Biometric Systems Engineering, B.S.B.S.E.

Degree Offered

• Bachelor of Science in Biometric Systems Engineering (B.S.B.S.E.)

Nature of the Program

Biometric systems allow for personal identification based upon fundamental biometric features that are unique and time invariant, such as features derived from fingerprints, faces, irises, retinas, and voices. Biometric systems are composed of complex hardware and software designed to measure a signature of the human body, compare the signature to a database, and make a decision based on this matching process. The Statler College intends to seek ABET accreditation for the biometric systems engineering program.

WVU's Bachelor of Science in Biometric Systems Engineering degree program trains engineers in the skills needed to design, build, test, and modify biometric systems, as well as the application and interpretation of data from these systems. Biometric Systems Engineering majors take fundamental coursework in circuits and electronics; in digital and computing systems; and in computer programming, similar to our Computer Engineering majors. During their junior and senior years, Biometric Systems Engineering majors take advanced classes in image processing; in computer security; in biometric devices; and in biomedical systems. During their senior year, all Biometric Systems Engineering majors complete a two semester Capstone project in which they work with a team of students to design, build and test a device, systems or application which makes use of biometric techniques. Required courses in biology and statistics, provide Biometric Systems Engineering students with a specialized skill set that distinguishes this major from other engineering disciplines.

Graduates of the Biometric Systems Engineerings degree program are in high demand for engineering positions in law enforcement agencies, as well as government agencies and contractors in the defense and security fields. Demand for biometric systems engineers is also rapidly growing in commercial fields such as banking, manufacturing and consumer products that enhance the human computer interface. The continued rapid advance of integrated sensor, signal/image processing, computer, and mass storage technology promises to extend these applications further into our daily lives with even the most inanimate objects able to identify, interact with, and assist their users.

Areas of Emphasis

Presently, five specialization paths have been identified for the biometric systems engineering curriculum and each specialization path has a corresponding Area of Emphasis. Each Area of Emphasis enables students to develop an in-depth technical background in an area of their own choosing which is central to biometric system development. Currently designated Areas of Emphasis are (1) Sensors and Circuits, (2) Signal Processing, (3) Statistics, (4) Software Systems, and (5) Cybersecurity. Each Area of Emphasis is fulfilled by the successful completion of three courses. Each emphasis area curriculum is defined by three courses chosen from a set of classes prescribed for that area. Successful completion of an emphasis area’s requirements is designated on the student’s transcript.

Click here to view the Suggested Plan of Study (p. 4)

Curriculum in Biometric Systems Engineering

General Education Foundations

Please use this link to view a list of courses that meet each GEF requirement. (http://registrar.wvu.edu/gef/)

NOTE: Some major requirements will fulfill specific GEF requirements. Please see the curriculum requirements listed below for details on which GEFs you will need to select.

General Education Foundations

<table>
<thead>
<tr>
<th>General Education Foundations</th>
<th>3-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 - Composition &amp; Rhetoric</td>
<td>3-6</td>
</tr>
<tr>
<td>ENGL 101 &amp; ENGL 102 or ENGL 103</td>
<td>Introduction to Composition and Rhetoric and Composition, Rhetoric, and Research</td>
</tr>
<tr>
<td>F2A/F2B - Science &amp; Technology</td>
<td>4-6</td>
</tr>
<tr>
<td>F3 - Math &amp; Quantitative Reasoning</td>
<td>3-4</td>
</tr>
<tr>
<td>F4 - Society &amp; Connections</td>
<td>3</td>
</tr>
<tr>
<td>F5 - Human Inquiry &amp; the Past</td>
<td>3</td>
</tr>
<tr>
<td>F6 - The Arts &amp; Creativity</td>
<td>3</td>
</tr>
<tr>
<td>F7 - Global Studies &amp; Diversity</td>
<td>3</td>
</tr>
</tbody>
</table>
Degree Requirements

Students must meet the following criteria to qualify for a Bachelor of Science in Biometric Systems Engineering degree:

• Complete a minimum of 126 credit hours
• Satisfy WVU's undergraduate degree requirements
• Satisfy Statler College's undergraduate degree requirements (http://catalog.wvu.edu/undergraduate/collegeofengineeringandmineralresources/#policiestext)
• Complete all courses listed in the curriculum requirements with the required minimum grades
• Attain an overall grade point average of 2.25 or better
• Attain a WVU grade point average of 2.25 or better
• Attain a Statler grade point average of 2.25 or better
• A maximum of one math or science courses with a grade of D+, D, or D- may apply towards a Statler College degree
• Complete a survey regarding their academic and professional experiences at WVU, as well as post-graduation job placement or continuing education plans.

That Statler GPA is computed based on all work taken at WVU with a subject code within Statler College (BIOM, BMEG, CE, CHE, CPE, CS, CSEE, CYBE, EE, ENGR, IH&S, MAE, MINE, PDA, PNGE, SAFM, SENG) excluding ENGR 140, ENGR 150, and CS 101. The WVU GPA is computed based on all work taken at WVU. The Overall GPA is computed based on all work taken at WVU and transfer work.

Curriculum Requirements

University Requirements

General Education Foundations (GEF) 1, 2, 3, 4, 5, 6, 7, and 8 (31-37 Credits)

Outstanding GEF Requirements 1, 5, 6, and 7

ENGR 191 First-Year Seminar

Total Hours

Fundamentals of Engineering Requirements

A minimum grade of C- is required in all Fundamentals of Engineering courses.

