# AGRICULTURAL ENGINEERING

For the undergraduate curriculum in agricultural engineering leading to the degree bachelor of science. The Agricultural Engineering program is accredited by the Engineering Accreditation Commission of ABET, http://www.abet.org/.

**Goal:** To educate students in the analysis and design of machinery, animal housing, and environmental systems for the production, processing, storage, handling, distribution, and use of food, feed, fiber and other biomaterials, and the management of related natural resources, by integrating basic physical and biological sciences with engineering design principles.

**Program Educational Objectives:**Three to five years after graduation, our graduates will be using the knowledge, skills, and abilities from their agricultural 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.

Graduates find employment in diverse ag- and bio-related industries and government agencies dealing with agricultural machines and buildings, animal and environmental control, grain processing and handling, soil and water resources, food, biorenewables, and biotechnology. Their work involves engineering design, development, testing, research, manufacturing, consulting, sales, and service. Students are highly encouraged to participate in either cooperative education or internship programs.

The department also offers a bachelor of science curriculum in biological systems engineering. Additionally, the department offers bachelor of science curricula in agricultural systems technology and in industrial technology.

Well-qualified juniors and seniors in agricultural 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 agricultural engineering and a master of science degree in agricultural engineering. A concurrent bachelor of science and master of business administration program is also offered by the department. Refer to Graduate Study for more information.

## Curriculum in Agricultural Engineering

Administered by the Department of Agricultural and Biosystems Engineering.

Leading to the degree bachelor of science.

Total credits required: 126.0cr Land and Water Resources Engineering Option, 128.0cr Power and Machinery Engineering Option, 128.0cr Animal Production Systems Engineering 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.** [1]
**U.S. Diversity: 3 cr.** [1]
**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 | |
| ENGL 314 | Technical Communication | |
| SP CM 212 | Fundamentals of Public Speaking | |
| MKT 343 | Personal Sales | |

**Social Sciences and Humanities: 12 cr.** [1,2]

| | | |
|---|---|---|
| 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] | 3 |
| CHEM 167 | General Chemistry for Engineering Students | 4 |
| or CHEM 177 | | |
| and | | |
| CHEM 178 | General Chemistry II | |
| 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 |
| ENGR 101 | Engineering Orientation | R |
| 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 |

**Math and Physical Science: 7 cr.**

| | | |
|---|---|---|
| CHEM 167L | Laboratory in General Chemistry for Engineering | 1 |
| or CHEM 177L | Laboratory in General Chemistry I | |
| MATH 266 | Elementary Differential Equations | 3 |
| STAT 305 | Engineering Statistics | 3 |
| Total Credits | | 7 |

**Ag Engineering Core: 35 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 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 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 |
| 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 | | 35 |

**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) | | 3 |
| AGEDS 311 | Presentation and Sales Strategies for Agricultural Audiences | |
| 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:

**Land and Water Resources Engineering Option: 37 cr.**

| | | |
|---|---|---|
| A B E 431 | Design and Evaluation of Soil and Water Conservation Systems | 3 |
| AGRON 181 | Introduction to Crop Science | 3 |
| AGRON 182 | Introduction to Soil Science | 3 |
| BIOL 251 | Biological Processes in the Environment | 3 |
| or BIOL 211 | | |
| C E 326 | Principles of Environmental Engineering | 3 |
| C E 372 | Engineering Hydrology and Hydraulics | 3 |
| GEOL 201 | Geology for Engineers and Environmental Scientists | 3 |
| MICRO 201 | Introduction to Microbiology | 2 |
| MICRO 201L | Introductory Microbiology Laboratory | 1 |
| Computer Graphics (One of the following): | | 1 |
| A B E 271 | Engineering Applications of Parametric Solid Modeling | |
| A B E 272 | Parametric Solid Models, Drawings, and Assemblies Using Pro/ENGINEER | |
| A B E 273 | CAD for Process Facilities and Land Use Planning (Preferred) | |
| GIS Elective (One of the following): | | 3 |
| C R P 251X | Fundamentals of Geographic Information Systems | |
| C R P 451 | Introduction to Geographic Information Systems | |
| ENSCI 270X | Geospatial Technology | |
| ENSCI 461I | Introduction to GIS | |
| GEOL 452 | GIS for Geoscientists | |
| NREM 345 | Natural Resource Photogrammetry and Geographic Information Systems | |
| NREM 446 | Integrating GPS and GIS for Natural Resource Management | |
| Subsurface Systems Elective (One of the following): | | 3 |
| C E 360 | Geotechnical Engineering | |
| C E 473 | Groundwater Hydrology | |

