BIOLOGICAL SYSTEMS ENGINEERING

For the undergraduate curriculum in biological systems engineering leading to the degree bachelor of science. This curriculum is accredited under the General Criteria and Program Criteria for Biological Systems Engineering Programs by the Engineering Accreditation Commission of ABET, http://www.abet.org/.

Curriculum Educational Goal, Objectives, and Learning Outcomes

Biological Systems Engineering integrates life sciences with engineering to solve problems related to, or using, biological systems. These biological systems may include microbes, plants, animals, humans and/or ecosystems. Biological systems engineers have a worldview shaped by an understanding of fundamental principles of engineering and life-sciences. They use their understanding of engineering to analyze organisms or ecosystems, and their knowledge of biological systems to inspire and inform their designs. They approach engineering design from a biological systems perspective, appreciating the complexity of biological systems and developing solutions that accommodate and anticipate the adaptability of biological systems.

Goal: To educate students to solve problems related to biorenewables production and processing, water quality, environmental impacts of the bioeconomy, food processing, and biosensors, and in so doing to prepare students for professional practice and post-graduate educational opportunities.

Program Educational Objectives: Three to five years after graduation, our graduates will be using the knowledge, skills, and abilities from their biological systems engineering degree to improve the human condition through successful careers in a wide variety of fields. They will be effective leaders, collaborators, and innovators who address environmental, social, technical, and business challenges. They will be engaged in life-long learning and professional development through self-study, continuing education, or graduate/professional school.

Student Outcomes: At graduation, students will have developed and demonstrated:

(a) an ability to apply knowledge of mathematics, science, and engineering;
(b) an ability to design and conduct experiments, as well as to analyze and interpret data;
(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability;
(d) an ability to function on multidisciplinary teams;

(e) an ability to identify, formulate, and solve engineering problems;
(f) an understanding of professional and ethical responsibility;
(g) an ability to communicate effectively;
(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context;
(i) a recognition of the need for, and an ability to engage in life-long learning;
(j) a knowledge of contemporary issues;
(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Well-qualified juniors and seniors in biological systems engineering who are interested in graduate study may apply for concurrent enrollment in the Graduate College to simultaneously pursue a bachelor of science degree in biological systems engineering and a master of science degree in agricultural engineering. Under concurrent enrollment, students are eligible for assistantships and simultaneously take undergraduate and graduate courses.

A concurrent bachelor of science and master of business administration program is also offered by the department.

The department also offers a bachelor of science curriculum in agricultural engineering. See College of Engineering. Additionally, the department offers bachelor of science curricula in agricultural systems technology and in industrial technology. See College of Agriculture and Life Sciences.

The department also participates in interdepartmental majors in environmental science, sustainable agriculture, biorenewable resources and technology, human computer interaction, and toxicology (see Index).

Curriculum in Biological Systems Engineering

Administered by the Department of Agricultural and Biosystems Engineering.

Leading to the degree bachelor of science.

Total credits required:
128.0 cr: Biorenewable Resources Option
127.0 cr: Bioenvironmental Engineering Option
128.0 cr: Food Engineering Option
128.0 cr: Open Option.

Any transfer credit courses applied to the degree program require a grade of C or better (but will not be calculated into the ISU cumulative GPA, Basic Program GPA or Core GPA). See also Basic Program and Special Programs. International Perspectives: 3 cr.
U.S. Diversity: 3 cr.
Communication Proficiency/Library requirement:
(Minimum GPA of 2.00 in this set of courses.)
ENGL 150  Critical Thinking and Communication (Must have a C or better in this course) 3
ENGL 250  Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course) 3
LIB 160  Information Literacy 1
Communication Elective: One of the following (Must have a C or better in this course) 3
AGEDS 311  Presentation and Sales Strategies for Agricultural Audiences
ENGL 309  Proposal and Report Writing
MKT 343  Personal Sales
ENGL 314  Technical Communication
SP CM 212  Fundamentals of Public Speaking

Social Sciences and Humanities: 12 cr.  
3 credits from international perspectives-university approved list 3
3 credits from U.S. diversity-university approved list 3
6 credits from Social Sciences and Humanities courses-department approved list 6

Total Credits 12

Basic Program: 27 cr.
A minimum GPA of 2.00 required for this set of courses, including any transfer courses (please note that transfer course grades will not be calculated into the Basic Program GPA). See Requirement for Entry into Professional Program in College of Engineering Overview section.

A B E 160  Systematic Problem Solving and Computer Programming 3
CHEM 167  General Chemistry for Engineering Students 4
or CHEM 177 and CHEM 178
ENGL 150  Critical Thinking and Communication 3
ENGL 250  Written, Oral, Visual, and Electronic Composition 3
ENGR 101  Engineering Orientation
LIB 160  Information Literacy 1
MATH 165  Calculus I 4
MATH 166  Calculus II 4
PHYS 221  Introduction to Classical Physics I 5

Total Credits 27

Biological, Math and Physical Science: 23 cr.
BIOL 212  Principles of Biology II 3
CHEM 167L  Laboratory in General Chemistry for Engineering 1
or CHEM 177L  Laboratory in General Chemistry I
Chemistry Sequence I (select from list of lecture with corresponding lab)
CHEM 231  Elementary Organic Chemistry
CHEM 231L  Laboratory in Elementary Organic Chemistry
CHEM 331  Organic Chemistry I
CHEM 331L  Laboratory in Organic Chemistry I
MATH 267  Elementary Differential Equations and Laplace Transforms 4
MICRO 302  Biology of Microorganisms 3
MICRO 302L  Microbiology Laboratory 1
STAT 305  Engineering Statistics (Chemistry Sequence I) 3

