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:**

<table>
<thead>
<tr>
<th>Option II</th>
<th>Land and Water Resources Engineering Option</th>
<th>126.0 cr</th>
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</thead>
<tbody>
<tr>
<td>Option III</td>
<td>Power and Machinery Engineering Option</td>
<td>128.0 cr</td>
</tr>
<tr>
<td>Option IV</td>
<td>Animal Production Systems Engineering Option</td>
<td>128.0 cr</td>
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</tbody>
</table>

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:**

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tr>
<td>ENGL 150</td>
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<td>ENGL 250</td>
<td>Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)</td>
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<td>LIB 160</td>
<td>Information Literacy</td>
<td>1</td>
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**Communication Elective:** One of the following (Must have a C or better in this course)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
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</thead>
<tbody>
<tr>
<td>AGEDS 311</td>
<td>Presentation and Sales Strategies for Agricultural Audiences</td>
</tr>
<tr>
<td>ENGL 309</td>
<td>Proposal and Report Writing</td>
</tr>
<tr>
<td>ENGL 314</td>
<td>Technical Communication</td>
</tr>
<tr>
<td>MKT 450</td>
<td>Advanced Professional Selling</td>
</tr>
<tr>
<td>SP CM 212</td>
<td>Fundamentals of Public Speaking</td>
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<tr>
<td>SP CM 312</td>
<td>Business and Professional Speaking</td>
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**Social Sciences and Humanities:** 12 cr.

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<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>3 credits from international perspectives-university approved list</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>3 credits from U.S. diversity-university approved list</td>
<td>3</td>
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</tr>
<tr>
<td>6 credits from Social Sciences and Humanities courses-department approved list</td>
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**Total Credits:** 12

**Basic Program:** 24 cr.

A minimum GPA of 2.00 required for this set of 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. Within the Agricultural Engineering Basic Program, students are required to complete CHEM 167 and CHEM 167L or the sequence of CHEM 177, CHEM 177L, and CHEM 178. This is a departmental requirement within the College of Engineering Basic Program requirements. CHEM 178 credits can then be applied to the Math/Science Elective within the options of Power and Machinery Engineering and Animal Production Systems Engineering of the Agricultural Engineering major requirements.

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ABE 160</td>
<td>Systematic Problem Solving and Computer Programming</td>
<td>3</td>
</tr>
<tr>
<td>CHEM 167</td>
<td>General Chemistry for Engineering Students</td>
<td>4</td>
</tr>
<tr>
<td>or CHEM 177 and</td>
<td></td>
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<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>CHEM 178</td>
<td>General Chemistry II</td>
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<td>ENGL 150</td>
<td>Critical Thinking and Communication (Must have a C or better in this course)</td>
<td>3</td>
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<td>ENGR 101</td>
<td>Engineering Orientation</td>
<td>R</td>
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<tr>
<td>LIB 160</td>
<td>Information Literacy</td>
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<tr>
<td>MATH 165</td>
<td>Calculus I</td>
<td>4</td>
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<tr>
<td>MATH 166</td>
<td>Calculus II</td>
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<tr>
<td>PHYS 221</td>
<td>Introduction to Classical Physics I</td>
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**Total Credits:** 24

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

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<tr>
<td>CHEM 167L</td>
<td>Laboratory in General Chemistry for Engineering</td>
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<tr>
<td>or CHEM 177L</td>
<td>Laboratory in General Chemistry I</td>
<td></td>
</tr>
<tr>
<td>MATH 266</td>
<td>Elementary Differential Equations</td>
<td>3</td>
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<td>STAT 305</td>
<td>Engineering Statistics</td>
<td>3</td>
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**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).