ENGR 101 Engineering Problem Solving 1

Engineering Problem Solving (Select one of the following):

CHE 102 Introduction to Chemical Engineering
ENGR 102 Engineering Problem-Solving 2
ENGR 103 Introduction to Nanotechnology Design
MAE 102 Introduction to Mechanical and Aerospace Engineering Design

Total Hours

Math and Science Requirements

A minimum grade of C- is required in all Math and Science courses.

BIOL 115 & BIOL 116 Principles of Biology and Principles of Biology Laboratory (GEF 8)
CHEM 115 & 115L Fundamentals of Chemistry 1 and Fundamentals of Chemistry 1 - Laboratory (GEF 2B)
Biometric Systems Engineering, B.S.B.S.E.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>MATH 155</td>
<td>Calculus 1</td>
<td>4</td>
</tr>
<tr>
<td>MATH 153 &amp; MATH 154</td>
<td>Calculus 1a with Precalculus and Calculus 1b with Precalculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 156</td>
<td>Calculus 2 (GEF 8)</td>
<td>4</td>
</tr>
<tr>
<td>MATH 251</td>
<td>Multivariable Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 261</td>
<td>Elementary Differential Equations</td>
<td>4</td>
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Math Elective (Select one of the following):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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</thead>
<tbody>
<tr>
<td>CS 220</td>
<td>Discrete Mathematics</td>
<td>3</td>
</tr>
<tr>
<td>MATH 343</td>
<td>Introduction to Linear Algebra</td>
<td></td>
</tr>
<tr>
<td>MATH 373</td>
<td>Introduction to Cryptography</td>
<td></td>
</tr>
<tr>
<td>MATH 375</td>
<td>Applied Modern Algebra</td>
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</tr>
<tr>
<td>PHYS 111</td>
<td>General Physics (GEF 8)</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 112</td>
<td>General Physics</td>
<td>4</td>
</tr>
<tr>
<td>STAT 215</td>
<td>Introduction to Probability and Statistics</td>
<td>3</td>
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</table>

Total Hours 38

Biometric Systems Engineering Program Requirements

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>ECON 201</td>
<td>Principles of Microeconomics (GEF 4)</td>
<td>3</td>
</tr>
<tr>
<td>BIOM 201</td>
<td>Introduction to Biometrics Systems</td>
<td>1</td>
</tr>
<tr>
<td>BIOM 426</td>
<td>Biometric Systems</td>
<td>3</td>
</tr>
<tr>
<td>CSEE 380</td>
<td>Engineering Professionalism Seminar</td>
<td>1</td>
</tr>
<tr>
<td>CSEE 480</td>
<td>Capstone Project - Design</td>
<td>2</td>
</tr>
<tr>
<td>or BIOM 480</td>
<td>Capstone Project - Design</td>
<td></td>
</tr>
<tr>
<td>CSEE 481</td>
<td>Capstone Project - Implementation</td>
<td>3</td>
</tr>
<tr>
<td>or BIOM 481</td>
<td>Capstone Project - Implementation</td>
<td></td>
</tr>
<tr>
<td>CPE 271</td>
<td>Introduction to Digital Logic Design</td>
<td>3</td>
</tr>
<tr>
<td>CPE 272</td>
<td>Digital Logic Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>CPE 310</td>
<td>Microprocessor Systems</td>
<td>3</td>
</tr>
<tr>
<td>CPE 311</td>
<td>Microprocessor Laboratory</td>
<td>1</td>
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<tr>
<td>CS 110</td>
<td>Introduction to Computer Science</td>
<td>4</td>
</tr>
<tr>
<td>CS 111</td>
<td>Introduction to Data Structures</td>
<td>4</td>
</tr>
<tr>
<td>CS 350</td>
<td>Computer System Concepts</td>
<td>3</td>
</tr>
<tr>
<td>CS 465</td>
<td>Cybersecurity Principles and Practice</td>
<td>3</td>
</tr>
<tr>
<td>EE 221</td>
<td>Introduction to Electrical Engineering</td>
<td>3</td>
</tr>
<tr>
<td>EE 222</td>
<td>Introduction to Electrical Engineering Laboratory</td>
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<tr>
<td>EE 223</td>
<td>Electrical Circuits</td>
<td>3</td>
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<tr>
<td>EE 224</td>
<td>Electrical Circuits Laboratory</td>
<td>1</td>
</tr>
<tr>
<td>EE 327</td>
<td>Signals and Systems 1</td>
<td>3</td>
</tr>
<tr>
<td>EE 425</td>
<td>Bioengineering</td>
<td>3</td>
</tr>
<tr>
<td>EE 465</td>
<td>Introduction to Digital Image Processing</td>
<td>3</td>
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Bioscience Elective (Select one of the following):

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
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<tbody>
<tr>
<td>BIOL 235</td>
<td>Human Physiology</td>
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<tr>
<td>BMG 80</td>
<td>Cellular Machinery</td>
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</tbody>
</table>

Technical Elective (300 level or higher course in BIOM, CPE, CS, CYBE, or EE) * 3

Area of Emphasis 9

Total Hours 67

* Excludes any 490, 491, 495
# Suggested Plan of Study

It is important for students to take courses in the order specified as much as possible; all prerequisites and concurrent requirements must be observed. A typical B.S.B.S.E. degree program, which completes degree requirements in four years, is as follows.

