

## Department of

# *Biological and Irrigation Engineering*

## *College of Engineering*

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**Degrees offered:** Bachelor of Science (BS) in Biological Engineering; Master of Science (MS) and Doctor of Philosophy (PhD) in Biological and Agricultural Engineering, and in Irrigation Engineering

**Undergraduate options:** BS—Bioprocess; Bioenvironmental; Biomedical; and Soil and Water Resource Systems Engineering; **Graduate specializations:** MS, PhD—Agricultural Hydrology; Crop Water-Yield Analysis; Drainage; Evapotranspiration; Groundwater Management and Simulation; Irrigation Conveyance and Control Structures; Irrigation Project Planning, Design, and Operation and Management; Molecular Biology; On-Farm Water Management; Remote Sensing and Geographical Information Systems; Surface, Sprinkle, and Trickle Irrigation Methods

## *Mission*

The mission of the Department of Biological and Irrigation Engineering (BIE) is to teach students preparing to become biological engineers how to apply engineering principles and the knowledge of biological sciences to the solutions of bioresource problems. The department also prepares students for entry into other professions, such as biomedical engineering, medicine, or law.

The BIE program is designed to help students learn to manipulate biological materials for useful purposes, understand the biological literature, and be able to communicate with biological scientists. Biological engineering encompasses engineering applications in a broad range of biological systems. The biological engineering curriculum at USU emphasizes bioprocess and biomedical engineering, as well as soil and water resource systems engineering. The curriculum at both the Bachelor of Science and graduate levels is designed to prepare students for a wide variety of professional jobs related to the utilization, management, and protection of bioresources.

## *Scope and Objectives*

The objective of the Biological Engineering Program is to provide students with broad-based engineering skills necessary to

solve biological-based problems. Students first learn to integrate biological sciences with conventional studies in mathematics and chemistry. These skills are broadened with a liberal exposure to humanities and social sciences, then sharpened with the study of engineering topics which develop practical problem-solving abilities; expand a sensitivity to the economic, social, and legal dimensions of technical problems; provide an understanding of ethics and professional responsibility; and stimulate a desire for life-long learning.

## *Outcomes*

The Biological Engineering curriculum emphasizes three important outcomes:

1. The knowledge needed to identify, formulate, and perform the functions of a biological engineer.
2. The intellectual skills and creative abilities graduates should possess in order to design systems and conduct experiments in an interdisciplinary team setting, as well as the ability to use these skills in modern engineering practice.
3. The specific career-preparation competencies of ethical responsibility, effective communications, comprehension of engineering in the global context, and a commitment to life-long learning and self-improvement.

## Assessment and Evaluation

The BIE Department is committed to an assessment process aimed at evaluating the effectiveness of BIE programs in preparing graduates as productive professionals. The foundation of departmental assessment is the undergraduate accreditation by the Engineering Accreditation Commission (EAC) of the Accreditation Board for Engineering and Technology (ABET).

The accreditation activities performed every six years by the EAC/ABET provide the only formal and external review of the undergraduate program. This assessment insures that the USU program meets an overall objective and structure consistent with similar programs in the U.S. and Canada.

The biological engineering program that currently exists is the result of integrating the results of this formal assessment with the day-to-day assessments garnered from both students and faculty. To insure the overall quality of the program, the department conducts several specific assessments. These are:

1. Annual faculty survey
2. Teaching evaluations
3. Graduating student exit interviews
4. Fundamentals of Engineering Examination performances
5. Biological and Irrigation Engineering Advisory Board, involving employer responses and board reviews

## Undergraduate Programs

General biological engineering concepts include the properties of biological materials, electronics and instrumentation, computer use and programming, engineering mechanics, thermodynamics, computer-aided drafting, bio-environmental transport phenomena, and fluid mechanics.

Students gain a strong foundation in biological, chemical, and physical sciences. Each student then selects an option within the field, based on personal interest. These areas of study are tailored for each student with 24 semester credits of technical electives and one-on-one academic advisement with a member of the faculty. Design is a major theme of both the student's general coursework and specialization, with most courses including open-ended design problems. The entire design experience is brought together in a capstone design course.

The Biological Engineering Program is accredited by the Engineering Accreditation Commission of the Accreditation Board for Engineering and Technology (EAC/ABET).