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>A B E 216</td>
<td>Fundamentals of Agricultural and Biosystems Engineering</td>
<td>3</td>
</tr>
<tr>
<td>A B E 218</td>
<td>Project Management &amp; Design in Agricultural and Biosystems Engineering</td>
<td>2</td>
</tr>
<tr>
<td>A B E 316</td>
<td>Applied Numerical Methods for Agricultural and Biosystems Engineering</td>
<td>3</td>
</tr>
<tr>
<td>A B E 363</td>
<td>Agri-Industrial Applications of Electric Power and Electronics</td>
<td>4</td>
</tr>
<tr>
<td>A B E 378</td>
<td>Mechanics of Fluids</td>
<td>3</td>
</tr>
<tr>
<td>A B E 404</td>
<td>Instrumentation for Agricultural and Biosystems Engineering</td>
<td>3</td>
</tr>
<tr>
<td>A B E 415</td>
<td>Agricultural &amp; Biosystems Engineering Design I</td>
<td>2</td>
</tr>
<tr>
<td>A B E 416</td>
<td>Agricultural &amp; Biosystems Engineering Design II</td>
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<td>C E 274</td>
<td>Engineering Statics</td>
<td>3</td>
</tr>
<tr>
<td>E M 324</td>
<td>Mechanics of Materials</td>
<td>3</td>
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<tr>
<td>E M 327</td>
<td>Mechanics of Materials Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>I E 305</td>
<td>Engineering Economic Analysis</td>
<td>3</td>
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<tr>
<td>M E 231</td>
<td>Engineering Thermodynamics I</td>
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**Total Credits:** 35

**Other Remaining Courses: 11 cr.**

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<tbody>
<tr>
<td>A B E 110</td>
<td>Experiencing Agricultural and Biosystems Engineering</td>
<td>1</td>
</tr>
<tr>
<td>A B E 170</td>
<td>Engineering Graphics and Introductory Design</td>
<td>3</td>
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<tr>
<td>A B E 201</td>
<td>Preparing for Workplace Seminar</td>
<td>1</td>
</tr>
<tr>
<td>ENGL 250</td>
<td>Written, Oral, Visual, and Electronic Composition (Must have a C or better in this course)</td>
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</tr>
<tr>
<td>Communication Elective: One of the following (Must have a C or better in this course)</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>AGEDS 311</td>
<td>Presentation and Sales Strategies for Agricultural Audiences</td>
<td></td>
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<tr>
<td>ENGL 309</td>
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<td>SP CM 312</td>
<td>Business and Professional Speaking</td>
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**Total Credits:** 11

Complete remaining courses from one of the following options:

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

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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<tbody>
<tr>
<td>A B E 431</td>
<td>Design and Evaluation of Soil and Water Conservation Systems</td>
<td>3</td>
</tr>
<tr>
<td>AGRON 181</td>
<td>Introduction to Crop Science</td>
<td>3</td>
</tr>
<tr>
<td>AGRON 182</td>
<td>Introduction to Soil Science</td>
<td>3</td>
</tr>
<tr>
<td>BIOL 251</td>
<td>Biological Processes in the Environment</td>
<td>3</td>
</tr>
<tr>
<td>or BIOL 211</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C E 326</td>
<td>Principles of Environmental Engineering</td>
<td>3</td>
</tr>
<tr>
<td>C E 372</td>
<td>Engineering Hydrology and Hydraulics</td>
<td>3</td>
</tr>
<tr>
<td>GEOL 201</td>
<td>Geology for Engineers and Environmental Scientists</td>
<td>3</td>
</tr>
<tr>
<td>MICRO 201</td>
<td>Introduction to Microbiology</td>
<td>2</td>
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<tr>
<td>MICRO 201L</td>
<td>Introductory Microbiology Laboratory</td>
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</tr>
<tr>
<td>A B E 273</td>
<td>CAD for Process Facilities and Land Use Planning</td>
<td>1</td>
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<tr>
<td>GIS Elective (One of the following):</td>
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<tr>
<td>C R P 251</td>
<td>Fundamentals of Geographic Information Systems</td>
<td></td>
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<tr>
<td>C R P 451</td>
<td>Introduction to Geographic Information Systems</td>
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<tr>
<td>ENSCI 270</td>
<td>Geospatial Technologies</td>
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<tr>
<td>ENSCI 461I</td>
<td>Introduction to GIS</td>
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<tr>
<td>GEOL 452</td>
<td>GIS for Geoscientists</td>
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<tr>
<td>NREM 345</td>
<td>Natural Resource Photogrammetry and Geographic Information Systems</td>
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<tr>
<td>NREM 446</td>
<td>Integrating GPS and GIS for Natural Resource Management</td>
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<tr>
<td>Subsurface Systems Elective (One of the following):</td>
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<tr>
<td>C E 360</td>
<td>Geotechnical Engineering</td>
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</tr>
<tr>
<td>C E 473</td>
<td>Groundwater Hydrology</td>
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**Water Quality Elective (One of the following):** 3