## First Year

<table>
<thead>
<tr>
<th></th>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 110</td>
<td>4 CHEM 115 &amp; 115L (GEF 2)</td>
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<tr>
<td>ENGL 101 (GEF 1)</td>
<td>3 CS 111</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ENGR 101</td>
<td>2 ENGR 102</td>
<td></td>
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</tr>
<tr>
<td>ENGR 191</td>
<td>1 MATH 156 (GEF 8)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>MATH 155 (GEF 3)</td>
<td>4 PHYS 111 (GEF 8)</td>
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<tr>
<td>GEF 5</td>
<td>3</td>
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Total credit hours: 17

## Second Year

<table>
<thead>
<tr>
<th></th>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 115 &amp; BIOL 116*</td>
<td>4 BIOM 201</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 221</td>
<td>3 CPE 271</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 222</td>
<td>1 CPE 272</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>MATH 251</td>
<td>4 EE 223</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PHYS 112</td>
<td>4 EE 224</td>
<td></td>
<td>ENGL 102 (GEF 1)</td>
<td>3</td>
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<td></td>
<td></td>
<td></td>
<td>MATH 261</td>
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</table>

Total credit hours: 16

## Third Year

<table>
<thead>
<tr>
<th></th>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>BIOM 426*</td>
<td>3 CPE 310</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CS 350</td>
<td>3 CPE 311</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>EE 425*</td>
<td>3 CS 465*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 327*</td>
<td>3 EE 465*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STAT 215</td>
<td>3 Bioscience Elective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CSEE 380</td>
<td>1 Math Elective</td>
<td></td>
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</table>

Total credit hours: 16

## Fourth Year

<table>
<thead>
<tr>
<th></th>
<th>Fall</th>
<th>Hours</th>
<th>Spring</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>CSEE 480</td>
<td>2 CSEE 481</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ECON 201 (GEF 4)</td>
<td>3 Area of Emphasis Course 3</td>
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<td></td>
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<tr>
<td>Area of Emphasis Course 1</td>
<td>3 GEF 6</td>
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</tr>
<tr>
<td>Area of Emphasis Course 2</td>
<td>3 GEF 7</td>
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<tr>
<td>Technical Elective</td>
<td>3</td>
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</tbody>
</table>

Total credit hours: 12

* Offered once per year in the semester shown.

## Areas of Emphasis

- Cybersecurity
- MicroSensors and Circuits
- Signal Processing
- Statistics
- Software Systems
### AREA OF EMPHASIS IN CYBERSECURITY

A minimum grade of C- is required in each course.

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 453</td>
<td>Data and Computer Communications</td>
<td>3</td>
</tr>
<tr>
<td>CS 465</td>
<td>Cybersecurity Principles and Practice</td>
<td>3</td>
</tr>
<tr>
<td>CYBE 366</td>
<td>Secure Software Development</td>
<td>3</td>
</tr>
<tr>
<td>CYBE 467</td>
<td>Practicing Cybersecurity: Attacks &amp; Countermeasures</td>
<td>3</td>
</tr>
</tbody>
</table>

Select one of the following:

- CPE 435 Computer Incident Response
- CYBE 466 Host Based Cyber Defense

Total Hours: 15

### MICROSENSORS AND CIRCUITS AREA OF EMPHASIS REQUIREMENTS

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>EE 251</td>
<td>Digital Electronics and Digital Electronics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>&amp; EE 252</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Choose two of the following:

- PHYS 314 Introductory Modern Physics
- PHYS 321 Optics
- EE 355 Analog Electronics
- & EE 356 and Analog Electronics Laboratory
- EE 450 Device Design and Integration
- EE 455 Introduction to Microfabrication

Total Hours: 10

### SIGNAL PROCESSING AREA OF EMPHASIS REQUIREMENTS

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE 251</td>
<td>Digital Electronics and Digital Electronics Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>&amp; EE 252</td>
<td></td>
<td></td>
</tr>
<tr>
<td>EE 329</td>
<td>Signals and Systems Laboratory</td>
<td>4</td>
</tr>
<tr>
<td>&amp; EE 328</td>
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<td></td>
</tr>
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</table>

Choose one of the following:

- CS 453 Data and Computer Communications
- EE 463 Digital Signal Processing Fundamentals
- EE 565 Advanced Image Processing

Total Hours: 11

### STATISTICS AREA OF EMPHASIS REQUIREMENTS

Choose either the Applied or Theory Option

**Applied Option**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT 312</td>
<td>Intermediate Statistical Methods</td>
<td>3</td>
</tr>
</tbody>
</table>

Choose two of the following:

- STAT 313 Introduction to Statistical Analysis
- STAT 331 Sampling Methods
- STAT 421 Statistical Analysis System (SAS)

**Theory Option**

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>STAT 312</td>
<td>Intermediate Statistical Methods</td>
<td>3</td>
</tr>
<tr>
<td>STAT 461</td>
<td>Theory of Probability</td>
<td>3</td>
</tr>
<tr>
<td>STAT 462</td>
<td>Theory of Statistics</td>
<td>3</td>
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</tbody>
</table>

Total Hours: 9

### SOFTWARE SYSTEMS AREA OF EMPHASIS REQUIREMENTS

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS 230</td>
<td>Introduction to Software Engineering</td>
<td>3</td>
</tr>
<tr>
<td>or CPE 484</td>
<td>Real-Time Systems Development</td>
<td>3</td>
</tr>
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</table>

Choose two of the following:

Total Hours: 6
Program Educational Objectives

The Program Educational Objectives (PEO) of the Biometric Systems Engineering (BSE) program at West Virginia University is to produce graduates who will apply their knowledge and skills to achieve success in their careers in industry, research, government service or graduate study. It is expected that in the first five years after graduation our graduates will achieve success and proficiency in their profession, be recognized as leaders, and contribute to the well-being of society.

