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January 23, 2018

RE: Documentation for Discontinuation of BSESM: the Bachelor of Science Engineering Science and Mechanics

To Whom It May Concern,

The College of Engineering plans to discontinue the BSESM: the Bachelor of Science Engineering Science and Mechanics.

### **Background**

Virginia Tech has offered a Bachelor of Science in Engineering Mechanics since 1958, renamed the Bachelor of Science in Engineering Science and Mechanics in 1972. While numerous institutions offered this and similar degrees in the past, the number of actual departments and degree programs has declined over the past 25 years, changing with the needs of the global engineering community. For many years the program at Virginia Tech has been a leader in the nation, producing graduates that often continued into graduate programs and future research positions.

The ever-changing needs of the engineering professional community is reflected in the undergraduate enrollment across all degree programs in the College. For example, in the past 25 years several degree programs have watched their enrollments decline in synch with national or global demand. Throughout these periods the departments had to maintain a strong presence, venturing into other, often emerging, industries in order to keep their degree programs and graduates relevant and in high demand. These changing enrollment patterns experienced by many degree programs over time must be addressed to sustain and grow a vibrant department and degree. The engineering science and mechanics degree program ESM has a decreasing presence in the COE as their student enrollment has declined over time. Moreover, the number of undergraduate students seeking engineering science and mechanics as their first degree choice has been declining.

Dean Julia Ross supports the discontinuation of the Bachelor of Science in Engineering Science and Mechanics (see attached letter). The College of Engineering Curriculum Committee voted 8-4 (with 1 abstain) on the discontinuation of the Bachelor of Science in Engineering Science and Mechanics degree offered by the College of Engineering on February 6, 2019.

### **Rationale**

As a benchmark, in 2000 when Engineering Science and Mechanics existed as a separate department, their undergraduate enrollment was 73 undergraduates and 81 graduate students<sup>1</sup>.

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<sup>1</sup> All data provided in this document is derived from Virginia Tech Institutional Research using on campus headcounts.

The College undergraduate enrollment was 5464, with 1370 graduate students. The past 18 years has seen unprecedented growth in the University and, correspondingly, the College. By fall 2013, the College enrollment was 7199, a 32% increase for undergraduate students. Graduate student enrollment had also grown by 32% to 1864. ESM experienced enrollment growth during this same period (80%) to 127 undergraduate and 103 (27%) graduate students. A college wide plan was created to address growing enrollment management concerns across all departments.

#### *College Enrollment Management Plan*

The College of Engineering implemented an enrollment management plan in 2013 to allow for stable growth across all degree programs. All students must complete a set of common freshman year courses, then apply to their desired degree program. A 3.0 GPA will guarantee a student their first choice degree program. All other students are ranked by GPA and placed into their 1<sup>st</sup>, 2<sup>nd</sup>, or 3<sup>rd</sup> degree choice, depending on the number of seats available in the particular program. The number of seats, or students enrolled by each department in a given year, is currently based on a 7:1 student to tenure track faculty ratio.

The implementation of the College enrollment management plan in fall 2013 had an impact on all degree programs. Enrollment targets for each department were initially set based on an incoming student faculty ratio of 6:1. The intent was to evenly distribute students based on departmental resource capabilities. ESM's overall student faculty ratio for the department was lower than all other departments and degree programs at approximately 3:1 whereas the COE average overall was approximately 19:1.

By 2014 undergraduate enrollment had not appreciably improved. Dean Richard Benson merged ESM with SBES to form BEAM, the Department of Biomedical Engineering and Mechanics. This action was intended to bring improved growth prospects for the ESM undergraduate program as well as provide an undergraduate degree program to complement, and take advantage of the synergies between the biomedical engineering and the engineering mechanics graduate programs. The enrollment management plan had been implemented and it was anticipated that the biomechanics area of ESM would benefit from proximity to the biomedical undergraduate minor. Simultaneously, there were efforts to create a new biomedical engineering undergraduate degree. It was believed that having the ESM faculty and staff as an integral part of the development and implementation of the proposed degree was essential. At the same time, the University was publically discussing increasing undergraduate enrollments, where the College expected to, and anticipated being an integral partner.

As can be seen in the following table, ESM enrollments initially increased and then declined as the College grew. From 2013 to 2018, engineering undergraduate enrollment grew 12% while the ESM undergraduate enrollment declined 23%. Given the decline in graduate enrollment in 2018, both 2018 and 2017 comparisons are provided. ESM graduate enrollment declined 35% from 2013 to 2017 compared to a College increase of 9% over that same time period.