Chemistry Sequence II (select from list of lecture with corresponding lab) 4
CHEM 211  Quantitative and Environmental Analysis
CHEM 211L  Quantitative and Environmental Analysis Laboratory
CHEM 332  Organic Chemistry II
CHEM 332L  Laboratory in Organic Chemistry II
FS HN 311  Food Chemistry
FS HN 311L  Food Chemistry Laboratory

Total Credits 23

Biological Systems Engineering Core: 45 cr.
(A minimum GPA of 2.00 required for this set of courses, including any transfer courses; please note that transfer course grades will not be calculated into the Core GPA).

A B E 216  Fundamentals of Agricultural and Biosystems Engineering 3
A B E 218  Project Management & Design in Agricultural and Biosystems Engineering 2
A B E 273  CAD for Process Facilities and Land Use Planning 1
A B E 316  Applied Numerical Methods for Agricultural and Biosystems Engineering 3
A B E 363  Agri-Industrial Applications of Electric Power and Electronics 4
A B E 380  Principles of Biological Systems Engineering 3
A B E 404  Instrumentation for Agricultural and Biosystems Engineering 3
A B E 415  Agricultural & Biosystems Engineering Design I 2
A B E 416  Agricultural & Biosystems Engineering Design II 2
A B E 451  Food and Bioprocess Engineering 3
A B E 480  Engineering Analysis of Biological Systems 3
E M 274  Engineering Statics 3
E M 324  Mechanics of Materials 3
E M 327  Mechanics of Materials Laboratory 1
E M 378  Mechanics of Fluids 3
I E 305  Engineering Economic Analysis 3
M E 231  Engineering Thermodynamics I  3

Total Credits  45

Other Remaining Courses: 8 cr.
A B E 110  Experiencing Agricultural and Biosystems Engineering  1
A B E 170  Engineering Graphics and Introductory Design  3
A B E 201  Preparing for Workplace Seminar  1

Communication Elective: One of the following (Must have a C or better in this course)
AGEDS 311  Presentation and Sales Strategies for Agricultural Audiences  3
ENGL 309  Proposal and Report Writing
ENGL 314  Technical Communication
MKT 343  Personal Sales
SP CM 212  Fundamentals of Public Speaking

Total Credits  8

Complete remaining courses from one of the following options:

Biorenewable Resources Engineering Option: 13cr.
A B E 325  Biorenewable Systems  3
A B E 469  Grain Processing and Handling  3
M E 436  Heat Transfer  4

Biorenewable Elective (select 3cr from the following):
SCM 301  Supply Chain Management  3
FS HN 471  Food Processing I

Total Credits  13

Bioenvironmental Engineering Option: 12 cr.
A B E 431  Design and Evaluation of Soil and Water Conservation Systems  3
C E 326  Principles of Environmental Engineering  3
C E 372  Engineering Hydrology and Hydraulics  3

Bioenvironmental Elective  2  3

Total Credits  12

Food Engineering Option: 13 cr.
A B E 469  Grain Processing and Handling  3
FS HN 420  Food Microbiology  3
M E 436  Heat Transfer  4

Food Elective (select 3cr from the following):
FS HN 471  Food Processing I  3
SCM 301  Supply Chain Management

Total Credits  13

Open Option: 13 cr.

M E 436  Heat Transfer  4

Sequence I, II & III Elective  2  9

Total Credits  13

Co-op/Internships (Optional)
1. These university requirements will add to the minimum credits of the program unless the university-approved courses are also approved by the department to meet other course requirements within the degree program.
U.S. Diversity, International Perspectives and Social Science/Humanities courses may not be taken Pass/Not Pass.
2. Choose from department approved list. (http://www.abe.iastate.edu/undergraduate-students/biological-systems-engineering/bse-curricula)
3. See Basic Program for Professional Engineering Curricula for accepted substitutions for curriculum designated courses in the Basic Program.

See also: A 4-year plan of study grid showing course template by semester for Biological Systems Engineering.

Biological Systems Engineering, B.S. - bioenvironmental engr option

First Year
Fall  Credits  Spring  Credits
ENGR 101  0 A B E 110  1
A B E 170  3 A B E 160  3
CHEM 167  4 MATH 166  4
CHEM 167L  1 PHYS 221  5
MATH 165  4 ENGL 250  3
ENGL 150  3
LIB 160  1

16  16

Second Year
Fall  Credits  Spring  Credits
A B E 216  3 A B E 218  2
E M 274  3 A B E 201  1
BIOL 212  3 A B E 273  1
Chemistry Sequence I with Lab  4 M E 231  3
US Diversity Elective  3 MATH 267  4
Chemistry Sequence II with Lab

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Biological Systems Engineering, B.S. - biorenewable resources engr option

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Biological Systems Engineering, B.S. - Open Option

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Chemistry Sequence II with Lab: 3 A B E 363, 4 A B E 380, 3 E M 324, 3 I E 305, 1 International Perspective, 3 M E 327, 3 M E 436, 3 Social Science or Humanities Elective.
### Biological Systems Engineering, B.S. Food Engineering Option

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### Graduate Study

The department offers master of science, master of engineering, and doctor of philosophy degrees with a major in agricultural and biosystems engineering. Within the agricultural and biosystems engineering major the student may specialize in advanced machinery engineering, animal production systems engineering, biological and process engineering, occupational safety engineering, or water and environmental stewardship engineering. Details on current research programs available at [http://www.abe.iastate.edu/](http://www.abe.iastate.edu/).