Major Learning Outcomes

BIOMETRIC SYSTEMS ENGINEERING

Upon graduation, all Bachelor of Science in Biometric Systems Engineering students will have:

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
3. An ability to communicate effectively with a range of audiences.
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.
8. An ability to understand the significance of biometric traits, explain the components of a biometric system, and assess its performance.

BIOMETRIC SYSTEMS COURSES

BIOM 191. First-Year Seminar. 1-3 Hours.
Engages students in active learning strategies that enable effective transition to college life at WVU. Students will explore school, college and university programs, policies and services relevant to academic success. Provides active learning activities that enable effective transition to the academic environment. Students examine school, college and university programs, policies and services.

BIOM 201. Introduction to Biometrics Systems. 1 Hour.
PR: ENGR 102 with a minimum grade of C-. A basic introduction to biometric technologies, including the modalities of fingerprints, face, iris, and voice. An overview of essential biometrics terminology, use cases, and trends. Perspectives from industry, government, and academia, as presented by guest speakers.

BIOM 426. Biometric Systems. 3 Hours.
PR: STAT 215 and MATH 261 and CS 111. This course presents an introduction to the principles of operation, design, testing, and implementation of biometric systems, and the legal, social, and ethical concerns associated with their use. (Cross-listed with EE 426.)

BIOM 480. Capstone Project - Design. 2 Hours.
PR: ENGL 102 or ENGL 103 and consent. Penultimate semester. Group senior design projects with individual design assignments appropriate to student's discipline. Complete system-level designs of the subsequent semester's project presented in written proposals and oral presentations. (Equivalent to CPE 480, CS 480 and EE 480.) (2 hr. lec., 1 hr. conf.).

BIOM 481. Capstone Project - Implementation. 3 Hours.
PR: BIOM 480. Continuation of BIOM 480. Detailed design and implementation of the system including choice of components, algorithm development, interfacing, troubleshooting, working in groups, and project management. Also covers professional topics including ethics, liability, safety, socio-legal issues, risks, and employment agreements. (1 hr. lec., 1 hr. conf., 2 hr. lab.).

BIOM 494. Seminar. 1-3 Hours.
PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

BIOM 497. Research. 1-15 Hours.
Independent research projects.
COMPUTER ENGINEERING COURSES

CPE 191. First-Year Seminar. 1-3 Hours.
Engages students in active learning strategies that enable effective transition to college life at WVU. Students will explore school, college and university programs, policies and services relevant to academic success. Provides active learning activities that enable effective transition to the academic environment. Students examine school, college and university programs, policies and services.

CPE 271. Introduction to Digital Logic Design. 3 Hours.
PR: MATH 156 or consent. Introduction to the design of digital systems. Topics include number systems, coding, Boolean and switching algebra, minimization of logic, analysis and design of combinational and sequential logic circuits.

CPE 272. Digital Logic Laboratory. 1 Hour.
CoReq: CPE 271. Experiments with digital electronic circuits including number systems, design and application of modern digital circuitry for both combinational and sequential logic circuits. (3 hr. lab.).

CPE 293. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

CPE 310. Microprocessor Systems. 3 Hours.
PR: CPE 271 and CPE 272 and PR or CONC: CPE 311. Theory and design of microprocessors: organization and architecture of modern processors; integration of microprocessors with RAM, ROM, and I/O devices; machine language, assembly language and software development. (3 hr. lec.).

CPE 311. Microprocessor Laboratory. 1 Hour.
CoReq: CPE 310. Machine language, assembly language and hardware and software interfacing. (This includes editing, linking, and debugging.) Memory, I/O and basic techniques of microprocessor interfacing. (3 hr. lab.).

CPE 312. Microcomputer Structures and Interfacing. 3 Hours.
PR: CPE 310 and CPE 311 and EE 251 and EE 252 and CoReq: CPE 313 and CS 350. Design of computer systems with emphasis on interface hardware including communications, high power interface devices, line driver/receiver circuits, A/D and D/A devices, and utilization of software techniques for programmed, interrupt, and direct memory access. (3 hr. lec.).

CPE 313. Microcomputer Structures and Interfacing Laboratory. 1 Hour.
PR: CPE 310 and CPE 311 and CoReq: CPE 312. A microprocessor based single-board computer is designed and built. A semester project is required using standard I/O techniques. (3 hr. lab.).

CPE 412. Mobile Robotics. 3 Hours.
PR: Consent. Introduction to fundamental topics in Mobile robotics; methods of locomotion; common mobile robot sensors, state estimation and navigation algorithms; path planning and obstacle avoidance methods; robot decision making and control processes; and mobile robot systems design.

CPE 435. Computer Incident Response. 3 Hours.
PR: CPE 310 and CPE 311 and (CS 350 or CS 355) or consent. Introduction to computer incident response, forensics, and computer security. Legal basis, proper procedures, and multiple operating systems application.

CPE 442. Introduction to Digital Computer Architecture. 3 Hours.
PR: (MATH 375 or MATH 378) and (CPE 310 or CPE 320). Control, data, and demand-driven computer architecture; parallel processing, pipelining, and vector processing; structures and algorithms for array processors, systolic architectures, design of architectures. (3 hr. lec.).

CPE 462. Wireless Networking. 3 Hours.
PR: EE 327 and (STAT 215 or MATH 448). Design and analysis of modern wireless data networks. Digital modulation techniques, wireless channel models, design of cellular networks, spread spectrum, carrier sense multiple access, ad-hoc networks routing, error control coding, automatic request strategies.