<i>year</i>	<b>COE Undergraduate Enrollment</b>	<b>COE Graduate Enrollment</b>	<b>ESM Undergraduate Enrollment</b>	<b>ESM Sophomore Enrollment</b>	<b>ESM Graduate Enrollment</b>	<b>Graduate Degrees Awarded</b>
2013	6980	2037	127	19	103	36
2014	7132	2001	194	38	85	36
2015	7492	2198	198	34	78	42
2016	7569	2290	165	24	73	32
2017	7871	2233	121	21	70	58
2018	8090	2114	98	19	67	
2018	16%	3%	-23%		-35%	
2017		9%			-32%	

Over the past 5 years, the number of first-time freshman students requesting ESM as their first choice has steadily declined as shown by the number of ESM sophomores.

### **Conclusion**

Dean Ross hosted forums with BEAM department faculty and staff to discuss declining enrollments resulting in low student to faculty ratio, expressing concern for the future viability of the degree and requesting feedback that would address the situation. The ESM degree program needs to be an equal contributor to the educational mission of the college and enroll a comparable student to faculty ratio. With respect to undergraduate enrollments, the low student to faculty ratio for ESM makes it difficult for the College to balance enrollment resources (people, space and money) with respect to the other departments and degree programs where enrollments are steadily, if not markedly, increasing.

There are additional factors considered. A new undergraduate degree in biomedical engineering was approved in September 2018 which is expected to draw a significant number of students. All BEAM faculty will be involved in launching and maintaining the new degree, which the College expects to play a significant role in managing future growth in undergraduate enrollments. Further, the University has recently strengthened its commitment to the partnership with the new position of the Virginia Tech Carilion School of Medicine and the growth of research and education in the health sciences. This will enhance the already strong presence of BEAM with its renowned applied mechanics and biomedical research programs as faculty partnerships develop and evolve with the new college.

**Teach Out Plan:  
Last Term/Year**

The last term that students will be able to complete the Bachelor of Science in Engineering Science and Mechanics degree is August 2023. The College of Engineering has a common freshman program, allowing students to seek entry to a degree program for the start of their sophomore year. Current freshman (fall 2018) will represent the last entering class where we will recruit for the degree. These students will enter the ESM degree program in fall of 2019. Using the August 2023 date will allow these students 4 additional years to complete the sophomore, junior and senior level requirements. The time to degree for students that entered Virginia Tech as First-time, Full-time Freshmen is as follows:

**Virginia Tech  
First Majors Time to Baccalaureate Degree  
Degrees Conferred 2009-2010 through 2014-2015  
By Degree Major: Engineering**

		Students who Entered Virginia Tech as First-time, Full-time Freshmen					
		Conferred Year					
		2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015
<b>Engineering</b>	Number of First Majors	1032	1099	1086	1109	1253	1384
	Mean Years to Degree	4.38	4.31	4.36	4.33	4.21	4.30
ESM	Number of First Majors	32	24	32	35	33	33
	Mean Years to Degree	4.45	4.35	4.18	4.08	3.95	4.29

\*\*\* Means of groups with fewer than five students are not reported.

Note: Degree recipients who entered the university as transfer students or as part-time students are not included in the above table.

Institutional Research and Effectiveness  
Data Sources: Student Census Files

**Lead Time**

Approximately 99 current students are expected to graduate by May 2021. However, we have just accepted a new incoming class of freshmen and transfer students. The transfer students will easily meet the deadline. The freshmen will need the full four years to complete the degree (May 2022). However, to accommodate students who wish to intern or coop, we will allow 5 full years to complete their degree. To ensure that students with challenges can meet the deadline, we have extended the discontinuation of the major beyond the expected date for all students to graduate. The major will be discontinued after May 2023 graduation. We will no longer accept students to the BSESM major after the January 2020 change major period to ensure students can meet the deadline. This will allow the current freshman students a chance to declare BSESM as their major or add it as a second major.

## "Stopped Out" Students

The 198 students that have "stopped out" since fall 2012 have been considered. There is a 6-year period in which students may return and complete their BSESM Engineering Science and Mechanics degree. These students will be notified in writing about the discontinuation of the major. However, students will have the option to change their major within the College of Engineering or to other majors within the university should they be eligible. Additionally, a student that cannot complete the BSESM Engineering Science and Mechanics degree by May 2022, may transition to another major within the College of Engineering or another viable major on campus. The Biomedical Engineering and Mechanics academic advisor will assist all students through the transition process.