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Name</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>A B E 432</td>
<td>Nonpoint Source Pollution and Control</td>
<td></td>
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</tbody>
</table>
### Agricultural Engineering

#### A B E 437
Watershed Modeling and Policy

#### A B E Breadth (One of the following):
- A B E 340 Functional Analysis of Soil, Crop, and Machine Systems
- A B E 380 Principles of Biological Systems Engineering
- A B E 424 (3 different 1 cr 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 Engineering for Grain Storage, Preservation, Handling, and Processing Systems
- 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 of Soil, Crop, and Machine Systems 3
- A B E 342 Agricultural Tractor Power 3
- A B E 410 Electronic Systems Integration for Agricultural Machinery 3
- A B E 413 Fluid Power Engineering 3
- A B E 469 Engineering for Grain Storage, Preservation, Handling, and Processing Systems 3
- A B E 472 Design of Environmental Modification Systems for Animal Housing (offered Spring even years) 3
- A B E 478 Wood Frame Structural Design (offered Spring odd years) 3
- A B E 480 Engineering Analysis of Biological Systems 3

#### Total Credits
39

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

- A B E 327Lx Animal Production Systems Design Lab 1
- A B E 469 Engineering for Grain Storage, Preservation, Handling, and Processing Systems 3
- A B E 472 Design of Environmental Modification Systems for Animal Housing (offered Spring even years) 3
- A B E 478 Wood Frame Structural Design (offered Spring odd years) 3
- 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
- TSM 327 Animal Production Systems 3
- Animal Science/Horticulture Elective (One of the following): 3
  - 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
  - HORT 221 Principles of Horticulture Science

#### Computer Graphics (One of the following):
- A B E 271 Engineering Applications of Parametric Solid Modeling 2
- A B E 272 Parametric Solid Models, Drawings, and Assemblies Using Creo Parametric 1
- A B E 273 CAD for Process Facilities and Land Use Planning 1
- A B E 271 Engineering Applications of Parametric Solid Modeling 1
- A B E 272 Parametric Solid Models, Drawings, and Assemblies Using Creo Parametric 1
- A B E Elective (One of the following): 3
- A B E 431 Design and Evaluation of Soil and Water Conservation Systems
### 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/](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.

### TRANSFER CREDIT REQUIREMENTS

Students graduating with a degree in A E or BSE are required to have a minimum of 18 credits of 300-level and 400-level ABE courses taken at Iowa State University (excluding 490, 415, and 416), and must complete the two-semester ABE Capstone sequence (ABE 415 & 416) at Iowa State University. The Department of Agricultural & Biosystems Engineering requires a grade of C or better for any transfer credit course that is applied to the degree program.

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

### Agricultural Engineering, B.S. - power & machinery option

#### First Year

<table>
<thead>
<tr>
<th>Semester</th>
<th>Credits</th>
</tr>
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<tbody>
<tr>
<td><strong>Fall</strong></td>
<td><strong>Credits</strong></td>
</tr>
<tr>
<td>ENGR 101</td>
<td>R A B E 110</td>
</tr>
<tr>
<td>A B E 170</td>
<td>3 A B E 160</td>
</tr>
<tr>
<td>CHEM 167</td>
<td>4 MATH 166</td>
</tr>
<tr>
<td>CHEM 167L</td>
<td>1 PHYS 221</td>
</tr>
<tr>
<td>MATH 165</td>
<td>4 ENGL 250</td>
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<tr>
<td>ENGL 150</td>
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<td><strong>Total Credits</strong></td>
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<table>
<thead>
<tr>
<th>Semester</th>
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<tbody>
<tr>
<td><strong>Spring</strong></td>
<td><strong>Credits</strong></td>
</tr>
<tr>
<td>A B E 216</td>
<td>3 A B E 218</td>
</tr>
<tr>
<td>C E 274</td>
<td>3 A B E 201</td>
</tr>
<tr>
<td>MAT E 273</td>
<td>3 E M 324</td>
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<tr>
<td>AGRON 182</td>
<td>3 MATH 266</td>
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<tr>
<td>Math/Science Elective</td>
<td>3 STAT 305</td>
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<td>International Perspectives Elective</td>
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#### Second Year

