*

245. Advances in Combustion Theory (4)
Asymptotic analyses of flame structure. Combustion in two phase flows. Turbulent combustion. *Prerequisites: MAE 210AB; MAE 211; MAE 213.*

246. Advances in Engine Combustion (4)
Mathematical models of combustion in diesel engines and spark-ignition engines. Mechanisms of soot formation. *Prerequisites: MAE 210AB; MAE 211; MAE 213.*

247. Advances in Experimental and Theoretical Mechanics of Materials (4)
The focus will be on coordinated experimental evaluation and theoretical modeling of thermal mechanical properties of a broad class of materials. Using state-of-the-art techniques, students will gain hands-on experience with modern experimental tools in the area of mechanics and materials. *Prerequisites: consent of the instructor.*

248. Advances in Magnetic Recording (4)
This course will address recent advances in mechanics, tribology, and materials problems of magnetic recording technology. Of special interest will be the treatment of the head/disk and head/tape interface, the numerical schemes used to model the head/medium interface and advanced tribological phenomena needed to understand this fast developing and changing technology. Additional (guest) lecturers on magnetic recording theory and signal processing will be part of the class.

249. Advances in Materials Computations (4)
This course will cover nonlinear finite element methods in large deformations and nonlinear materials. Particular emphasis will be placed on material models that are appropriate for high strain rates, high pressures, and phase transformations. *Prerequisites: MAE 231A, 232A.*

256. Rheology of Fluids (4)
Continuum mechanics of fluids; definition of material functions for viscous and viscoelastic liquids; principles of rheological measurement; relationship to molecular structure. *Prerequisite: consent of instructor.*

261. Sensors and Measurements (4)
Manufacturing sensors and measurement systems, measurement techniques, modern metrology, statistical methods, and experiment design. *Prerequisite: consent of instructor.*

262. Manufacturing Systems (4)
The manufacturing process as a system. Design, production, inspection, quality control, inventory control, material handling, and other functional engineering components. Information flow among components and the effect of components on the whole system. Statistical and process control techniques. *Prerequisite: consent of instructor.*

270. Mechanics of Powder Processing (4)
Powder packing structures. Methods of powder manufacturing, rapid prototyping. Fundamentals of the continuum mechanics of powder deformation, densification in non-uniform temperature fields. Micromechanical models of cold powder yielding. Hot consolidation fundamentals, micromechanical models of plastic yielding, power-law creep, diffusion. *Prerequisite: MAE 231A-C, 233B, or consent of instructor.*

271A. Thermodynamics of Solids (4)
The thermodynamics and statistical mechanics of solids. Basic concepts, equilibrium properties of alloy systems, thermodynamic information from phase diagrams, surfaces and interfaces, crystalline defects. Cross-listed with MATS 201A. *Prerequisite: consent of instructor.*

271B. Solid State Diffusion and Reaction Kinetics (4)
Thermally activated processes, Boltzmann factor, homogenous and heterogenous reactions, solid state diffusion, Fick's laws, diffusion mechanisms, Kirkendall effect, Boltzmann-Matano analysis, high diffusivity paths. Cross-listed with MATS 201 B. *Prerequisite: consent of instructor.*

271C. Phase Transformations (4)
Classification of phase transformations; displacive and reconstructive transformations; classical and non-classical theories of nucleation; Becker-Doering, Volmer-Weber, lattice instabilities, spinodal decomposition. Growth theories; interface migration, stress effects, terrace-ledge mechanisms, epitaxial growth, kinetics and mechanics. Precipitation. Order-disorder transformations. Solidification. Amorphization. Cross-listed with MATS 201C. *Prerequisites: consent of instructor.*

272. Imperfections in Solids (4)
Point, line, and planar defects in crystalline solids, including vacancies, self interstitials, solute atoms, dislocations, stacking faults, and grain boundaries; effects of imperfections on mechanical properties; interactions of dislocations with point defects; strain hardening by micro-obstacles, precipitation, and alloying elements. Cross-listed with MATS 205A. *Prerequisite: MAE 141A or consent of instructor.*

273A. Dynamic Behavior of Materials (4)
Elastic waves in continuum; longitudinal and shear waves. Surface waves. Plastic waves; shock waves, Rankine-Hugoniot relations. Method of characteristics, differential and difference form of conservation equations; dynamic plasticity and dynamic fracture. Shock wave reflection and interaction. Cross listed with MATS 213A. *Prerequisite: consent of instructor.*

273B. Dynamic Behavior of Materials II (4)
Shock-induced phase transformations and reactions. Wave propagation through distended materials. Impact; Mie-Gruneisan and other equations of state, the Gurney equation. Detonation theory. Dislocation behavior at high strain rates. Shear instabilities. Spalling and fragmentation. Cross-listed with MATS 213B. *Prerequisite: consent of instructor.*

274. Fatigue, Fracture, and Failure Analysis in Engineering Materials (4)
This course will cover the engineering and scientific aspects of fatigue crack initiation, stable crack growth, fatigue life predictions, selection of materials for fatigue applications, fractography, and failure analysis, including case studies. Cross-listed with MATS 218. *Prerequisites: MAE 160 and consent of instructor.*