CPE 480. Capstone Project - Design. 2 Hours.
PR: ENGL 102 or ENGL 103 and consent. Penultimate semester group senior design projects with individual design assignments appropriate to student's discipline. Complete system-level designs of the subsequent semester's project presented in written proposals and oral presentations. (Equivalent to BIOM 480, CS 480, and EE 480). (2 hr. lec., 1 hr. conf.).

CPE 481. Capstone Project - Implementation. 3 Hours.
PR: CPE 480. Continuation of CPE 480. Detailed design and implementation of the system including choice of components, algorithm development, interfacing troubleshooting, working in groups, and project management. Also covers professional topics, including ethics, liability, safety, socio-legal issues, risks and employment agreements. (1 hr. lec., 1 hr. conf., 2 hr. lab.).

CPE 484. Real-Time Systems Development. 3 Hours.
PR: CS 350 or working knowledge of C programming language and UNIX. Characteristics of real-time systems, system and software development standards, structured and object oriented development methods for real-time systems, using a computer aided software engineering (CASE) tool in the development of a large engineering project. Emphasis is on real-time systems requirements analysis and design. This is a project based course. (3 hr. lec.).

CPE 490. Teaching Practicum. 1-3 Hours.
PR: Consent. Teaching practice as a tutor or assistant.
CPE 491. Professional Field Experience. 1-18 Hours.
PR: Consent. (May be repeated up to a maximum of 18 hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

CPE 493. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

CPE 494. Seminar. 1-3 Hours.
PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

CPE 495. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.

CPE 496. Senior Thesis. 1-3 Hours.
PR: Consent.

CPE 498. Honors. 1-3 Hours.
PR: Students in Honors Program and consent by the honors director. Independent reading, study or research.

COMPUTER SCIENCE COURSES

CS 101. Intro to Computer Applications. 4 Hours.
Introduction to spreadsheets and databases for problem-solving in disciplines such as math, science, engineering, business, social sciences, behavioral sciences, and environment: using computer applications to create technical reports and presentations.

CS 110. Introduction to Computer Science. 4 Hours.
PR: (MATH 126 and MATH 128 with a minimum grade of C- in both) or MATH 129 with a minimum grade of C- or meets the entry requirements of MATH 153. Programming and design; simple data types, variables, and expressions; program modularization through procedures, functions, and classes; repetition, selection through control structures; structured data types including arrays and records; application. (3 hr. lec., 1 hr. lab.).

CS 111. Introduction to Data Structures. 4 Hours.
PR: CS 110 with a minimum grade of C-. Software development with abstract data types; elementary data structures including lists, stacks, queues and binary trees. Object-oriented design and development, dynamic allocation, recursion, design methodology. (3 hr. lec., 2 hr. lab.).

CS 191. First-Year Seminar. 1-3 Hours.
Engages students in active learning strategies that enable effective transition to college life at WVU. Students will explore school, college and university programs, policies and services relevant to academic success. Provides active learning activities that enable effective transition to the academic environment. Students examine school, college and university programs, policies and services.

CS 210. File and Data Structures. 4 Hours.
PR: CS 111 with a minimum grade of C- or consent for non-majors. Complex internal data structures including hashing, record collision and overflow techniques. Extension of internal data structures to external storage; indexed structures, external sorting and merging, direct access methods.

CS 220. Discrete Mathematics. 3 Hours.
PR: (CS 110 with a minimum grade of C- or CS 122) and (MATH 154 or MATH 155). Mathematical concepts used in computer science such as sets, relations, functions, counting principles, graphs, trees, and automata; introduction to basic graph algorithms and applications. (3 hr. lec.).

CS 230. Introduction to Software Engineering. 4 Hours.
PR: CS 111 with a minimum grade of C-. Techniques and methodologies of software engineering; specification, modeling, requirement analysis and definition, design, quality assurance, testing, reuse, development tools and environments.

CS 293. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

CS 310. Principles of Programming Languages. 3 Hours.
PR: CS 111 with a minimum grade of C- or CS 201. Theoretical and practical aspects of languages including internal representations, run-time environments, run-time storage management; historical, current, special purpose and experimental languages; finite-state automata, regular expressions and context-free grammars, language translation, semantics and paradigms. (3 hr. lec.).

CS 320. Analysis of Algorithms. 3 Hours.
PR: WVU sections require CS 111 and (CS 220 or MATH 303) and MATH 156 with a minimum grade of C- in each; WVUIT sections require CS 201 and CS 220 and MATH 156 with a minimum grade of C- in each. Introduction to algorithm design and analysis. Growth rate of functions and asymptotic notation. Divide-and-conquer algorithms and recurrences; searching and sorting; graph algorithms including graph searching, minimum spanning trees, and shortest paths.

CS 350. Computer System Concepts. 3 Hours.
PR: CS 111 with a minimum grade of C-. System software organization; operating system concepts including processes, threads, memory management, and the user interface; elementary network concepts. (Equivalent to CS 355).
CS 376. Research Methods. 3 Hours.
PR: CS 110 and CS 111 with a minimum grade of C- in each. An introduction to the tools and mathematics that scientists use to solve scientific problems. Mathematical modeling, experimental design, hypothesis formulation, data collection, use of statistics, reading and evaluating the scientific literature, writing and reviewing scientific papers, and oral presentation of scientific research.

CS 410. Compiler Construction. 3 Hours.
PR: WVU sections require CS 310 with a C- or better or consent for non-majors. WVUIT sections require CS 310 or consent for non-majors. Theory and practice of the construction of programming language translators; scanning and parsing techniques, semantic processing, runtime storage organization, and code generation; design and implementation of interpreter or compiler by students. (3 hr. lec.).