| | | |
|---|---|---|
| Water Quality Elective (One of the following): | | 3 |
| A B E 432 | Nonpoint Source Pollution and Control | |
| A B E 436 | Design and Evaluation of Soil and Water Monitoring Systems (offered Spring even years) | |
| A B E 537 | Watershed Modeling and Policy | |
| A B E Breadth (One of the following): | | 3 |
| A B E 340 | Functional Analysis and Design of Agricultural Field Machinery | |
| A B E 380 | Principles of Biological Systems Engineering | |
| A B E 424 (3 different 1cr modules) | | |
| A B E 424A | Air Pollution: Air quality and effects of pollutants | |
| A B E 424B | Air Pollution: Climate change and causes | |
| A B E 424C | Air Pollution: Transportation Air Quality | |
| A B E 424D | Air Pollution: Off-gas treatment technology | |
| A B E 424E | Air Pollution: Agricultural sources of pollution | |
| A B E 469 | Grain Processing and Handling | |
| A B E 472 | Design of Environmental Modification Systems for Animal Housing (offered Spring even years) | |
| A B E 478 | Wood Frame Structural Design (offered Spring odd years) | |
| A B E 480 | Engineering Analysis of Biological Systems | |
| Total Credits | | 37 |

**Power and Machinery Engineering Option: 39 cr.**

| | | |
|---|---|---|
| A B E 340 | Functional Analysis and Design of Agricultural Field Machinery | 3 |
| A B E 342 | Agricultural Tractor Power | 3 |
| A B E 410 | Electronic Systems Integration for Agricultural Machinery & Production Systems | 3 |
| A B E 413 | Fluid Power Engineering | 3 |
| AGRON 182 | Introduction to Soil Science | 3 |
| BIOL 251 | Biological Processes in the Environment | 3 |
| or BIOL 211 | | |
| E M 345 | Engineering Dynamics | 3 |
| MAT E 273 | Principles of Materials Science and Engineering | 3 |
| M E 324 | Manufacturing Engineering | 3 |
| M E 324L | Manufacturing Engineering Laboratory | 1 |
| M E 325 | Mechanical Component Design | 3 |
| Computer Graphics (Two of the following): | | 2 |
| A B E 271 | Engineering Applications of Parametric Solid Modeling | |
| A B E 272 | Parametric Solid Models, Drawings, and Assemblies Using Pro/ENGINEER | |
| A B E 273 | CAD for Process Facilities and Land Use Planning | |
| A B E Elective (One of the following): | | 3 |
| A B E 431 | Design and Evaluation of Soil and Water Conservation Systems | |
| A B E 469 | Grain Processing and Handling | |
| A B E 472 | Design of Environmental Modification Systems for Animal Housing (offered Spring even years) | |
| A B E 478 | Wood Frame Structural Design (offered Spring odd years) | |
| A B E 480 | Engineering Analysis of Biological Systems | |
| Math/Science Elective | | 3 |
| AGRON 181 | Introduction to Crop Science | |
| CHEM 178 | General Chemistry II (In combination with CHEM 177) | |
| MATH 207 | Matrices and Linear Algebra | |
| MATH 265 | Calculus III | |
| PHYS 222 | Introduction to Classical Physics II | |
| Total Credits | | 39 |