## Communication Plan

A communication plan is in place and current students will be notified by email concerning the discontinuation of the major. They will be notified of the feasibility of completing the major. A notice will be posted on our website as soon as 15-day review is complete to let all students know that the major will no longer accept students after the January 2020 change major period. We will also communicate this information with advisors throughout campus using the Advisor Listserv. Non-COE students will be told about the discontinuation of BSESM degree during all Information Sessions held throughout the 2018-2019 academic year. Current students in general engineering will be notified to change or declare BSESM if desired, or add BSESM as a second major during the January 2020 change major period. Finally, all "stopped out" students will be notified in writing by mail concerning the discontinuance of the BSESM degree.

## Other Considerations

The engineering science core classes will continue to be offered through the BEAM department, as will ESM degree specific courses.



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## Memo

TO: Commission on Undergraduate Studies and Polices  
FROM: Julia M. Ross, Dean   
College of Engineering  
DATE: February 13, 2019  
RE: Bachelor of Science in Engineering Science and Mechanics

The College of Engineering Undergraduate Curriculum Committee voted to support the discontinuation of the Bachelor of Science in Engineering Science and Mechanics on February 6, 2019 with a vote of 8 yes, 4 no, 1 abstention. I fully support the discontinuation of the degree as outlined in the attached resolution and documentation.

I base my support for discontinuation on the following reasons:

1. Historic and ongoing low program enrollment that is declining despite significant College growth
2. Availability and growth of mechanics-related programs in the Mechanical Engineering and Aerospace and Ocean Engineering departments
3. A new biomedical engineering degree starting in fall 2019 with high student interest and offered through the same department as the ESM degree
4. Planned College growth on the order of 2000 undergraduates in computer science, computer engineering and related disciplines

The College has a teach out plan, a "stopped out" student plan, and a communication plan in place for working with our current BS ESM students. The last degree granted will be in May 2023.

COLLEGE OF ENGINEERING  
DEPARTMENT OF BIOMEDICAL ENGINEERING AND MECHANICS  
**BACHELOR OF SCIENCE IN ENGINEERING SCIENCE AND MECHANICS**  
FOR STUDENTS GRADUATING IN CALENDAR YEAR 2020  
130 CREDITS REQUIRED FOR GRADUATION