### Requirements

**Admission and Graduation Requirements.** The student who is majoring in or planning to major in Biological Engineering needs to be aware of the College of Engineering requirements concerning admission to the college, pre-engineering, admission to the professional engineering school, general education, and other academic requirements. Additional information concerning these items is given in the College of Engineering write-up on pages 90-92. It is the responsibility of the student to be aware of these rules and regulations.

### Biological Engineering Curriculum

Biological Engineering is divided into a preprofessional and a professional program involving either a four-year or a five-year schedule that will satisfy the requirements for a BS degree in Biological Engineering. Students receiving credit from the College Level Examination Program (CLEP) or from Advanced Placement (AP) may complete a BS degree program in less than four years. The academic work, particularly in the junior and senior years, is supplemented by hands-on laboratories which are required as part of the coursework. Modification in the program to meet special needs and priorities of a student may be obtained with the approval of the department head and advisor.

**Preprofessional Program:** BIE 1880, 2330; Chem 1210, 1230, 2300, 2330; Engr 1010, 2000, 2020, 2200; Biol 1210; Engl 2010; ITE 2270; MAE 2400; Math 1210, 1220, 2250; Phyx 2200; and three credits of communication literacy.

**Professional Program:** BIE 3000, 3200, 3670, 3870, 4880, 4890; Biol 3300, 5200; CEE 3500; Chem 3700, 3710; Stat 3000; ECE 2200; Biological Engineering Electives (6-21 credits); Engineering Electives (0-15 credits); Technical Electives (0-12 credits); and University Studies (18 credits).

### Additional Information

For more information about the Bachelor of Science requirements and the sequence in which courses should be taken, see major requirement sheet, available from the Biological and Irrigation Engineering Department.

### Financial Support

Scholarships, assistantships, grants-in-aid, and work-study programs are available through the University. In addition, the department employs students to assist in engineering research and development. Cooperative education and industrial employment opportunities for students are coordinated by the University Placement Office.

### Concurrent BS/Master's Program

The concurrent BS/Master's program allows engineering students to begin taking graduate-level classes during their senior year. This permits them to complete requirements for *both* the BS degree *and* the master's degree concurrently during two years. Students in this program have a greater selection of graduate courses, since many graduate courses are taught during alternate years. In addition, the student's senior design project could be a start for a graduate design project or thesis. After completing their BS degree, students in the program can earn a master's degree in only one additional year. Both the BS and the master's degree can generally be earned with 150 total credits, although students should note that a Plan C MS requires 3 extra credits. Finally, students with a master's degree can expect a much higher starting salary following graduation. (For more information, see *College of Engineering* section of this catalog, page 92.)

## Graduate Programs

### Admission Requirements

See general admission requirements, pages 72-73. Admission committees also consider experience, undergraduate record and curriculum, and formal recommendations. A student without an undergraduate engineering background will be required to complete selected undergraduate courses prior to or concurrently with enrollment in graduate courses.

**Prerequisites for Matriculation.** Students who are admitted provisionally or who have been changed from matriculated to probationary matriculated status will have their records reviewed by a faculty committee when they have completed 12 credits of coursework (among which must be formal engineering courses) or at the end of their second semester at USU. Those students who have earned a 3.0 GPA at that time and desire to be matriculated may apply to the department to have their status changed. If they meet all other academic requirements of the School of Graduate Studies and the department, they will be matriculated and admitted to the degree program. When a student is admitted as a degree candidate, the committee may allow up to 12 credits taken while on nonmatriculated status to be transferred. Nonmatriculated students may continue to study at USU but without degree candidate status. At the end of their studies, nondegree students are granted a Certificate of Completion.

**Prerequisite Requirements.** All students must have had formal courses in engineering and computer programming, as well as at least one year of calculus. Students without this background can satisfy these requirements by taking the appropriate undergraduate courses at USU. An additional year of calculus (Math 1210, 1220, and 2250, or equivalent) is required for the MS degree in Irrigation Engineering and for all PhD programs. These background courses will not be counted toward the degree credit requirements.

### MS in Biological and Agricultural Engineering and in Irrigation Engineering

Students must have a BS from an ABET-accredited engineering program in the U.S. or its equivalent in their home countries or must take the make-up coursework required for a BS in engineering at USU. It is assumed that the bachelor's degree mathematical training includes courses in calculus, linear analysis, and differential equations.