For the master of science program, at least 30 credits of acceptable graduate work must be completed with a minimum of 22 credits of course work; corresponding numbers for the master of engineering program are 32 and 27. For the doctor of philosophy degree, at least 72 credits of acceptable graduate work must be completed with a minimum of 42 credits of course work. All Ph.D. students must complete a teaching/extension experience prior to graduation.

The department also offers both master of science and doctor of philosophy degrees in industrial and agricultural technology.
Courses primarily for undergraduates:

**A B E 110: Experiencing Agricultural and Biosystems Engineering**
(0-2) Cr. 1. S.
Laboratory-based, team-oriented experiences in a spectrum of topics common to the practice of agricultural and biosystems engineering. Report writing, co-ops, internships, careers, registration planning.

**A B E 160: Systematic Problem Solving and Computer Programming**
(2-2) Cr. 3. S.
Prereq: Credit or enrollment in MATH 143 or MATH 165
Engineering approach to problem solution and presentation in the context of real world problems. Introduction to basic principles from statics, projectile motion, conservation of mass and energy and electricity and magnetism. Use of spreadsheet programs and computer programming language(s) to solve and present engineering problems. Introduction to interfacing computers to sensor systems for data collection.

**A B E 170: Engineering Graphics and Introductory Design**
(2-2) Cr. 3.
Prereq: Satisfactory scores in math placement assessments; credit or enrollment in MATH 142.
Applications of multi-view drawings and dimensioning. Techniques for visualizing, analyzing, and communicating 3-D geometries. Application of the design process including written and oral reports.

**A B E 201: Preparing for Workplace Seminar**
(Cross-listed with TSM). (1-0) Cr. 1. F.S.
Prereq: Prereq: Sophomore classification in AE, AST, BSE, or I TEC
8 week course. Professionalism in the context of the engineering/technical workplace. Development and demonstration of key workplace competencies: teamwork, initiative, communication, and engineering/technical knowledge. Resumes; Cover Letters; Behavioral Based Interviewing; Industry Speakers; Preparation for internships experiences.

**A B E 216: Fundamentals of Agricultural and Biosystems Engineering**
(2-2) Cr. 3. F.
Prereq: A B E 160 or permission of the instructor
Application of mathematics and engineering sciences to mass and energy balances in agricultural and biological systems. Emphasis is on solving engineering problems in the areas of heat and mass transfer, air and water vapor systems; animal production systems, grain systems; food systems, hydrologic systems, and bioprocessing.

**A B E 218: Project Management & Design in Agricultural and Biosystems Engineering**
(1-2) Cr. 2. S.
Prereq: A B E 216
Project management - critical path, Gantt charts, resource allocations, basic project budgeting, and project management software. Engineering design approaches. Open-ended design projects to demonstrate the preceding principles through application of technical concepts taught in prerequisite coursework.

**A B E 271: Engineering Applications of Parametric Solid Modeling**
(1-2) Cr. 1. F.S.
Prereq: A B E 170 or TSM 116 or equivalent
8 week-course. Creating, editing, and documenting part and assembly models using Solidworks.

**A B E 272: Parametric Solid Models, Drawings, and Assemblies Using Pro/ENGINEER**
(1-2) Cr. 1. F.S.
Prereq: A B E 170 or TSM 116 or equivalent
8 week-course. Applications of Creo Parametric software. Create solid models of parts and assemblies. Utilize the solid models to create design documentation (standard drawing views, dimensions, and notes) and for the geometric analysis of parts and assemblies.

**A B E 273: CAD for Process Facilities and Land Use Planning**
(1-2) Cr. 1. F.S.
Prereq: ENGR 170 or TSM 116 or equivalent. 8-week course.
8-week course. Application of 2-D AutoCAD software to create and interpret 2-D drawings and 3-D models of facilities. Topics include geometric construction, design documentation: (using views, dimension, notes), and AutoCAD specific features (i.e. Layers, Blocks, Standards, Styles).

**A B E 316: Applied Numerical Methods for Agricultural and Biosystems Engineering**
(2-2) Cr. 3. F.
Prereq: A B E 160 or permission of the instructor
Computer aided solution of agricultural engineering problems by use of numerical techniques and mathematical models. Systems analysis and optimization applicable to agricultural and biological systems.

**A B E 325: Biorenewable Systems**
(Cross-listed with TSM). (3-0) Cr. 3. F.
Prereq: ECON 101; CHEM 163 or higher; and MATH 140 or higher
Converting biorenewable resources into bioenergy and biobased products. Biorenewable concepts as they relate to drivers of change, feedstock production, processes, products, co-products, economics, and transportation/logistics.
A B E 340: Functional Analysis and Design of Agricultural Field Machinery
(2-2) Cr. 3. F.
Prereq: A B E 110, A B E 216
Principles of operation, design, selection, testing and evaluation of agricultural field machinery and systems. Functional and mechanical performances. Crop and soil interaction with machines. Machine systems, including land preparation, crop establishment, crop protection, harvesting and post-harvest, materials handling systems.