CS 420. Design of Algorithms. 3 Hours.
PR: WVU sections require CS 310 with a C- or better or consent for non-majors. WVUIT sections require CS 310 or consent for non-majors. Algorithm design paradigms: divide-and-conquer, dynamic programming, greedy. Advanced data structures: balanced search trees, mergeable heaps, union-find. Introduction to computational complexity. Selected topics such as backtracking, branch-and-bound, amortized analysis, approximation algorithms.

CS 422. Automata Theory. 3 Hours.
PR: WVU sections require CS 220 with a minimum of C- or better or consent for non-majors. WVUIT sections require CS 220 or consent for non-majors. Introduction to formal languages, grammars, and automata; regular expressions and finite automata, context- free and context-sensitive languages; push down and linear- bounded automata; turning machines and recursively enumerable languages.

CS 426. Discrete Mathematics 2. 3 Hours.
PR: CS 320 with a minimum grade of C- or consent for non-majors. Applications of discrete mathematics to computer science. Selected topics from algorithmic graph theory, combinatorics, and order theory.

CS 430. Advanced Software Engineering. 3 Hours.
PR: CS 230 with a C- or better or CS 222 or consent for non-majors. Engineering process, project economics, project organizational and management issues, configuration management. (3 hr. lec.).

CS 440. Database Design and Theory. 3 Hours.
PR: CS 230 with minimum grade of C- or consent for non-majors. Database terminology, SQL, stored procedures, the relational and object-relational data model, triggers, and entity-relationship model.

CS 450. Operating Systems Structure. 4 Hours.
PR: CS 350 with a minimum grade of C- or CS 355. Support of computer components; device management and interrupts, process scheduling, file management, complete OS structure, OS development and debugging, configuration management, and performance testing. (3 hr. lec., 1 hr. lab.).

CS 453. Data and Computer Communications. 3 Hours.
PR: (CS 350 with a C- or better or CS 355) or consent for non-majors. or consent for non-majors. An in-depth study of the Internet, networking fundamentals, protocols, algorithms, and principles of distributed computing, introduction to network security and management.

CS 455. Computer Architecture. 3 Hours.
PR: CPE 271. Computer structure; emphasis on implications for software design; evolution of computers; elementary digital logic; CPU structures; memory and I/O structures; pipelining and memory management; introduction to parallel and high-level architectures. (3 hr. lec.).

CS 460. Introduction to Big Data Engineering. 3 Hours.
PR: (CS 221 or CS 320 or CS 350) with a minimum grade of C-. Fundamental topics in big data analytics. Includes data structures, representations, and search techniques used in big data analytics. Basic methods in predictive analytics and machine learning, distributed file systems and high-performance computing used in addressing big data problems. Basic techniques for social network analysis and visualization in big data.

CS 465. Cybersecurity Principles and Practice. 3 Hours.
PR: WVU and PSC sections require CS 350 with a minimum grade of C- and WVUIT sections require CS 321. Covers the principles and practice of cybersecurity. Addresses encryption; malicious code, spyware, and spam; authentication and access control; database security; operating system security; network security; and social engineering. Provides comprehensive overview of the cybersecurity threats, technologies for information assurance, and engineering approaches to build and maintain secure cyber space.

CS 470. Introduction to Computer Graphics. 3 Hours.
PR: CS 201 or CS 210 with a minimum grade of C- or consent for non-majors. Overview of 3D graphics hardware and gaming consoles; focus on developing 3D graphics software; fundamental algorithms for real-time 3D graphics with focus on game engine component development; introduction to three-dimensional game engine development.

CS 472. Artificial Intelligence. 3 Hours.
PR: CS 222 or CS 230 with a minimum grade of C- or consent for non-majors. Survey of AI techniques, heuristic search, game playing, and knowledge representation schemes: logic, semantic net, frames, rule-based; natural language processing, advanced AI techniques/systems: planning, blackboard architecture, neural net model; AI implementation. (3 hr. lec.).

CS 475. Game Development. 3 Hours.
PR: CS 222 or (CS 220 and CS 310 with a minimum grade of C- in each). Design and implementation of games using innovative technology in human-computer interfaces. Principles of game design, physiology and psychology of each of the five senses, and technologies for delivering sensory stimuli.
CS 480. Capstone Project - Design. 2 Hours.
PR: ENGL 102 or ENGL 103 and consent. Penultimate semester. Group senior design projects with individual design assignments appropriate to student's discipline. Complete system-level designs of the subsequent semester's project presented in written proposals and oral presentations. (Equivalent to BIOM 480, CPE 480, and EE 480.) (2 hr. lec., 1 hr. conf.).

CS 481. Capstone Project - Implementation. 3 Hours.
PR: CS 480. Continuation of CS 480. Detailed design and implementation of the system including choice of components, algorithm development, interfacing, troubleshooting, working in groups, and project management. Also covers professional topics, including ethics, liability, safety, socio-legal issues, risks and employment agreements. (1 hr. lec., 1 hr. conf., 2 hr. lab.).

CS 490. Teaching Practicum. 1-3 Hours.
PR: Consent. Teaching practice as a tutor or assistant.

CS 491. Professional Field Experience. 1-18 Hours.
PR: Consent. (May be repeated up to a maximum of 18 hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

CS 492. Directed Study. 1-3 Hours.
Directed study, reading, and/or research.

CS 493. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

CS 494. Seminar. 1-3 Hours.
PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

CS 495. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.

CS 496. Senior Thesis. 1-3 Hours.
PR: Consent.

CS 497. Research. 1-6 Hours.
Independent research projects.