FALL SEMESTER FRESHMAN 2016		Credits	SPRING SEMESTER FRESHMAN 2017		Credits
CHEM 1035 General Chemistry		3	ENGL 1106 First-Year Writing <i>Pre: ENGL 1105</i>		3
CHEM 1045 General Chemistry Lab <i>Co: CHEM 1035</i>		1	MATH 1226 Calculus of a Single Variable <i>Pre: MATH 1225 (C-)</i>		4
ENGL 1105 First-Year Writing		3	MATH 2114 Introduction to Linear Algebra <i>Pre: MATH 1225 (B) or MATH 1226</i>		3
MATH 1225 Calculus of a Single Variable (C-) <i>Pre: Math Ready</i>		4	PHYS 2305 Found of Physics I w/lab <i>Pre: MATH 1225; Co: MATH 1226</i>		4
ENGE 1215 Foundations of Engineering (C-)		2	ENGE 1216 Foundations of Engineering (C-) <i>Pre: ENGE 1215 (C-) or ENGE 1024 (C-)</i>		2
CLE (Area 2 or 3)		3			
<b>TOTAL</b>		<b>16</b>	<b>TOTAL</b>		<b>16</b>
FALL SEMESTER SOPHOMORE 2017		Credits	SPRING SEMESTER SOPHOMORE 2018		Credits
MATH 2204 Intro Multivariable Calculus <i>Pre: MATH 1226</i>		3	ESM 2074 (AOE 2074) Computational Methods <i>Pre: ENGE 1114 or ENGE 1216 or ENGE 1434</i>		2
MATH 2214 Differential Equations <i>Pre: MATH 1226, MATH 1114 or 2114</i>		3	ECE 3054 Electrical Theory <i>Pre: PHYS 2306 Co: MATH 2214</i>		3
PHYS 2306 Foundations of Physics I w/lab <i>Pre: MATH 1226, PHYS 2305</i>		4	MSE 2034 Elements of Materials Engr <i>Pre: CHEM 1035 Co: PHYS 2305</i>		3
ESM 2014 Prof Development Seminar		1 <sup>[F]</sup>	ESM 2204 Mech of Deformable Bodies <i>Pre: ESM 2104 or 2114, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
ESM 2104 Statics <i>Co: MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H or MATH 2406H</i>		3	ESM 2304 Dynamics <i>Pre: ESM 2104 or 2114, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
CLE (Areas 2 or 3)		3			
<b>TOTAL</b>		<b>17</b>	<b>TOTAL</b>		<b>14</b>
FALL SEMESTER JUNIOR 2018		Credits	SPRING SEMESTER JUNIOR 2019		Credits
ESM 3034 Fluid Mechanics Lab <i>Pre: ESM 2304, ECE 3054 Co: 3234</i>		1 <sup>[F]</sup>	MATH 4574 Vector and Complex Analysis <i>Pre: MATH 2204 or MATH 2224 or MATH 2204H</i>		3
ESM 3054 (MSE 3054) Mech. Behavior of Matrls <i>Pre: ESM 2204, MSE 2034 or MSE 2044 or MSE 3094 or AOE 3094 or CEE 3684</i>		3	ESM 3114 Problem Definition & Scoping in Engineering Design <i>Pre: Junior Standing in ESM, ESM 2014</i>		1 <sup>[S]</sup>
ESM 3064 (MSE 3064) Mech Beh Matrls Lab <i>Pre: ESM 2204; Co: ESM 3054</i>		1	ESM 3134 Dyn III Vib/Controls <i>Pre: ESM 3124, MATH 4564</i>		3 <sup>[S]</sup>
ESM 3124 Dynamics II <i>Pre: ESM 2304, MATH 2214, (MATH 2224 or MATH 2204 or MATH 2204H)</i>		3 <sup>[F]</sup>	ESM 3154 Solid Mechanics <i>Pre: ESM 2204, MATH 2214 Co: MATH 4574</i>		3 <sup>[S]</sup>
ESM 3234 Fluid Mechanics I <i>Pre: ESM 2304, PHYS 2306</i>		3 <sup>[F]</sup>	ESM 3334 Fluid Mechanics II <i>Pre: ESM 3234 Co: MATH 4574</i>		3 <sup>[S]</sup>
MATH 4564 Operational Methods <i>Pre: (MATH 2214 or MATH 2214H) or MATH 2406H or CMDA 2006</i>		3	ESM 3444 Mechanics Lab <i>Pre: ESM 3034, 3054, 3064, 3124, 3234, ECE 3054 Co: ESM 3134, 3154, 3334</i>		2 <sup>[S]</sup>
Science Elective <i>Choose from: BCHM, BIOL, BMVS, CHEM, GEOS, PHYS</i>		3	Technical Elective		3
<b>TOTAL</b>		<b>17</b>	<b>TOTAL</b>		<b>18</b>
FALL SEMESTER SENIOR 2019		Credits	SPRING SEMESTER SENIOR 2020		Credits
STAT 4604 Statistical Methods for Eng <i>Pre: MATH 1226</i>		3	ESM 4016 Creative Design <i>Pre: ESM 4015</i>		3 <sup>[S]</sup>
ESM 4015 Creative Design <i>Pre: ESM 3114</i>		3 <sup>[F]</sup>	Technical Elective		3
ESM 4734 (AOE 4024) Into to Finite Elements <i>Pre: (CS 3414 or MATH 3414 or ESM/ AOE 2074), (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3 <sup>[F]</sup>	Technical Elective		3
Thermodynamics Elective <sup>1</sup>		3	CLE (Areas 2 or 3)		3
Technical Elective		3	CLE (Area 2/3 & 7)		3
Free Elective		1	CLE (Area 6)		1
<b>TOTAL</b>		<b>16</b>	<b>TOTAL</b>		<b>16</b>

<sup>1</sup> Thermodynamics Elective chosen from: BSE 3154, ME 3134, or PHYS 3704

Superscripted annotation (F, S, SI, SII) in credits column indicates terms when a course is expected to be offered.