A B E 342: Agricultural Tractor Power
(2-3) Cr. 3. S.
Prereq: Ch E 381 or M E 231
Thermodynamic principles and construction of tractor engines. Fuels, combustion, and lubrication. Kinematics and dynamics of tractor power applications; drawbar, power take-off and traction mechanisms.

A B E 363: Agri-Industrial Applications of Electric Power and Electronics
(3-2) Cr. 4. F.S.
Prereq: A B E 218

A B E 380: Principles of Biological Systems Engineering
(2-2) Cr. 3. S.
Prereq: A B E 316
Unit-operation analysis of biological systems, through the study of mass, energy, and information transport in bioresource production and conversion systems. Quantification and modeling of biomass production, ecological interactions, and bioreactor operations.

A B E 388: Sustainable Engineering and International Development
(Cross-listed with C E, E E). (2-2) Cr. 3. F.
Prereq: Junior classification in engineering
Multi-disciplinary approach to sustainable engineering and international development, sustainable development, appropriate design and engineering, feasibility analysis, international aid, business development, philosophy and politics of technology, and ethics in engineering. Engineering-based projects from problem formulation through implementation. Interactions with partner community organizations or international partners such as nongovernment organizations (NGOs). Course readings, final project/design report. Meets International Perspectives Requirement.

A B E 396: Summer Internship
Cr. R. Repeatable. SS.
Prereq: Permission of department and Engineering Career Services
Professional work period of at least 10 weeks during the summer. Students must register for this course prior to commencing work. Offered on a satisfactory-fail basis only.

A B E 398: Cooperative Education
Cr. R. Repeatable. F.S.
Prereq: A B E 218 and permission of department and Engineering Career Services
Professional work period. One semester per academic or calendar year. Students must register for this course before commencing work. Offered on a satisfactory-fail basis only.

A B E 403: Modeling, Simulation, and Controls for Agricultural and Biological Systems
(Dual-listed with A B E 503). (2-2) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: A B E 316, and A B E 363, and MATH 266 or MATH 267
Modeling dynamic systems with ordinary differential equations. Introduction to state variable methods of system analysis. Analysis of mechanical, electrical, and fluid power systems. Analytical and numerical solutions of differential equations. Introduction to classical control theory. Feedback and stability examined in the s domain. Frequency response as an analytical and experimental tool. MATLAB will be used throughout the course for modeling. Individual and/or group projects required for graduate credit.

A B E 404: Instrumentation for Agricultural and Biosystems Engineering
(Dual-listed with A B E 504). (2-2) Cr. 3. F.
Prereq: A B E 316 and A B E 363 or CPR E 281
Interfacing techniques for computer-based data acquisition and control systems. Basic interfacing components including A/D and D/A conversion, signal filtering, multiplexing, and process control. Sensors and theory of operation applied to practical monitoring and control problems. Individual and group projects required for graduate credit.

A B E 408: GIS and Natural Resources Management
(Dual-listed with A B E 508). (Cross-listed with ENSCI). (2-2) Cr. 3. F.
Prereq: Working knowledge of computers and Windows environment
Introduction to fundamental concepts and applications of GIS in natural resources management with specific focus on watersheds. Topics include: basic GIS technology, data structures, database management, spatial analysis, and modeling; visualization and display of natural resource data. Case studies in watershed and natural resource management using ArcView GIS.
A B E 410: Electronic Systems Integration for Agricultural Machinery & Production Systems  
(Dual-listed with A B E 510). Cr. 3. Alt. S., offered odd-numbered years.  
Prereq: A B E 363  
System architecture and design of electronics used in agricultural machinery and production systems. Emphasis on information technology and systems integration for automated agriculture processes. Design of Controller Area Network (CAN BUS) communication systems and discussion of relevant standards (ISO 11783 and SAE J1939). Application of technologies for sensing, distribution control, and automation of agricultural machinery will be emphasized.

A B E 413: Fluid Power Engineering  
(Cross-listed with M E). (2-2) Cr. 3. F.  
Prereq: Credit or enrollment in E M 378 or M E 335, A B E 216 or M E 270  

A B E 415: Agricultural & Biosystems Engineering Design I  
(1-2) Cr. 2. F.S.  
Prereq: A B E 316 (majors only)  
Identification of current design problems in ag & biosystems engineering. Development of alternate solutions using creativity and engineering analysis and synthesis techniques.

A B E 416: Agricultural & Biosystems Engineering Design II  
(1-2) Cr. 2. F.S.  
Prereq: A B E 415 (majors only)  
Selection of promising solutions to design problems identified in 415 for development by design teams. Presentation of designs through oral and written reports and prototypes.

A B E 418: Fundamentals of Engineering Review  
(1-0) Cr. 1.  
Prereq: senior classification.  
8 week course. Review of core concepts covered in the Fundamentals of Engineering examination with emphasis on statics, dynamics, fluid mechanics, heat transfer, electric circuits, and engineering economics. Open to all College of Engineering seniors, however focus is on the general exam, not discipline specific exams.

A B E 424A: Air Pollution: Air quality and effects of pollutants  
(Dual-listed with A B E 524A). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above  
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

A B E 424B: Air Pollution: Climate change and causes  
(Dual-listed with A B E 524B). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above  
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

A B E 424C: Air Pollution: Transportation Air Quality  
(Dual-listed with A B E 524C). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.  
Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in statistics. Senior classification or above.