Three MS options are available: research (Plan A), technical practice (Plan B), and training/extension (Plan C). All MS students are admitted initially into the technical practice (Plan B) option. They may subsequently transfer to one of the other two options depending upon interests and skills.

**Research Option.** Students wishing to gain experience in irrigation research may select the research option, particularly if they have a long-term goal of PhD study. The minimum requirements for this option are 30 credits, of which 8 may be awarded for the thesis.

**Technical Practice Option.** Some students wishing to study for either the biological and agricultural engineering degree or the irrigation engineering degree may not be interested in pursuing a PhD degree or in doing the research necessary for a thesis. For such students, the technical practice (Plan B) option is offered.

The requirements for the degree are similar to those for the research option, with the exception of the thesis. The 8 thesis credits are replaced by 4 credits for a significant engineering report or design project and 4 additional credits of coursework. The minimum course requirement for the technical practice option is 30 approved graduate credits.

**Training/Extension Option.** Students expecting to terminate their graduate studies at the MS level and wishing to develop an emphasis in the training and/or extension fields of biological and agricultural engineering, or irrigation engineering, may choose the training/extension option (Plan C). The same engineering BS or equivalent requirements noted under the Plan A option apply. The minimum requirements for this degree are 30 approved graduate credits. No report or thesis is required. The degree requirements under this option can be met by taking courses.

### Doctor of Philosophy

Two PhD programs are offered in the department: (1) **Biological and Agricultural Engineering**, and (2) **Irrigation Engineering**. Students who have completed an MS with a thesis (Plan A or equivalent) in an engineering discipline are eligible to apply for admission to a PhD program in either biological and agricultural engineering or irrigation engineering. Admission will be based on the students' prior academic records and, if they are graduates of USU, the recommendations of their graduate committees. It is assumed that students are adequately prepared in mathematics and engineering design courses to compete at the PhD level. If such is not the case, a program of courses to make up the deficiency will be required.

In addition to any prescribed review courses and seminars, the minimum requirements for a PhD program include 60 credits of approved graduate courses beyond a master's degree, satisfactory completion of the comprehensive examinations after completion of the formal coursework, and the writing of a dissertation based on an original research project. The degree requirements beyond a master's degree can be met by taking courses in engineering design, synthesis, and systems; mathematics; and related science.

### Research

In more than 80 years of irrigation engineering experience, USU has attained worldwide prestige through the successful professional records of its many graduates.

The department is heavily involved in overseas research and training activities concerned with managing irrigation systems, on-farm water management, and water resource development.

Research projects in several areas of irrigation and drainage engineering are currently being conducted by the department. Hence, graduate students have the opportunity to conduct research for their degree programs and obtain financial support. Current projects include hydraulics of surface irrigation, consumptive use, return flow quantity and quality of irrigation waters and application techniques, transient flow in tile drainage systems, drain envelopes, sprinkler irrigation, trickle irrigation, crop production and water requirements, salt movement, regional groundwater modeling for optimizing sustainable yield, conveyance system modeling and control, and remote sensing.

Specific research projects in the bioprocessing option include ventilation and environmental control of livestock buildings, the contribution of rural municipalities to nonpoint source pollution, and agricultural waste management.

Land application of food processing wastes, extrusion of dairy-based foods, multi-stage anaerobic digestion of biological materials, functional properties of foods, and biological detoxification of metals are some of the topics researched in food engineering.

### **Financial Assistance**

The large departmental research programs make it possible to offer graduate students financial support in the form of assistantships and traineeships. The financial support is mainly available to U.S. citizens with a small number of assistantships for others. The traineeships and assistantships are attached to research projects on the Logan campus and overseas. Traineeships carry tuition waivers and additional financial support.

### **Additional Information**

Two guides are available from the department to assist students: (1) *Report, Thesis, and Dissertation Format Guidelines and Policies*, and (2) *Policies and Procedures for Graduate Study*.