<b>Curriculum for Liberal Education (CLE)</b>				
Consult the CLE Alphabetical Listing at: <a href="https://www.pathways.prov.vt.edu/cle.html">https://www.pathways.prov.vt.edu/cle.html</a> . CLE courses need to be completed prior to graduation				
CLE Area 1: Writing and Discourse (6 hrs)	ENGL 1105	(3)	ENGL 1106	(3)
CLE Area 2: Ideas, Cultural Traditions, Values Electives (6 hrs)		(3)		(3)
CLE Area 3: Society & Human Behavior electives (6 hrs)		(3)		(3)
CLE Area 4: Scientific Reasoning and Discovery (8 hrs)	PHYS 2305	(4)	PHYS 2306	(4)
CLE Area 5: Quantitative and Symbolic Reasoning (6 hrs)	MATH 1225	(3)	MATH 1226	(3)
CLE Area 6: Creativity & Aesthetic Experience elective (1 hr)				(1)
CLE Area 7: Global Issues Elective (3 hrs) <sup>1</sup>				(3)
<sup>1</sup> A total of 6 hours of Area 2 and 6 hours of Area 3 courses must be completed. Only selected courses can simultaneously satisfy both Area 2/3 & 7 requirements. Use extra care when selecting this course.				
<b>Electives:</b>				
The ESM degree requires 12 credits of technical electives from list, 3 hours of thermodynamics electives from list, and 3 hours of science electives. Free electives or Area 6 courses offered only on a P/F basis may be taken under the P/F grading option.				
<b>Change of Major Requirements:</b>				
For Change of Major requirements, please see <a href="http://www.enge.vt.edu/undergraduate-changing-majors.html">http://www.enge.vt.edu/undergraduate-changing-majors.html</a> .				
<b>Foreign Language Requirements:</b>				
Students must have had 2 years of a foreign language in high school or one year at the college level (6 credit hours) of the same language. College-level credits used to meet this requirement do not count towards the degree.				
<b>Satisfactory Progress Towards Degree:</b>				
University Policy 91 outlines university-wide minimum criteria to determine if students are making satisfactory progress towards the completion of their degrees. The ESM Department fully supports this policy. Specific expectations for satisfactory progress for Engineering Science and Mechanics majors are as follows:				
<ul style="list-style-type: none"> <li>• Each student must meet the minimum University-wide criteria as described in Policy 91 and summarized in the Undergraduate Catalog (under Academic Policies)</li> <li>• After having completed 72 credit hours (including transfer, advanced placement, advanced standing, and credit by examination) must have completed ESM 2014, 2104, 2204, 2304, MATH 2214, 2204, and PHYS 2305, 2306</li> <li>• Maintain an in-major GPA (in-major GPA is calculated using all courses taught under the ESM designator) and an extended in-major GPA (extended in-major GPA is calculated using all ESM courses and MATH 2204, 2214, 4564, and 4574) of 2.0 or better</li> <li>• Complete a minimum of 12 credits that apply toward the ESM degree per academic year (including summer and winter sessions).</li> </ul>				
<b>Statement of Prerequisites:</b>				
<ul style="list-style-type: none"> <li>• Pre-requisites for each course are listed after the course title. The (letter grade) notation, such as (C-), indicates the minimum grade students must earn in the pre-requisite course. There are no hidden pre-requisites in the program of study. Prerequisites may change from what is indicated. Be sure to consult the University Catalog or check with your advisor for the most current pre-requisites.</li> </ul>				
<b>Graduation Requirements:</b>				
Each student must complete at least 130 semester credit hours with a minimum overall GPA of 2.00 and a minimum in-major GPA of 2.00. All ESM prefix courses count towards the in-major GPA.				