275. Structure and Bonding of Solids (4)
Key concepts in the atomic structure and bonding of solids such as metals, ceramics, and semiconductors. symmetry operations, point groups, lattice types, space groups, simple and complex inorganic compounds, structure/property comparisons, structure determination with X-ray diffraction. Ionic, covalent, mettalic bonding compared with physical properties. Atomic and molecular orbitals, bands vs. bonds, free electron theory. Cross-listed with MATS 227. *Prerequisite: consent of instructor.*

276AB. Synthesis and Processing of Advanced Materials (4)
Introduction to various materials processing techniques used in fabricating dense bodies with optimal structure and properties. Solidification processing, chemical synthesis of ceramics, theory of densification, composite fabrication, superconductor synthesis, electronic and optical materials processing, and techniques to generate amorphons solids. Cross-listed with MATS 233AB. *Prerequisite: MAE 141A or consent of instructor.*

277. Ceramic and Glass Materials (4)
Powder synthesis, powder compaction and densification via different processing routes. Phase equilibria and crystallography in ceramic materials. Sintering liquid, and vapor phase processing and single crystal growth. Control of the microstructural development and interfacial properties optimize properties for structural, thermal, electrical, or magnetic use. Topics in processing and use of advanced ceramic materials. Glass formation and structure, phase separation, viscous flow

and relaxation. Cross-listed with MATS 236. *Prerequisite: MAE 141A or consent of instructor.*

280A. Linear Systems Theory (4)
Linear algebra: inner products, outer products, vector norms, matrix norms, least squares problems, Jordan forms, coordinate transformations, positive definite matrices, etc. Properties of linear dynamic systems described by ODEs: observability, controllability, detectability, stabilizability, trackability, optimality. Control systems design: state estimation, pole assignment, linear quadratic control. *Prerequisite: MAE 141A or consent of instructor.*

280B. Linear Control Design (4)
Parametrization of all stabilizing output feedback controllers, covariance controllers, H-infinity controllers, and L-2 to L-infinity controllers. Continuous and discrete-time treatment. Alternating projection algorithms for solving output feedback problems. Model reduction. All control design problems reduced to one critical theorem in linear algebra. *Prerequisite: MAE 280A*

281A. Nonlinear Systems (4)
Existence and uniqueness of solutions of EDE's, sensitivity equations. Stability, direct and converse Lyapunov theorems, LaSalle's theorem, linearization, invariance theorems. Center manifold theorem. Stability of perturbed systems with vanishing and non-vanishing perturbations, input-to-state ability, comparison method. Input-output stability. Perturbation theory and averaging. Singular perturbations. Circle and Popov criteria. *Prerequisite: MAE 280A.*

281B. Nonlinear Control (4)
Small gain theorem, passivity. Describing functions. Nonlinear controllability, feedback linearization, input-state and input-output linearization, zero dynamics. Stabilization, Brockett's necessary conditions (local), control Lyapunov functions, Sontag's formula (global). Integrator back stepping, forwarding. Inverse optimality, stability margins. Disturbance attenuation, deterministic and stochastic, nonlinear H-infinity. Nonlinear observers. *Prerequisite: MAE 281A.*

282. Adaptive Control (4)
Parametric models. Parameter identifiers and algorithms, Spr-Lyapunov, gradient, least-squares, persistence of excitation, adaptive observers. Model reference adaptive control, certainity equivalence. Pole placement, polynomial, LQR, indirect. Robustification, parameter drift, leakage, projection, dead zone, dynamic normalization. Adaptive nonlinear control, tuning functions, modular design. Extremum seeking. *Prerequisites: MAE 281A or consent of instructor.*

283A. Parametric Identification: Theory and Methods (4)
Constructing dynamical models from experimental data. Deterministic and stochastic discrete time signals. Discrete time systems. Non-parametric identification: correlation and spectral analysis. Parametric identification: realization and prediction error methods, least squares estimation, approximate modeling. Experiment design. Frequency domain identification. *Prerequisite: MAE 141B or MAE 143C recommended.*

283B. Approximate Identification and Control (4)
Identification for control: approximate identification, estimation of models via closed-loop experiments. Closed-loop identification techniques. Estimation of model uncertainty. Model invalidation techniques. Iterative techniques for model estimation and control design. *Prerequisite: MAE 283A.*

284. Robust and Multi-Variable Control (4)
Multivariable feedback systems: transfer function matrices, Smith-McMillan form, poles, zeros, principal gains, operator norms, limits on performance. Model uncertainties, stability and performance robustness. Design of robust controllers, H_inf and mu synthesis. Controller reduction. *Prerequisite: MAE 141B or MAE 143C, or MAE 280A.*

285. Optimal Control and Estimation (4)
Functional optimization, Bellman's principle of optimality, optimal control and the Pontriagin maximal principle, matrix maximum principle, two-point boundary value problems, Hamilton's principle in dynamics, quadratic costs and linear systems, LQG and optimal estimation, Stochastic processes, case studies. *Prerequisite: MAE 280A*