A B E 424D: Air Pollution: Off-gas treatment technology  
(Dual-listed with A B E 524D). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.  
Prereq: C E 524A, C E 524B; Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above.

A B E 424E: Air Pollution: Agricultural sources of pollution  
(Dual-listed with A B E 524E). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.  
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above  
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

A B E 431: Design and Evaluation of Soil and Water Conservation Systems  
(Dual-listed with A B E 531). (2-3) Cr. 3. F.  
Prereq: E M 378 or CH E 356  
Hydrology and hydraulics in agricultural and urbanizing watersheds. Design and evaluation of systems for the conservation and quality preservation of soil and water resources. Use and analysis of hydrologic data in engineering design; relationship of topography, soils, crops, climate, and cultural practices in conservation and quality preservation of soil and water for agriculture. Small watershed hydrology, water movement and utilization in the soil-plant-atmosphere system, agricultural water management, best management practices, and agricultural water quality. Graduate students will prepare several research literature reviews on topics covered in the class in addition to the other assignments.
A B E 432: Nonpoint Source Pollution and Control
(Dual-listed with A B E 532). (3-0) Cr. 3.
Prereq: A B E 431 or C E 372 or instructor permission
Characteristics and courses of non-point source (NPS) pollution in agricultural and urban watersheds, computer modeling and NPS pollution for terrestrial and aquatic systems, strategies to control and manage NPS pollution of water bodies, total maximum daily loads (TMDLs) and integrated watershed management. Graduate students are required to review research papers and develop/deliver lecture models on assigned topics.

A B E 436: Design and Evaluation of Soil and Water Monitoring Systems
(Dual-listed with A B E 536). (2-3) Cr. 3. Alt. S., offered even-numbered years.
Prereq: A B E 431/A B E 531
Development of monitoring systems that support effective planning, performance evaluation, modeling, or environmental impact assessment of soil-, water-, and waste-management systems. Typical soil and water pollutants and physical, chemical, and biological characteristics that affect sample location and timing. Sample collection, documentation, chain-of-custody, and quality assurance procedures. In addition to other assignments, graduate students will prepare several research literature reviews on topics covered in the class and develop monitoring plans.

A B E 437: Watershed Modeling and Policy
(Dual-listed with A B E 537). (Cross-listed with ENSCI). (2-2) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: CE 372 or equivalent
A project-based course on watershed-scale models for improving water quality. Legislative and judicial basis of the Total Maximum Daily Load (TMDL) program; approaches to TMDL development; principles and techniques for implementation; stakeholder engagement strategies. Hands-on experiences with GIS-interfaced models, data sources, calibration/validation, statistical assessment of model results, and simulation using multiple tools. In addition to other assignments, graduate students will present case studies of TMDLs using different modeling tools.

A B E 451: Food and Bioprocess Engineering
(Dual-listed with A B E 551). (3-0) Cr. 3. S.
Prereq: A B E 216 and credit or enrollment in M E 436 or CH E 357; or FS HN 351 and MATH 266 or MATH 267
Application of engineering principles and mathematical modeling to the quantitative analysis of food and bioprocessing systems. Physical/chemical characteristics of foods and biological systems, flow processes, thermal processes and separation processes. Term paper required for graduate credit.

A B E 466: Multidisciplinary Engineering Design
(Cross-listed with AER E, B M E, C R P E, E E, E NGR, I E, M E, M AT E). (1-4) Cr. 3. Repeatable. F.S.
Prereq: Student must be within two semesters of graduation; permission of instructor.
Application of team design concepts to projects of a multidisciplinary nature. Concurrent treatment of design, manufacturing, and life cycle considerations. Application of design tools such as CAD, CAM, and FEM. Design methodologies, project scheduling, cost estimating, quality control, manufacturing processes. Development of a prototype and appropriate documentation in the form of written reports, oral presentations and computer models and engineering drawings.

A B E 469: Grain Processing and Handling
(Dual-listed with A B E 569). (Cross-listed with BSE). (2-3) Cr. 3. S.
Prereq: A B E 216
Cereal grain and oilseed properties, quality measurement, processing, and end-use value. Design of drying systems using computer simulation. Corn wet and dry milling. Soybean oil extraction. Grain handling systems.

A B E 472: Design of Environmental Modification Systems for Animal Housing
(Dual-listed with A B E 572). (3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: A B E 216, M E 231
Principles and design of animal environmental control systems. Insulation, heat and mass transfer, fans, ventilation, air distribution, heating and cooling equipment, and controls. Individual and group projects required for graduate credit.

A B E 475: Design in Animal Production Systems Engineering
(2-0) Cr. 2. F.S.
Prereq: A B E 271 or A B E 272, E M 324 and enrollment in APSE option of AE program.
Application of engineering fundamentals to the independent solution of an animal production systems engineering problem with well defined criteria and constraints in either environmental control, structural design, manure management, or air quality/mitigation.

A B E 478: Wood Frame Structural Design
(Dual-listed with A B E 578). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: A B E 216, E M 324
A BE 480: Engineering Analysis of Biological Systems
(Cross-listed with ENSCI). (2-2) Cr. 3. F.
Prereq: A B E 380 or permission of the instructor
Systems-level quantitative analysis of biological systems, including applications in foods, feeds, biofuels, bioenergy, and other biological systems. Introduction to economic analysis and life-cycle assessment of these systems at multiple production scales. Applying these tools to evaluate and improve cost and sustainability performance of these biological systems.