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<tbody>
<tr>
<td><strong>Fall</strong></td>
<td><strong>Credits</strong></td>
</tr>
<tr>
<td>A B E 340</td>
<td>3 A B E 316</td>
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<tr>
<td>A B E 363</td>
<td>4 A B E 342</td>
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<td>1 A B E 378</td>
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<td>M E 231</td>
<td>3 M E 324L</td>
</tr>
<tr>
<td>M E 345</td>
<td>3 BIOL 251 (OR BIOL 211)</td>
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<tr>
<td>Communication Elective</td>
<td>3 Computer Graphics Elective</td>
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<td><strong>Total Credits</strong></td>
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#### Third Year

<table>
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<td><strong>Credits</strong></td>
</tr>
<tr>
<td>A B E 415</td>
<td>2 A B E 416</td>
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<td>A B E 404</td>
<td>3 A B E 410</td>
</tr>
<tr>
<td>A B E 413</td>
<td>3 A B E Elective</td>
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<tr>
<td>M E 324</td>
<td>3 I E 305</td>
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<tr>
<td>M E 325</td>
<td>3 Social Science or Humanities Elective</td>
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<td><strong>Total Credits</strong></td>
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### Agricultural Engineering, B.S. - animal production systems engineering option

#### First Year

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<thead>
<tr>
<th>Fall</th>
<th>Credits</th>
<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ENGR 101</td>
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<tr>
<td>A B E 170</td>
<td>3 A B E 160</td>
<td>3</td>
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<tr>
<td>CHEM 167</td>
<td>4 MATH 166</td>
<td>CHEM 167</td>
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<td>CHEM 167L</td>
<td>1 PHYS 221</td>
<td>CHEM 167L</td>
<td>5</td>
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<tr>
<td>MATH 165</td>
<td>4 ENGL 250</td>
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<td>LIB 160</td>
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**Credits Total:** 16

#### Second Year

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<th>Spring</th>
<th>Credits</th>
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<tbody>
<tr>
<td>A B E 216</td>
<td>3 A B E 218</td>
<td>A B E 216</td>
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<tr>
<td>C E 274</td>
<td>3 A B E 201</td>
<td>C E 274</td>
<td>1</td>
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<tr>
<td>MATH 266</td>
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<tr>
<td>TSM 327</td>
<td>3 M E 231</td>
<td>AGRON 181</td>
<td>3</td>
</tr>
<tr>
<td>A B E 327LX</td>
<td>1 STAT 305</td>
<td>AGRON 182</td>
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### Agricultural Engineering, B.S. - land and water resources engineering option

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**Credits Total:** 17
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 102: Learning Communities**  
Cr. 0.5. F.  
8 week learning communities course focusing on student success, engineering, and department curriculum. Building community within the ABE Department. Offered on a satisfactory-fail basis only.

**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  
Introduction to principles of dynamics, statics, and mass and energy conservation. Introduction to algorithmic thinking; use of spreadsheet programs and computer programming language(s) to solve engineering problems. Only one of ENGR 160, A B E 160, AER E 160, C E 160, CH E 160, CPR E 185, EE 185, IE 148, M E 160 and S E 185 may count towards graduation.

**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: 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 in agricultural and biosystems engineering. Emphasis is on solving engineering problems.

**A B E 218: Project Management & Design in Agricultural and Biosystems Engineering**  
(1-2) Cr. 2. S.  
Prereq: A B E 216  
Engineering design process with emphasis on criteria and constraints, ideation, and analysis. Fundamental principles of project management including project management software. Open-ended project(s) to apply core principles using concepts from prerequisite courses.

**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 Creo Parametric
(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.

(2-2) Cr. 3. F.
Prereq: A B E 216

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

A B E 378: Mechanics of Fluids
(2-2) Cr. 3. F.S.
Prereq: C E 274

A B E 380: Principles of Biological Systems Engineering
(2-2) Cr. 3. S.
Prereq: A B E 316
Engineering analysis of biological systems, through the study of mass, energy, and information transport. Quantification and modeling of biological interactions, biological activities and bioreactor operations. Includes laboratory experiences on biological materials characterization, unit operation for bioprocesses and fermentation for producing bioproducts.