286. Optimization and Control of Fluid-Mechanical Systems (4)
Model-based control approaches for systems governed by the Navier-Stokes equation are presented. Topics discussed include: transition delay, stabilization of convection, turbulence mitigation and enhancement, noise reduction, weather forecasting, and aerodynamic shape optimization. A general mathematical framework is developed and discussed for robust control in such systems. Techniques for determination of effective control approaches by large-scale simulation are discussed. Gradient-based techniques and reduced-storage inverse-Hessein techniques (BFGS, DFP, SQP) are presented. A class project is required. *Prerequisite: consent of instructor.*

287. Control of Distributed Parameter Systems (4)
Strongly continuous semigroups, infinitesmal generators, unbounded closed linear operators, Hille-Yosida theorem, Riesz-spectral operators. Existence and uniqueness of solutions of abstract evolution equations, pertubation and composite systems. Boundary control systems. Controllability, exact and approximate, Hilbert uniqueness method, fixed point method. Input-output maps, transfer functions. Exponential stability, stabilizability, Lyapunov equation. Controllability via stabiliability. Compensator design. *Prerequisite: MAE 280A or consent of instructor.*

290A. Numerical Methods in Science and Engineering (4)
A general introductory course to numerical methods. Introduction to linear calculus, solution of systems of linear and nonlinear algebraic equations, the algebraic eigenvalue problem, polynomial and trigonometric function interpolation, function differentiation and integration, function approximation. *Prerequisite: MAE 107 or consent of instructor.*

290B. Numerical Methods for Differential Equations (4)
Numerical solution of differential equations in mathematical physics and engineering, ordinary and partial differential equations. Linear and nonlinear hyperbolic parabolic, and elliptic equations, with emphasis on prototypical cases, the convection-diffusion equation, Laplace's and Poisson equation. Finite difference methods will be considered in depth, and additional topics. *Prerequisite: MAE 290A or consent of instructor.*

291. Design and Mechanics in Computer Technology (4)
Design and mechanics problems inherent in computer peripherals such as disk files, tape drives, and printers. Formulation and solution of problems involving mechanics, fluid mechanics, and materials; Reynolds equation, slider bearings; friction and wear; actuator design, impact printing; silicon fluid jets. *Prerequisite: consent of instructor.*

292. Computer-Aided Design and Analysis (4)
Introduction to 2-D and 3-D computer-aided design. Design problems may include: ball bearing kinematics, Weibull statistics, non-repeatable spindle run-out, four bar linkages, beam deflection and vibration, design of magnetic head suspension, hydrodynamic theory of lubrication, air bearings, heat transfer, optical servo, design of ink jet print head. *Prerequisite: consent of instructor.*

293. Advanced Computer Graphics for Engineers and Scientists (4)
Advanced topics used to enhance scientific and engineering visualization. C programming assignments and the use of advanced graphics software. Continuation of topics from MAE 152, including color, computational geometry, 3-D contouring, volume visualization, and hardware architectures. *Prerequisite: MAE 152 or consent of instructor.*

294A. Methods in Applied Mechanics I (4)
Linear algebra and linear spaces. Applications to linear transformations and equations, tensor analysis, linear programming and network analysis. Linear ordinary differential equations and difference equations, integral and discrete transforms, and spectral theory. Applications to linear stability, stochastic processes and numerical methods. *Prerequisite: Math. 110, Math.120A ,or consent of instructor.*

294B. Methods in Applied Mechanics II (4)
Nonlinear ordinary differential and difference equations, applications to dynamical systems, stability, bifurcation and chaos. Regular and singular perturbations, asymptotic expansions and multiscale analyses. Applications to the dynamics of mechanical, chemical and biological systems. *Prerequisite: MAE 294A or consent of instructor.*

294C. Methods in Applied Mechanics III (4)
Partial differential equations and boundary-value problems, classification of PDE's and transform methods. Green's functions and spectral theory. Non- linear PDE's, variational methods and the methods of characteristics. Non- linear waves and shocks. Asymptotic methods: WKB and stationary phase. Galerkin methods and numberical analysis of PDE's. Applications to continuum mechanics and transport phenomena. *Prere-quisite: MAE 294B or consent of instructor.*

296. Independent Study (4)
Independent reading or research on a problem as arranged by a designated faculty member. Must be taken for a letter grade only. *Prerequisite: consent of instructor.*

298. Directed Group Study (1-4)
Directed group study on a topic or in a field not included in regular department curriculum, by special arrangement with a faculty member. *Prerequisite: consent of instructor.* (S/U grades permitted.)

299. Graduate Research (1-12)
(S/U grades only.)

501. Teaching Experience (2)
Teaching experience in an appropriate MAE undergraduate course under direction of the faculty member in charge of the course. Lecturing one hour per week in either a problem-solving section or regular lecture. (S/U grade only.) Prerequisites: consent of instructor and the MAE department.