**Animal Production Systems Engineering Option: 39 cr.**

| | | |
|---|---|---|
| A B E 469 | Grain Processing and Handling | 3 |
| A B E 472 | Design of Environmental Modification Systems for Animal Housing (offered Spring even years) | 3 |
| A B E 475 | Design in Animal Production Systems Engineering | 2 |
| A B E 478 | Wood Frame Structural Design (offered Spring odd years) | 3 |
| AN S 114 | Survey of the Animal Industry | 2 |
| BIOL 251 | Biological Processes in the Environment | 3 |
| or BIOL 211 | | |
| C E 332 | Structural Analysis I | 3 |
| C E 333 | Structural Steel Design I | 3 |
| C E 334 | Reinforced Concrete Design I | 3 |
| M E 436 | Heat Transfer | 4 |
| Animal Science/Agronomy Elective (One of the following): | | 3 |
| AGRON 206 | Introduction to Weather and Climate | |
| AN S 223 | Poultry Science | |
| AN S 225 | Swine Science | |
| AN S 226 | Beef Cattle Science | |
| AN S 229 | Sheep Science | |
| AN S 235 | Dairy Cattle Science | |
| Computer Graphics (One of the following): | | 1 |
| A B E 271 | Engineering Applications of Parametric Solid Modeling | |
| A B E 272 | Parametric Solid Models, Drawings, and Assemblies Using Pro/ENGINEER | |

| | | |
|---|---|---|
| A B E 273 | CAD for Process Facilities and Land Use Planning (Preferred) | |
| A B E elective (One of the following): [2] | | 3 |
| A B E 431 | Design and Evaluation of Soil and Water Conservation Systems | |
| A B E 340 | Functional Analysis and Design of Agricultural Field Machinery | |
| A B E 480 | Engineering Analysis of Biological Systems | |
| Math/Science Elective | | 3 |
| AGRON 181 | Introduction to Crop Science | |
| AGRON 182 | Introduction to Soil Science | |
| CHEM 178 | General Chemistry II (In combination with CHEM 177) | |
| MATH 265 | Calculus III | |
| MATH 207 | Matrices and Linear Algebra | |
| PHYS 222 | Introduction to Classical Physics II | |
| Total Credits | | 39 |

**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/agricultural-engineering/ae-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.

Agricultural Engineering, B.S. - power & machinery 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 |
| MAT E 273 | 3 | E M 324 | 3 |
| AGRON 182 | 3 | MATH 266 | 3 |
| Math/Science Elective | 3 | STAT 305 | 3 |
| | | US Diversity Elective | 3 |
| | 15 | | 15 |

**Third Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| A B E 340 | 3 | A B E 316 | 3 |
| A B E 363 | 4 | A B E 342 | 3 |
| E M 327 | 1 | E M 378 | 3 |
| E M 345 | 3 | M E 324L | 1 |
| M E 231 | 3 | BIOL 251 (OR BIOL 211) | 3 |
| International Perspectives Elective | 3 | Computer Graphics Elective | 2 |
| | 17 | | 15 |

**Fourth Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| A B E 415 | 2 | A B E 416 | 2 |
| A B E 404 | 3 | A B E 410 | 3 |
| A B E 413 | 3 | A B E Elective | 3 |
| M E 324 | 3 | I E 305 | 3 |
| M E 325 | 3 | Social Science or Humanities Elective | 3 |
| Communication Elective | 3 | Social Science or Humanities Elective | 3 |
| | 17 | | 17 |

Agricultural Engineering, B.S. - animal production systems engineering 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 |
| MATH 266 | 3 | E M 324 | 3 |
| Math/Science Elective | 3 | M E 231 | 3 |
| US Diversity Elective | 3 | STAT 305 | 3 |
| | | BIOL 211 (OR BIOL 251) | 3 |
| | 15 | | 15 |

**Third Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| A B E 316 | 3 | A B E 478 | 3 |
| A B E 363 | 4 | C E 333 | 3 |
| C E 332 | 3 | I E 305 | 3 |
| E M 327 | 1 | Computer Graphics Elective | 1 |
| E M 378 | 3 | Communications Elective | 3 |
| AN S 114 | 2 | International Perspective Elective | 3 |
| | 16 | | 16 |

**Fourth Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| A B E 415 | 2 | A B E 416 | 2 |
| A B E 404 | 3 | A B E 469 | 3 |
| M E 436 | 4 | A B E 472 | 3 |
| A B E Elective | 3 | A B E 475 | 2 |
| An Sci/Agron Elective | 3 | C E 334 | 3 |
| Social Science or Humanities Elective | 3 | SS&H Elective | 3 |
| | 18 | | 16 |

Agricultural Engineering, B.S. - land and water resources engineering 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 |
| MATH 266 | 3 | E M 324 | 3 |
| AGRON 181 | 3 | M E 231 | 3 |
| AGRON 182 | 3 | STAT 305 | 3 |
| | | BIOL 251 (OR BIOL 211) | 3 |
| | 15 | | 15 |