ELECTRICAL ENGINEERING COURSES

EE 191. First-Year Seminar. 1-3 Hours.
Engages students in active learning strategies that enable effective transition to college life at WVU. Students will explore school, college and university programs, policies and services relevant to academic success. Provides active learning activities that enable effective transition to the academic environment. Students examine school, college and university programs, policies and services.

EE 221. Introduction to Electrical Engineering. 3 Hours.
PR: WVU and PSC sections require PHYS 111 and MATH 156, WVUIT sections require MATH 156. Electrical engineering units, circuit elements, circuit laws, measurement principles, mesh and node equations, network theorems, operational amplifier circuits, energy storage elements, sinusoids and phasors, sinusoidal steady state analysis, average and RMS values, complex power. Pre-requisite(s) and/or co-requisite(s) may differ on regional campuses.

EE 222. Introduction to Electrical Engineering Laboratory. 1 Hour.
CoReq: EE 221. Design and experimental exercises basic electrical circuits. Use of the digital computer to solve circuit problems. (3 hr. lab.).

EE 223. Electrical Circuits. 3 Hours.
PR: WVU and PSC sections require EE 221 and EE 222 and PHYS 112 and MATH 251 all with a grade of C- or better, WVUIT sections require EE 221 and EE 222 and MATH 251 all with a grade of C- or better. Time response of RC and RL circuits, unit step response, second order circuits, poly-phase systems, mutual inductance, complex frequency, network frequency response, two-port networks and transformers. Fourier methods and Laplace Transforms.

EE 224. Electrical Circuits Laboratory. 1 Hour.
CoReq: EE 223. Design and experimental exercises in circuits. Transient circuits, steady state AC circuits, frequency response of networks. Use of digital computer to solve circuit problems. (3 hr. lab.).

EE 251. Digital Electronics. 3 Hours.
PR: EE 221 with a minimum grade of C-, PHYS 112 with a minimum grade of C- and CPE 271. Diode and bipolar and field-effect transistor device operation and switching models. Use of bipolar and field-effect transistors and diodes in switching and logic circuits. Switching circuits and logic gates including logic levels, circuit configuration, and interfacing. (3 hr. lec.).

EE 252. Digital Electronics Laboratory. 1 Hour.
CoReq: EE 251. Design, fabrication, and measurement of digital electronic circuits. Modeling and use of discrete devices, logic gates, display devices in switching circuits and timer circuits, Interfacing with integrated logic gates. (3 hr. lab.).

EE 293. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.
EE 327. Signals and Systems 1. 3 Hours.
PR: MATH 261 and EE 223. Introduction to linear system models and solutions in the time and frequency domains. Balanced emphasis is placed on both continuous and discrete time and frequency methods. (3 hr. lec.).

EE 328. Signals and Systems Laboratory. 1 Hour.
PR: EE 327 and CoReq: EE 329. Laboratory experiments in measurement and analysis of systems and signals. (3 hr. lab.).

EE 329. Signals and Systems 2. 3 Hours.
PR: EE 327 and (MATH 448 or PR or CONC: STAT 215). Analysis of continuous and discrete time signals. Statistical description of nondeterministic signals, correlation functions, and spectral density with these concepts applied to communications and signal processing. (3 hr. lec.).

EE 335. Electromechanical Energy Conversion and Systems. 3 Hours.
PR: WVU sections require EE 223 and EE 224 and PHYS 112, WVUIT sections require EE 223 and EE 224 and a co-requisite of EE 345. Electric energy sources, fundamentals of electromechanical energy conversion, transformers and rotating machinery.

EE 336. Electromechanical Energy Conversion and Systems Lab. 1 Hour.
PR or CONC: WVUIT sections require EE 335. 1 Hr. Transformers, DC motors and generator performance and characteristics, synchronous machine performance and characteristics.

EE 345. Engineering Electromagnetics. 3 Hours.
PR: WVU sections require MATH 261 and PHYS 112, WVUIT sections require MATH 261 and PHYS 112 and EE 223. Continued use of vector calculus, electrostatics, magnetostatics, Maxwell's Equations, and boundary conditions. Introduction to electromagnetic waves, transmission lines, and radiation from antennas.

EE 355. Analog Electronics. 3 Hours.
PR: EE 223 and EE 251. Electronic devices in analog circuits. Small-signal and graphical analysis of BJT and FET circuits; frequency response, feedback, and stability. Linear and nonlinear operational amplifier circuits. Power amplifiers and power control by electronic devices. (3 hr. lec.).

EE 356. Analog Electronics Laboratory. 1 Hour.
CoReq: EE 355. Design, fabrication, and measurement of analog electronic circuits. Use of discrete devices, integrated circuits, operational amplifiers, and power electronic devices. Study of biasing and stability, frequency response, filters, analog computation circuits, and power control circuits. (3 hr. lab.).

EE 411. Fundamentals of Control Systems. 3 Hours.
PR: EE 327. Introduction to classical and modern control; signal flow graphs; state-variable characterization; time-domain, root locus, and frequency techniques; stability criteria. (3 hr. lec.).

EE 413. Introduction to Digital Control. 3 Hours.
PR: EE 327. Sampling of continuous-time signals and transform analysis. Stat-variable analysis for linear discrete-time systems and design of digital controller. (3 hr. lec.).

EE 425. Bioengineering. 3 Hours.
Introduction to human anatomy and physiology using an engineering systems approach. Gives the engineering student a basic understanding of the human system so that the student may include it as an integral part of the design. Co-listed with MAE 473. (3 hr. lec.).