A BE 490: A BE Independent Study
Cr. 1-5. Repeatable.
Independent Study.

Cr. 1-5. Repeatable.
Independent Study.

A BE 490B: A BE Independent Study: Biorenewable Resources
Cr. 1-5. Repeatable. F.S.SS.
Independent study.

A BE 490E: A BE Independent Study: Environmental Bioprocessing Engineering
Cr. 1-5. Repeatable. F.S.SS.
Independent study in environmental bioprocessing engineering.

A BE 490F: A BE Independent Study: Food Engineering
Cr. 1-5. Repeatable. F.S.SS.
Independent study in food engineering.

A BE 490G: A BE Independent Study: General Topics in A BE
Cr. 1-5. Repeatable. F.S.SS.
Independent study in general A BE topics.

A BE 490H: A BE Independent Study: Honors
Cr. 1-5. Repeatable.
Guided instructing in agricultural and biosystems engineering for honors students.

A BE 490L: A BE Independent Study: Land & Water Resources Engineering
Cr. 1-5. Repeatable.
Guided instruction in land and water resources engineering.

A BE 490M: A BE Independent Study: Advanced Machinery Systems Engineering
Cr. 1-5. Repeatable.
Guided instruction in advance machinery systems engineering.

A BE 495: Agricultural and Biosystems Engineering Department Study Abroad Preparation or Follow-up
(Cross-listed with TSM). Cr. 1-2. Repeatable. F.S.SS.
Prereq: Permission of instructor
Preparation for, or follow-up of, study abroad experience (496). For preparation, course focuses on understanding the tour destination through readings, discussions, and research on topics such as the regional industries, climate, crops, culture, economics, food, geography, government, history, natural resources, and public policies. For follow-up, course focuses on presentations by students, report writing, and reflection. Students enrolled in this course intend to register for 496 the following term or have had taken 496 the previous term.
Meets International Perspectives Requirement.

A BE 496: Agricultural and Biosystems Engineering Department Study Abroad
(Cross-listed with TSM). Cr. 1-4. Repeatable. F.S.SS.
Prereq: Permission of instructor
Tour and study at international sites relevant to disciplines of industrial technology, biological systems engineering, agricultural systems technology, and agricultural engineering. Location and duration of tours will vary. Trip expenses paid by students. Pre-trip preparation and/or post-trip reflection and reports arranged through 495.
Meets International Perspectives Requirement.

Courses primarily for graduate students, open to qualified undergraduates:

A BE 503: Modeling, Simulation, and Controls for Agricultural and Biological Systems
(Dual-listed with A B E 403). (2-2) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: A B E 316, and A B E 363, and MATH 266 or MATH 267
Modeling dynamic systems with ordinary differential equations. Introduction to state variable methods of system analysis. Analysis of mechanical, electrical, and fluid power systems. Analytical and numerical solutions of differential equations. Introduction to classical control theory. Feedback and stability examined in the s domain. Frequency response as an analytical and experimental tool. MATLAB will be used throughout the course for modeling. Individual and/or group projects required for graduate credit.

A BE 504: Instrumentation for Agricultural and Biosystems Engineering
(Dual-listed with A B E 404). (2-2) Cr. 3. F.
Prereq: A B E 316 and A B E 363 or CPR E 281
Interfacing techniques for computer-based data acquisition and control systems. Basic interfacing components including A/D and D/A conversion, signal filtering, multiplexing, and process control. Sensors and theory of operation applied to practical monitoring and control problems. Individual and group projects required for graduate credit.
A B E 506: Applied Computational Intelligence
(2-2) Cr. 3. Alt. F., offered even-numbered years.
Prereq: A B E 316 or equivalent, MATH 166, STAT 305
Applications of biologically inspired computational intelligence tools for data mining, system modeling, and optimization for agricultural, biological and other engineered systems. Introduction to Artificial Neural Networks, Support Vector Machines, Fuzzy Logic, Genetic Algorithms, Bayesian and Decision Tree learning. Fundamental Machine Vision techniques will be introduced in the first part of course and be integrated into the lab exercises for learning different computational intelligence techniques. MATLAB will be used throughout the course for algorithm implementation.

A B E 508: GIS and Natural Resources Management
(Dual-listed with A B E 408). (Cross-listed with ENSCI). (2-2) Cr. 3. F.
Prereq: Working knowledge of computers and Windows environment
Introduction to fundamental concepts and applications of GIS in natural resources management with specific focus on watersheds. Topics include: basic GIS technology, data structures, database management, spatial analysis, and modeling; visualization and display of natural resource data. Case studies in watershed and natural resource management using ArcView GIS.

A B E 510: Electronic Systems Integration for Agricultural Machinery & Production Systems
(Dual-listed with A B E 410). Cr. 3. Alt. S., offered odd-numbered years.
Prereq: A B E 363
System architecture and design of electronics used in agricultural machinery and production systems. Emphasis on information technology and systems integration for automated agriculture processes. Design of Controller Area Network (CAN BUS) communication systems and discussion of relevant standards (ISO 11783 and SAE J1939). Application of technologies for sensing, distribution control, and automation of agricultural machinery will be emphasized.