**Third Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| A B E 316 | 3 | C E 326 | 3 |
| A B E 363 | 4 | C E 372 | 3 |
| E M 327 | 1 | MICRO 201 | 2 |
| E M 378 | 3 | MICRO 201L | 1 |
| GIS Elective | 3 | ABE Breadth Elective | 3 |
| International Perspective | 3 | Computer Graphics Elective | 1 |
| | | US Diversity Elective | 3 |
| | 17 | | 16 |

**Fourth Year**

| Fall | Credits | Spring | Credits |
|---|---|---|---|
| A B E 415 | 2 | A B E 416 | 2 |
| A B E 404 | 3 | I E 305 | 3 |
| A B E 431 | 3 | Subsurface Systems Elective | 3 |
| GEOL 201 | 3 | Water Quality Elective | 3 |
| Communication Elective | 3 | Social Science or Humanities Elective | 3 |
| Social Science or Humanities Elective | 3 | | |
| | 17 | | 14 |

# 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/.

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.

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

**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.

**A B E 170: Engineering Graphics and Introductory Design**
(2-2) Cr. 3.
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. 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.S.
*Prereq: A B E 160; MATH 266 or MATH 267*
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: CHEM 163 or higher; 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 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 216*
Single phase and three phase circuit design. Electrical safety. Electric motors and controls. Programmable logic controllers. Digital logic, instrumentation and sensors.

**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*
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 410: Electronic Systems Integration for Agricultural Machinery & Production Systems**
(Dual-listed with A B E 510). Cr. 3. S.
*Prereq: A B E 363 or E E 230 or E E 442 or E E 448*
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*
Properties of hydraulic fluids. Performance parameters of fixed and variable displacement pumps and motors. Hydraulic circuits and systems. Hydrostatic transmissions. Characteristics of control valves. Analysis and design of hydraulic systems for power and control functions.

**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 424: Air Pollution**
(Dual-listed with A B E 524). (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 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*
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*
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, CPR E, E E, ENGR, I E, M E, MAT 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, A B E 272, or A B E 273; 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: M E 231, E M 324*
Design of light-framed wood structures using LRFD and ASD design procedures. Includes analysis of wind, snow, dead, and live loads. Applications include animal housing and machine storage. Fasteners, laminated posts, truss design and use of National Design Specifications.

**A B E 480: Engineering Analysis of Biological Systems**
(Dual-listed with A B E 580). (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. Students enrolled in ABE 580 will be required to answer additional exam questions and report on two journal articles.

**A B E 490: A B E Independent Study**
Cr. 1-5. Repeatable.
Independent Study.

**A B E 490A: A B E Independent Study: Animal Production Systems Engineering**
Cr. 1-5. Repeatable.
Independent Study.

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

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

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

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

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

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

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

**A B E 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 B E 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 B E 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 B E 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*
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 510: Electronic Systems Integration for Agricultural Machinery & Production Systems**
(Dual-listed with A B E 410). Cr. 3. S.
*Prereq: A B E 363 or E E 230 or E E 442 or E E 448*
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 511: Bioprocessing and Bioproducts**
(3-0) Cr. 3. F.
*Prereq: A B E 216 or equivalent, MATH 160 or MATH 165, one of CHEM 167 or higher, BIOL 173 or BIOL 211 or higher or BRT 501, senior or graduate classification*
Sustainability, cleaner production. Taxonomy, kinetics, metabolism, aerobic and anaerobic fermentation. Biofuels, bioenergy and coproducts. Mass/energy balances, process integration, pretreatment, separation. Membrane reactors, bioelectrolysis, microbial fuel cells, nanotechnology, genetic engineering, mutagenesis. Term paper for graduate level only.

**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*
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. F.
*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*
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: M E 231, E M 324*
Design of light-framed wood structures using LRFD and ASD design procedures. Includes analysis of wind, snow, dead, and live loads. Applications include animal housing and machine storage. Fasteners, laminated posts, truss design and use of National Design Specifications.

**A B E 580: Engineering Analysis of Biological Systems**
(Dual-listed with A B E 480). (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. 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.

**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.
*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.