EE 426. Biometric Systems. 3 Hours.
PR: STAT 215 and MATH 261 and CS 111. It is also suggested (not required) that EE 327 and CS 350 also be taken prior to enrolling in this course. This course presents an introduction to the principles of operation, design, testing, and implementation of biometric systems, and the legal, social and ethical concerns associated with their use.

EE 427. Signals and Systems 1. 3 Hours.
PR: EE 335 and EE 336 or consent. General considerations; load characteristics; subtransmission and distribution substations; primary and secondary distribution, secondary network systems; distribution transformers; voltage regulation and application of capacitors; voltage fluctuations; protective device coordination. (3 hr. lec.).

EE 435. Introduction to Power Electronics. 3 Hours.
PR: EE 335 and EE 355 and EE 356 or consent; WVUIT sections require EE 335 and EE 365 and EE 366 or consent. Application of power semiconductor components and devices to power system problems; power control; conditioning processing, and switching. Course supplemented by laboratory problems. (3 hr. lec.).

EE 436. Power Systems Analysis. 3 Hours.

EE 437. Fiber Optics Communications. 3 Hours.
PR: EE 329 and EE 345. Fundamentals of optics and light wave propagation, guided wave propagation and optical wave guides, light sources and light detectors, couplers, connections, and fiber networks, modulation noise and detection in communication systems. (3 hr. lec.).

EE 445. Introduction to Antennas. 3 Hours.
PR: EE 345 or equivalent. Development of Maxwell's equations and general electromagnetic theory underpinning broadcast communication systems, wave propagation, antennas and antenna arrays.
EE 450. Device Design and Integration. 3 Hours.
PR: EE 345 and EE 355. Fundamentals of semiconductor materials, p-n junctions, metal-semiconductor junctions, JFET's, MESFET's, MOSFET's, physical device design, device simulation, gate level & CMOS design and layout. (3 hr. lec.).

EE 455. Introduction to Microfabrication. 3 Hours.
PR: EE 355 or consent. Introduction to the physical processes underlying current and emerging microfabrication technology and their selective use in the technology computer aided design (TCAD) and fabrication of electrical, optical, and micromechanical devices and systems.

EE 457. Fundamentals of Photonics. 3 Hours.
PR: EE 345 or equivalent. Basic physics and optical engineering concepts necessary to understand the design and operation of photonic -based systems, including communications, nanophotonics, sensing and display technologies. Scaling, integration, and packaging of optical approaches and their compatibility with micro/nanosystems.

EE 461. Introduction to Communications Systems. 3 Hours.
PR: EE 329. Application of random processes and spectral analysis to the design and analysis of communication systems. Analysis and comparison of standard modulation techniques relative to bandwidth, noise, threshold, and hardware constraints.

EE 463. Digital Signal Processing Fundamentals. 3 Hours.
PR: MATH 251 and EE 327. Theories, techniques, and procedure used in analysis, design, and implementation of digital and sampled data filters. Algorithms and computer programming for software realization. Digital and sampled data realizations, switched capacitor and charge-coupled device IC's. (3 hr. lec.).

EE 465. Introduction to Digital Image Processing. 3 Hours.
PR: EE 251 and EE 327. Introduction to the vision process fundamental mathematical characterization of digitized images, two-dimensional transform methods used in image processing, histogram analysis and manipulation, image and filtering techniques, image segmentation, and morphology. (3 hr. lec.).

EE 467. Digital Speech Processing. 3 Hours.
PR: EE 327 and EE 329. Covers fundamentals in digital speech processing including production, speech analysis, speech coding, speech enhancement, speech recognition and speaker recognition. Emphasize hand-on experience of processing speech signals using MATLAB.

EE 480. Capstone Project - Design. 3 Hours.
PR: ENGL 102 or ENGL 103 and consent. Penultimate semester. Group senior design projects with individual design assignments appropriate to student's discipline. Complete system-level designs of the subsequent semester's project presented in written proposals and oral presentations. (Equivalent to BIOM 480, CPE 480, CS 480) (2 hr. lec., 1 hr. conf.) Note: WVU Tech course is 3 credit hours.

EE 481. Capstone Project - Implementation. 3 Hours.
PR: EE 480. Detailed design and implementation of the system including choice of components, algorithm development, interfacing, trouble shooting, working in groups, and project management. Also covers professional topics, including ethics, liability, safety, socio-legal issues, risks and employment agreements. (1 hr. lec., 1 hr. conf., 2 hr. lab.).

EE 490. Teaching Practicum. 1-3 Hours.
PR: Consent. Teaching practice as a tutor or assistant.

EE 491. Professional Field Experience. 1-18 Hours.
PR: Consent. (May be repeated up to a maximum of 18 hours.) Prearranged experiential learning program, to be planned, supervised, and evaluated for credit by faculty and field supervisors. Involves temporary placement with public or private enterprise for professional competence development.

EE 492.. 1-6 Hours.
Directed study, reading, and/or research.

EE 493. Special Topics. 1-6 Hours.
PR: Consent. Investigation of topics not covered in regularly scheduled courses.

EE 494. Seminar. 1-3 Hours.
PR: Consent. Presentation and discussion of topics of mutual concern to students and faculty.

EE 495. Independent Study. 1-6 Hours.
Faculty supervised study of topics not available through regular course offerings.

EE 496. Senior Thesis. 1-3 Hours.
PR: Consent.

EE 497. Research. 1-6 Hours.
Independent research projects.

EE 498. Honors. 1-3 Hours.
PR: Students in Honors Program and consent by the honors director. Independent reading, study or research.