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.
Agricultural Engineering

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 and simulation of dynamic systems with modern software tools including Matlab Simulink and Modelica. Introduction to state variable methods of system analysis. Analysis of several engineering systems. Introduction to classical control theory. Term project 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
(Dual-listed with A B E 510). Cr. 3. S.
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, distributed 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)
Engineering design process with emphasis on team delivery of: clearly defined deliverables; criteria and constraints; wide-field ideation; discipline-appropriate analysis methods; identification and application of relevant standards.

A B E 416: Agricultural & Biosystems Engineering Design II
(1-2) Cr. 2. F.S.
PreReq: A B E 415
Final execution of the engineering design process with emphasis on team delivery of: oral and written communication in completion of the client-agreed deliverables.

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 mechanisms of non-point source (NPS) pollution in agricultural and urban watersheds, modeling of NPS pollution for terrestrial and aquatic systems, statistical tools to assess environmental datasets, strategies to control and manage NPS pollution of water bodies, and integrated watershed management. Graduate students are required to develop/deliver lecture models on assigned topics and/or complete additional assignments.

A B E 437: Watershed Modeling and Policy  
(Dual-listed with A B E 537). (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 transport phenomena in food and bioprocesses. Physical/chemical characteristics of foods and biological materials and systems, flow processes, thermal processes, cooling/freezing processes, dehydration processes and separation processes.

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: Engineering for Grain Storage, Preservation, Handling, and Processing Systems  
(Dual-listed with A B E 569). (2-3) Cr. 3. S.  
Prereq: A B E 216

Cereal grain and oilseed production, properties, and quality assessment. Design of storage systems, drying systems, material handling, and size reduction systems. Design of cereal grain processing systems, including dry milling, wet milling, flour milling, feed milling, and fermentation facilities.
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: E M 324

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 various biological systems, including applications in foods, feeds, biofuels, bioenergy, and other bio-based systems. Introduction to technoeconomic analysis and life-cycle assessment of these systems at multiple production scales. Applying these tools to evaluate and improve cost and sustainability performance. Students enrolled in ABE 580 will be required to conduct additional learning activities.

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

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.
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.S.
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 and simulation of dynamic systems with modern software tools including Matlab Simulink and Modelica. Introduction to state variable methods of system analysis. Analysis of several engineering systems. Introduction to classical control theory. Term project 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
(Dual-listed with A B E 410). Cr. 3. S.
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, distributed 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

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
1 cr. per module. Module A prereq for all modules; module B prereq for D
and E.

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

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 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,
grahuate 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 transport phenomena in food and bioprocesses.
Physical/chemical characteristics of foods and biological materials and
systems, flow processes, thermal processes, cooling/freezing processes,
dehydration processes and separation processes.

A B E 556: GIS Programming and Automation
(Dual-listed with A B E 556). (Cross-listed with C R P). (3-0) Cr. 3. F.
Prereq: C R P 351 or equivalent or permission of instructor
Introduction to automated geoprocessing in Geographic Information
Systems using Python. Focus on learning scripting language and object-
oriented programming, automation of custom-designed geoprocessing
scripts, and application toward student research and/or interests.
A B E 569: Engineering for Grain Storage, Preservation, Handling, and Processing Systems
(Dual-listed with A B E 469). (2-3) Cr. 3. S.
Prereq: A B E 216
Cereal grain and oilseed production, properties, and quality assessment. Design of storage systems, drying systems, material handling, and size reduction systems. Design of cereal grain processing systems, including dry milling, wet milling, flour milling, feed milling, and fermentation facilities.

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: E M 324

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 various biological systems, including applications in foods, feeds, biofuels, bioenergy, and other bio-based systems. Introduction to techno-economic analysis and life-cycle assessment of these systems at multiple production scales. Applying these tools to evaluate and improve cost and sustainability performance. Students enrolled in ABE 580 will be required to conduct additional learning activities.

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.

Courses for graduate students:

A B E 601: Graduate Seminar
(Cross-listed with TSM). (1-0) Cr. 1. F.
Keys to starting a successful graduate research project. Effective literature review, formulating research questions, and setting goals. Practicing effectively communicating research and science. Effective strategies for scholarly writing, professional development, responding to feedback, peer-reviewing, successful publishing in journals, and curating scholarly output.

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. 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 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.