**Approved Technical Electives:**

ESM 4014: Applied Fluid Mechanics  
ESM 4024: Advanced Mechanical Behavior of Materials  
ESM 4044: Mechanics of Composite Materials  
ESM 4084 (AOE 4084): Engineering Design Optimization  
ESM 4105-4106: Engineering Analysis of Physiologic Systems  
ESM 4114: Nonlinear Dynamics and Chaos  
ESM 4194 (ME 4194): Sustainable Energy Solutions for a Global Society  
ESM 4304: Hemodynamics  
ESM 4204: Musculoskeletal Biomechanics  
ESM 4224: Biodynamics & Control  
ESM 4245-6: Mechanics of Animal Locomotion  
ESM 4614: Probability-Based Modeling, Analysis, and Assessment  
ESM 4994: Undergraduate Research  
ESM 5014: Introduction to Continuum Mechanics  
ESM 5405 or 5406: Clinical Internship in Biomedical Engineering  
AOE 3024: Thin-Walled Structures  
AOE 3124: Aerospace Structures  
AOE 3224: Ocean Structures  
AOE 3134: Stability and Control  
AOE 4064: Fluid Flows in Nature  
AOE 4134: Astromechanics  
AOE 4214: Ocean Wave Mechanics  
BMES 3124: Introduction to Biomechanics  
BMES 3134: Introduction to Biomedical Imaging  
BMES 3144: Biomedical Devices  
BMES 3184: Problem Solving in BME  
BMES 4134: Global, Societal, and Ethical Considerations in Biomedical Engineering  
BMES 4154: Commercialization of BME Research  
CEE 3014: Construction Management  
CEE 3104: Introduction to Environmental Engineering  
CEE 3404: Theory of Structures  
CEE 3424: Reinforced Concrete Structures I  
CEE 3434: Design of Steel Structures I  
ECE 3105-3106: Electromagnetic Fields  
ECE 4405-4406: Control Systems  
ENGR 3124: Introduction to Green Engineering  
ENGR 3134: Environmental Life Cycle Analysis  
ME 4224: Aircraft Engines and Gas Turbines  
ME 4234: Aerospace Propulsion Systems  
ME 4524: Introduction to Robotics and Automation  
MSE 4055: Materials Selection and Design I  
MSE 4164: Principles of Materials Corrosion  
MSE 4304: Metals and Alloys  
MSE 4574: Biomaterials  
MSE 4614: Nanomaterials  
CHEM 2535-2536: Organic Chemistry  
CHEM 2545-2546: Organic Chemistry Laboratory  
MATH 3214: Calculus of Several Variables  
MATH 4234: Elementary Complex Analysis  
MATH 4445-4446: Introduction to Numerical Analysis  
PHYS 3324: Modern Physics  
PHYS 3405-3406: Intermediate Electricity and Magnetism  
PHYS 3655-3656: Introduction to Astrophysics  
PHYS 4455-4456: Introduction to Quantum Mechanics  
PHYS 4504: Introduction to Nuclear and Particle Physics  
PHYS 4714: Introduction to Biophysics

COLLEGE OF ENGINEERING  
DEPARTMENT OF BIOMEDICAL ENGINEERING AND MECHANICS  
**BACHELOR OF SCIENCE IN ENGINEERING SCIENCE AND MECHANICS, ENGINEERING PHYSICS OPTION**  
FOR STUDENTS GRADUATING IN CALENDAR YEAR 2020  
130 CREDITS REQUIRED FOR GRADUATION