## **Biological and Irrigation Engineering Courses (BIE)**

**BIE 1880. Engineering Quantification of Biological Processes.** Introduction to engineering practice of biological modeling and quantification of biological processes. Introduction to transport of heat and mass; bioenergetics, thermodynamics, and enzyme kinetics; metabolism; mechanical work processes; and modeling of biological systems. (3 cr) (Sp)

**BIE 2330. Engineering Properties of Biological Materials.** Relationships between composition, structure, and properties of biological materials. Definition, measurement, and use of mechanical, thermal, electromagnetic, chemical, and biological properties in computation and design. Prerequisites: Biol 1210, BIE 1880, Chem 1210, 1230. (3 cr) (F)

**BIE 3000. Instrumentation for Biological Systems.** Fundamentals of measurement systems used in agricultural, biological, and environmental applications. Selection and use of sensors, data acquisition systems, and elementary controls. Prerequisite: ECE 2200. (2 cr) (Sp)

**BIE 3200. Introduction to Unit Operations in Biological Engineering.** Introduction to the fundamental unit operations required to process biological materials in bioprocessing, biomedical, and food engineering applications. Integration of biology and chemistry into biological engineering using basic concepts in heat, mass, and energy conservation and transport. Prerequisites: BIE 2330, Chem 2300. (3 cr) (Sp)

**BIE 3670. Transport Phenomena in Bio-Environmental Systems.** Core course in both biological and environmental engineering. Students develop a detailed understanding of the principles, concepts, modes, and methods of calculating heat and mass transfer. Emphasis given to contaminant and nutrient flux, along with their state

transformations, in order for the biological or environmental engineer to evaluate options for production, clean-up, and control of bio-environmental systems. Prerequisite: CEE 3500. Also taught as CEE 3670. (3 cr) (Sp)

**BIE 3870. Biological Engineering Design I.** Students select and plan a senior design project. A project proposal, including a technical description of the project and management plans, is required. (1 cr) (F,Sp,Su)

**BIE 4250. Cooperative Practice.** Planned work experience in industry or government. Detailed program must be approved prior to registration. Written report required. (3 cr) (F,Sp,Su)

**BIE 4880 (CI). Biological Engineering Design II.** Execution and completion of a comprehensive senior design project. Design reviews and written reports are required. Prerequisite: BIE 3870. (3 cr) (F,Sp,Su)

**BIE 4890 (CI). Biological Engineering Design III.** Preparation and presentation of the senior design project. The presentation will involve a professional standard report and an evaluation and critique by Biological Engineering students and faculty. Prerequisite: BIE 4880. (3 cr) (F,Sp,Su)

**BIE 4930. Special Studies.** Independent or group study of biological and irrigation engineering subjects not covered in regular course offerings. (2 cr) (F,Sp,Su) ®

**BIE 5010 (d6010).<sup>1</sup> Principles of Irrigation Engineering.** Soil-water-plant relationships; evapotranspiration and water requirements; effective water use; irrigation scheduling; infiltration; irrigation systems planning. Prerequisites: CEE 3430, 3500, Engr 2200. (3 cr) (F)

**BIE 5110 (d6110). Sprinkle and Trickle Irrigation.** Sprinkle and trickle irrigation system demand, system selection and configuration, emitter and sprinkler characteristics and sizing, uniformity and efficiency, pipe network layout and sizing, and system operation, management, and maintenance. Prerequisite: BIE 5010/6010. (4 cr) (F)

**BIE 5150 (d6150). Surface Irrigation Design.** Design and evaluation of surface irrigation systems. Field measurements for evaluating and improving uniformity and efficiency. Simulation of surface systems. Land leveling computation and equipment. Prerequisite: BIE 5010/6010. (3 cr) (Sp)

**BIE 5250 (d6250). Remote Sensing of Land Surfaces.** Basic principles of radiation and remote sensing. Techniques for ground-based measurements of reflected and emitted radiation, as well as ancillary data collection to support airborne and satellite remote sensing studies in agriculture, geography, and hydrology. Prerequisites: Basic calculus and physics. Also taught as Bmet 5250/6250 and FRWS 5250/6250. (4 cr) (Sp)

**BIE 5300 (d6300). Irrigation Conveyance and Control Systems.** Design, evaluation, and operation of irrigation distribution systems. Measurement and monitoring of flows and water levels, and canal and pipeline automation. Simulation of system hydraulics. Prerequisite: BIE 5010/6010. (3 cr) (F)

**BIE 5350 (d6350). Drainage and Water Quality Engineering.** Introduction to principles and practices of drainage. Engineering investigation and design of drains. Formation and function of wetlands caused by irrigation and drainage systems. Prerequisite: BIE 5010/6010. (3 cr) (Sp)