A B E 515: Integrated Crop and Livestock Production Systems
(Cross-listed with AGRON, AN S, SUSAG). (3-0) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: SUSAG 509
Methods to maintain productivity and minimize the negative ecological effects of agricultural systems by understanding nutrient cycles, managing manure and crop residue, and utilizing multispecies interactions. Crop and livestock production within landscapes and watersheds is also considered. Course includes a significant field component, with student teams analyzing Iowa farms.

A B E 524: Air Pollution
(Dual-listed with A B E 424). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

A B E 524A: Air Pollution: Air quality and effects of pollutants
(Dual-listed with A B E 424A). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

A B E 524B: Air Pollution: Climate change and causes
(Dual-listed with A B E 424B). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.

A B E 524C: Air Pollution: Transportation Air Quality
(Dual-listed with A B E 424C). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.
Prereq: C E 524A; PHYS 221 or CHEM 178; MATH 166 or 3 credits in statistics. Senior classification or above.

A B E 524D: Air Pollution: Off-gas treatment technology
(Dual-listed with A B E 424D). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.
Prereq: C E 524A, C E 524B; Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above

A B E 524E: Air Pollution: Agricultural sources of pollution
(Dual-listed with A B E 424E). (Cross-listed with C E, ENSCI). (1-0) Cr. 1.
Prereq: Either PHYS 221 or CHEM 178 and either MATH 166 or 3 credits in statistics. Senior classification or above
1 cr. per module. Module A prereq for all modules; module B prereq for D and E.
A B E 531: Design and Evaluation of Soil and Water Conservation Systems
(Dual-listed with A B E 431). (Cross-listed with ENSCI). (2-3) Cr. 3. F.
Prereq: E M 378 or CH E 356
Hydrology and hydraulics in agricultural and urbanizing watersheds. Design and evaluation of systems for the conservation and quality preservation of soil and water resources. Use and analysis of hydrologic data in engineering design; relationship of topography, soils, crops, climate, and cultural practices in conservation and quality preservation of soil and water for agriculture. Small watershed hydrology, water movement and utilization in the soil-plant-atmosphere system, agricultural water management, best management practices, and agricultural water quality. Graduate students will prepare several research literature reviews on topics covered in the class in addition to the other assignments.

A B E 532: Nonpoint Source Pollution and Control
(Dual-listed with A B E 432). (Cross-listed with ENSCI). (3-0) Cr. 3.
Prereq: A B E 431 or C E 372 or instructor permission
Characteristics and courses of non-point source (NPS) pollution in agricultural and urban watersheds, computer modeling and NPS pollution for terrestrial and aquatic systems, strategies to control and manage NPS pollution of water bodies, total maximum daily loads (TMDLs) and integrated watershed management. Graduate students are required to review research papers and develop/deliver lecture models on assigned topics.

A B E 533: Erosion and Sediment Transport
(Cross-listed with ENSCI, NREM). (2-3) Cr. 3.
Prereq: C E 372 or GEOL/ENSCI/MTEOR 402, MATH 166 or equivalent
Soil erosion processes, soil loss equations and their application to conservation planning, sediment properties, initiation of sediment motion and over land flow, flow in alluvial channels and theory of sediment transport, channel stability, reservoir sedimentation, wind erosion, BMPs for controlling erosion.

A B E 536: Design and Evaluation of Soil and Water Monitoring Systems
(Dual-listed with A B E 436). (Cross-listed with ENSCI). (2-3) Cr. 3. Alt. S., offered even-numbered years.
Prereq: A B E 431/A B E 531
Development of monitoring systems that support effective planning, performance evaluation, modeling, or environmental impact assessment of soil-, water-, and waste-management systems. Typical soil and water pollutants and physical, chemical, and biological characteristics that affect sample location and timing. Sample collection, documentation, chain-of-custody, and quality assurance procedures. In addition to other assignments, graduate students will prepare several research literature reviews on topics covered in the class and develop monitoring plans.

A B E 537: Watershed Modeling and Policy
(Dual-listed with A B E 437). (Cross-listed with ENSCI). (2-2) Cr. 3. Alt. F., offered odd-numbered years.
Prereq: CE 372 or equivalent
A project-based course on watershed-scale models for improving water quality. Legislative and judicial basis of the Total Maximum Daily Load (TMDL) program; approaches to TMDL development; principles and techniques for implementation; stakeholder engagement strategies. Hands-on experiences with GIS-interfaced models, data sources, calibration/validation, statistical assessment of model results, and simulation using multiple tools. In addition to other assignments, graduate students will present case studies of TMDLs using different modeling tools.

A B E 551: Food and Bioprocess Engineering
(Dual-listed with A B E 451). (3-0) Cr. 3. S.
Prereq: A B E 216 and credit or enrollment in M E 436 or CH E 357; or FS HN 351 and MATH 266 or MATH 267
Application of engineering principles and mathematical modeling to the quantitative analysis of food and bioprocessing systems. Physical/chemical characteristics of foods and biological systems, flow processes, thermal processes and separation processes. Term paper required for graduate credit.

A B E 569: Grain Processing and Handling
(Dual-listed with A B E 469). (2-3) Cr. 3. S.
Prereq: A B E 216
Cereal grain and oilseed preservation, quality measurement, and end-use value. Design of drying systems using computer simulation. Corn wet and dry milling. Soybean oil extraction. Grain handling systems. Individual and group projects required for graduate credit.