**BIE 5520 (d6520). Irrigation Project Operation and Maintenance.** Organizing, administering, and financing irrigation and drainage projects. Operation and maintenance of irrigation distribution systems. Simulation of command area water demands. Prerequisite: BIE 5010/6010. (3 cr) (Sp)

**BIE 5550 (d6550). Groundwater Systems Engineering I.** Groundwater exploration; well drilling and testing; pumping plant design, operation, and testing; aquifer evaluations; siting of multiple well systems. Development of pumping strategies for water supply and environmental control systems. Introduction to conjunctive use. Prerequisite: BIE 5010/6010. (3 cr) (F)

**BIE 5610 (d6610). Food and Bioprocess Engineering.** Standardization and compounding of biomaterials and food products; preservation processing using heat, refrigeration, concentration, and dehydration. Basic unit operations in the bioprocessing industry. Prerequisite: BIE 3200. Also taught as NFS 5610/6610. (3 cr) (F)

**BIE 5810 (d6810). Biochemical Engineering.** Fundamentals of bioreactor design and bioengineering. Emphasizes mathematical models of microbial and enzymatic processes in environmental and industrial biotechnology. Prerequisites: BIE 3200 and BIE/CEE 3670; *or* BIE/CEE 3670, CEE/PubH 3610, and CEE 3640. Also taught as CEE 5810/6810. (3 cr) (F)

**BIE 5830 (d6830). Management and Utilization of Biological Solids and Wastewater.** Focuses on production, management, and disposal of biosolids and wastewater generated in food processing and wastewater treatment. Emphasizes beneficial use of biosolids and wastewater for agricultural production, forest enhancement, and land reclamation. Prerequisites: BIE 3200, BIE/CEE 3670, CEE/PubH 3610, CEE 3640. Also taught as CEE 5830/6830. (3 cr) (F)

**BIE 5850 (d6850). Biomaterials Engineering.** Explores identification and modification of properties of natural and artificial biomaterials. Design of applications for by-product recovery and recycling, environmental, food processing, and biomedical industries. Commercialization of biomaterial feed stocks, biotechnology output, and bioprocessing by-products into traditional and alternative products. Prerequisites: BIE 2330, BIE/NFS 5610/6610. (3 cr) (F)

**BIE 6010 (d5010). Principles of Irrigation Engineering.** Soil-water-plant relationships; evapotranspiration and water requirements; effective water use; irrigation scheduling; infiltration; irrigation systems planning. Prerequisites: CEE 3430, 3500, Engr 2200. (3 cr) (F)

**BIE 6110 (d5110). Sprinkle and Trickle Irrigation.** Sprinkle and trickle irrigation system demand, system selection and configuration, emitter and sprinkler characteristics and sizing, uniformity and efficiency, pipe network layout and sizing, and system operation, management, and maintenance. Prerequisite: BIE 6010/5010. (4 cr) (F)

**BIE 6150 (d5150). Surface Irrigation Design.** Design and evaluation of surface irrigation systems. Field measurements for evaluating and improving uniformity and efficiency. Simulation of surface systems. Land leveling computation and equipment. Prerequisite: BIE 6010/5010. (3 cr) (Sp)

**BIE 6250 (d5250). Remote Sensing of Land Surfaces.** Basic principles of radiation and remote sensing. Techniques for ground-based measurements of reflected and emitted radiation, as well as ancillary data collection to support airborne and satellite remote sensing studies in agriculture, geography, and hydrology. Prerequisites: Basic calculus and physics. Also taught as Bmet 6250/5250 and CEE 6250/5250. (4 cr) (Sp)

**BIE 6260. Hydrology of Irrigation Agriculture.** Impacts of irrigation activities on local and regional hydrology, wetlands, and natural systems. Determination of components of field and project water balances, including evapotranspiration. Effects of water conservation practices and changes in efficiency on timing and disposition of water resources and return flows. Irrigation scheduling and use of computer models. Prerequisite: BIE 6010/5010. (3 cr)

**BIE 6300 (d5300). Irrigation Conveyance and Control Systems.** Design, evaluation, and operation of irrigation distribution systems. Measurement and monitoring of flows and water levels, and canal and pipeline automation. Simulation of system hydraulics. Prerequisite: BIE 6010/5010. (3 cr) (F)

**BIE 6350 (d5350). Drainage and Water Quality Engineering.** Introduction to principles and practices of drainage. Engineering investigation and design of drains. Formation and function of wetlands caused by irrigation and drainage systems. Prerequisite: BIE 6010/5010. (3 cr) (Sp)

**BIE 6520 (d5520). Irrigation Project Operation and Maintenance.** Organizing, administering, and financing irrigation and drainage projects. Operation and maintenance of irrigation distribution systems. Simulation of command area water demands. Prerequisite: BIE 6010/5010. (3 cr) (Sp)

**BIE 6550 (d5550). Groundwater Systems Engineering I.** Groundwater exploration; well drilling and testing; pumping plant design, operation, and testing; aquifer evaluations; siting of multiple well systems. Development of pumping strategies for water supply and environmental control systems. Introduction to conjunctive use. Prerequisite: BIE 6010/5010. (3 cr) (F)

**BIE 6610 (d5610). Food and Bioprocess Engineering.** Standardization and compounding of biomaterials and food products; preservation processing using heat, refrigeration, concentration, and dehydration. Basic unit operations in the bioprocessing industry. Prerequisite: BIE 3200. Also taught as NFS 6610/5610. (3 cr) (F)

**BIE 6800 (d7800). Research Orientation and Planning.** Promotes familiarization with departmental and graduate school rules and procedures, departmental research, and tools for writing research proposals. (2 cr) (F)

**BIE 6810 (d5810). Biochemical Engineering.** Fundamentals of bioreactor design and bioengineering. Emphasizes mathematical models of microbial and enzymatic processes in environmental and industrial biotechnology. Prerequisites: BIE 3200 and BIE/CEE 3670; *or* BIE/CEE 3670, CEE/PubH 3610, and CEE 3640. Also taught as CEE 6810/5810. (3 cr) (F)

**BIE 6830 (d5830). Management and Utilization of Biological Solids and Wastewater.** Focuses on production, management, and disposal of biosolids and wastewater generated in food processing and wastewater treatment. Emphasizes beneficial use of biosolids and wastewater for agricultural production, forest enhancement, and land reclamation. Prerequisites: BIE 3200, BIE/CEE 3670, CEE/PubH 3610, CEE 3640. Also taught as CEE 6830/5830. (3 cr) (F)

**BIE 6850 (d5850). Biomaterials Engineering.** Explores identification and modification of properties of natural and artificial biomaterials. Design of applications for by-product recovery and recycling, environmental, food processing, and biomedical industries. Commercialization of biomaterial feed stocks, biotechnology output, and bioprocessing by-products into traditional and alternative products. Prerequisites: BIE 2330, BIE/NFS 6610/5610. (3 cr) (F)

**BIE 6930. Special Problems.** Independent study of problems in biological and agricultural engineering. (1-4 cr) (F,Sp,Su) ®

**BIE 6970. Thesis Research.** Credit for MS research and report requirements. (1-8 cr) (F,Sp,Su) ®

**BIE 6990. Continuing Graduate Advisement for MS and PhD Students.** (1-3 cr) (F,Sp,Su) ®

**BIE 7350. Groundwater Systems Engineering II.** System analysis techniques applied to aquifer and stream/aquifer management. Development of economically, quantitatively, and environmentally optimal strategies for alternative water policies. Modeling techniques for managing aquifer systems under volumetric, economic, and environmental management goals. Prerequisites: CEE 5470/6470 or 6500. (4 cr) (Sp)

**BIE 7600. Advanced Research Topics.** Study of advanced biological and engineering topics. Analysis of project scale water management issues, software development, crop modeling, advanced drainage systems, remote sensing, groundwater

systems, and other topics taken from the research interests of the faculty. Prerequisite: PhD enrollment. (3 cr) (Sp)

**BIE 7800 (d6800). Research Orientation and Planning.** Promotes familiarization with departmental and graduate school rules and procedures, departmental research, and tools for writing research proposals. (2 cr) (F)

**BIE 7970. Dissertation Research.** (1-10 cr) (F,Sp,Su) ®

**BIE 7990. Continuing Graduate Advisement for PhD Students.** (1-9 cr) (F,Sp,Su) ®

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<sup>1</sup> Parenthetical numbers preceded by *d* indicate a *dual* listing.

® Repeatable for credit. Check with major department for limitations on number of credits that can be counted for graduation.