A B E 572: Design of Environmental Modification Systems for Animal Housing
(Dual-listed with A B E 472). (3-0) Cr. 3. Alt. S., offered even-numbered years.
Prereq: A B E 216, M E 231
Principles and design of animal environmental control systems. Insulation, heat and mass transfer, fans, ventilation, air distribution, heating and cooling equipment, and controls. Individual and group projects required for graduate credit.

A B E 578: Wood Frame Structural Design
(Dual-listed with A B E 478). (3-0) Cr. 3. Alt. S., offered odd-numbered years.
Prereq: A B E 216, E M 324
A B E 580: Engineering Analysis of Biological Systems
(2-2) Cr. 3. F.
Prereq: A B E 216; MATH 266; BIOL 211 or BIOL 212; M E 231
Systems-level engineering analysis of biological systems. Economic and life-cycle analysis of bioresource production and conversion systems. Global energy and resource issues and the role of biologically derived materials in addressing these issues. Students enrolled in ABE 580 will be required to answer additional exam questions and report on two journal articles.

A B E 590: Special Topics in Agricultural & Biosystems Engineering
Cr. 1-3. Repeatable.
Guided instruction and self-study on special topics relevant to agricultural and biosystems engineering.

A B E 598: Technical Communications for a Master's Degree
(Cross-listed with TSM). Cr. 1. F.S.SS.
A technical paper draft based on the M.S. thesis or creative component is required of all master's students. This paper must be in a form that satisfies the requirements of some specific journal and be ready for submission. A technical presentation based on M.S. thesis or creative component is required of all master's students. This presentation must be in a form that satisfies the normal presentation requirements of a professional society. The presentation itself (oral or poster) may be made at a professional society meeting or at any international, regional, state, or university conference/event as long as the presentation content and form conforms to normal expectations. Offered on a satisfactory-fail basis only.

A B E 599: Creative Component
Cr. arr. Repeatable.
Creative Component.

Courses for graduate students:

A B E 601: Graduate Seminar
(Cross-listed with TSM). (1-0) Cr. 1. F.
Keys to starting a good MS thesis or PhD dissertation project. Learning how to begin formulating research questions. Review of literature, research hypotheses, objectives, methods, making figures and tables, and discussing results. Discussion of appropriate outlets including peer-reviewed journals, patents and intellectual property rights, responsible conduct, plagiarism, authorship, and reproducible research. Using peer review, conducting a peer review, and responding to feedback. Other topics may include on-campus library resources, data management, and time management.

A B E 610: Foundations of Sustainable Agriculture
(Cross-listed with AGRON, ANTHR, SOC, SUSAG). (3-0) Cr. 3. F.
Prereq: Graduate classification, permission of instructor
Historical, biophysical, socioeconomic, and ethical dimensions of agricultural sustainability. Strategies for evaluating existing and emerging agricultural systems in terms of the core concepts of sustainability and their theoretical contexts.

A B E 690: Advanced Topics
Cr. arr. Repeatable.
Advanced topics.

A B E 694: Teaching Practicum
(Cross-listed with TSM). Cr. 1-3. Repeatable. F.S.SS.
Prereq: Graduate classification and permission of instructor
Graduate student experience in the agricultural and biosystems engineering departmental teaching program.

A B E 697: Engineering Internship
Cr. R. Repeatable.
Prereq: Permission of department chair, graduate classification
One semester and one summer maximum per academic year professional work period.

A B E 698: Technical Communications for a Doctoral Degree
(Cross-listed with TSM). Cr. 1. F.S.SS.
A technical paper draft based on the dissertation is required of all Ph.D. students. This paper must be in a form that satisfies the requirements of some specific journal and be ready for submission. A technical presentation based on the dissertation is required of all Ph.D. students. This presentation must be in a form that satisfies the normal presentation requirements of a professional society. The presentation itself (oral or poster) may be made at a professional society meeting or at any international, regional, state, or university conference/event as long as the presentation content and form conforms to normal expectations. Offered on a satisfactory-fail basis only.

A B E 699: Research
Cr. arr. Repeatable.
Research.

A B E 699B: Research: Biosystems Engineering
Cr. arr. Repeatable.
Guided graduate research in biosystems engineering.

A B E 699C: Research: Computer Aided Design
Cr. arr. Repeatable.
Guided graduate research in computer-aided design.
A B E 699E: Research: Environmental Systems
Cr. arr. Repeatable.
Guided graduate research in environmental systems.

A B E 699F: Research: Food Engineering
Cr. arr. Repeatable.
Guided graduate research in food engineering.

A B E 699O: Research: Occupational Safety
Cr. arr. Repeatable.
Guided graduate research in occupational safety.

A B E 699P: Research: Power and Machinery Engineering
Cr. arr. Repeatable.
Guided graduate research in power and machinery engineering.

A B E 699Q: Research: Structures
Cr. arr. Repeatable.
Guided graduate research in structures.

A B E 699R: Research: Process Engineering
Cr. arr. Repeatable.
Guided graduate research in process engineering.

A B E 699S: Research: Environment and Natural Resources
Cr. arr. Repeatable.
Guided graduate research in environment and natural resources.

A B E 699U: Research: Waste Management
Cr. arr. Repeatable.
Guided graduate research in waste management.