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CHEM 1045 General Chemistry Lab <i>Co: CHEM 1035</i>		1	MATH 1226 Calculus of a Single Variable <i>Pre: MATH 1225 (C-)</i>		4
ENGL 1105 First-Year Writing		3	MATH 2114 Introduction to Linear Algebra <i>Pre: MATH 1225 (B) or MATH 1226</i>		3
MATH 1225 Calculus of a Single Variable (C-) <i>Pre: Math Ready</i>		4	PHYS 2305 Found of Physics I w/lab <i>Pre: MATH 1225; Co: MATH 1226</i>		4
ENGE 1215 Foundations of Engineering (C-)		2	ENGE 1216 Foundations of Engineering (C-) <i>Pre: ENGE 1215 (C-) or ENGE 1024 (C-)</i>		2
CLE (Area 2 or 3)		3			
<b>TOTAL</b>		<b>16</b>	<b>TOTAL</b>		<b>16</b>
FALL SEMESTER SOPHOMORE 2017		Credits	SPRING SEMESTER SOPHOMORE 2018		Credits
MATH 2204 Intro Multivariable Calculus <i>Pre: MATH 1226</i>		3	ESM 2074 (AOE 2074) Computational Methods <i>Pre: ENGE 1114 or ENGE 1216 or ENGE 1434</i>		2
MATH 2214 Differential Equations <i>Pre: MATH 1226, MATH 1114 or 2114</i>		3	ECE 3054 Electrical Theory <i>Pre: PHYS 2306 Co: MATH 2214</i>		3
PHYS 2306 Foundations of Physics I w/lab <i>Pre: MATH 1226, PHYS 2305</i>		4	MSE 2034 Elements of Materials Engr <i>Pre: CHEM 1035 Co: PHYS 2305</i>		3
ESM 2014 Prof Development Seminar		1 <sup>[F]</sup>	ESM 2204 Mech of Deformable Bodies <i>Pre: ESM 2104 or 2114, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
ESM 2104 Statics <i>Co: MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H or MATH 2406H</i>		3	ESM 2304 Dynamics <i>Pre: ESM 2104 or 2114, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
CLE (Areas 2 or 3)		3			
<b>TOTAL</b>		<b>17</b>	<b>TOTAL</b>		<b>14</b>
FALL SEMESTER JUNIOR 2018		Credits	SPRING SEMESTER JUNIOR 2019		Credits
ESM 3034 Fluid Mechanics Lab <i>Pre: ESM 2304, ECE 3054 Co: 3234</i>		1 <sup>[F]</sup>	MATH 4574 Vector and Complex Analysis <i>Pre: MATH 2204 or MATH 2224 or MATH 2204H</i>		3
ESM 3054 (MSE 3054) Mech. Behavior of Matrls <i>Pre: ESM 2204, MSE 2034 or MSE 2044 or MSE 3094 or AOE 3094 or CEE 3684</i>		3	ESM 3114 Problem Definition & Scoping in Engineering Design <i>Pre: Junior Standing in ESM, ESM 2014</i>		1 <sup>[S]</sup>
ESM 3064 (MSE 3064) Mech Beh Matrls Lab <i>Pre: ESM 2204; Co: ESM 3054</i>		1	ESM 3134 Dyn III Vib/Controls <i>Pre: ESM 3124, MATH 4564</i>		3 <sup>[S]</sup>
ESM 3124 Dynamics II <i>Pre: ESM 2304, MATH 2214, (MATH 2224 or MATH 2204 or MATH 2204H)</i>		3 <sup>[F]</sup>	ESM 3154 Solid Mechanics <i>Pre: ESM 2204, MATH 2214 Co: MATH 4574</i>		3 <sup>[S]</sup>
ESM 3234 Fluid Mechanics I <i>Pre: ESM 2304, PHYS 2306</i>		3 <sup>[F]</sup>	ESM 3334 Fluid Mechanics II <i>Pre: ESM 3234 Co: MATH 4574</i>		3 <sup>[S]</sup>
MATH 4564 Operational Methods <i>Pre: (MATH 2214 or MATH 2214H) or MATH 2406H or CMDA 2006</i>		3	ESM 3444 Mechanics Lab <i>Pre: ESM 3034, 3054, 3064, 3124, 3234, ECE 3054 Co: ESM 3134, 3154, 3334</i>		2 <sup>[S]</sup>
PHYS 3324 Modern Physics <i>Pre: PHYS 2306 Co: MATH 2214, PHYS 2504</i>		4 <sup>[F]</sup>	PHYS 3704 Thermal Physics <i>Pre: PHYS 2306, PHYS 3324 Co: MATH 2214, PHYS 2504</i>		3 <sup>[S]</sup>
<b>TOTAL</b>		<b>18</b>	<b>TOTAL</b>		<b>18</b>
FALL SEMESTER SENIOR 2019		Credits	SPRING SEMESTER SENIOR 2020		Credits
STAT 4604 Statistical Methods for Eng <i>Pre: MATH 1226</i>		3	ESM 4016 Creative Design and Design <i>Pre: ESM 4015</i>		3 <sup>[S]</sup>
ESM 4015 Creative Design and Project <i>Pre: ESM 3114</i>		3 <sup>[F]</sup>	PHYS 4455 Intro Quantum Mechanics <i>Pre: PHYS 3356 Co: PHYS 3406</i>		3 <sup>[S]</sup>
ESM 4734 (AOE 4024) Into to Finite Elements <i>Pre: (CS 3414 or MATH 3414 or ESM/AOE 2074), (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3 <sup>[F]</sup>	Technical Elective		3
PHYS 3405 Intermediate Elec & Mag <i>Pre: MATH 2214, PHYS 2305, PHYS 2306, PHYS 2504</i>		3 <sup>[F]</sup>	Technical Elective		3
CLE (Areas 2 or 3)		3	CLE (Area 2/3 & 7)		3
			CLE (Area 6)		1
<b>TOTAL</b>		<b>15</b>	<b>TOTAL</b>		<b>16</b>

Superscripted annotation (F, S, SI, SII) in credits column indicates terms when a course is expected to be offered.

<b>Curriculum for Liberal Education (CLE)</b>				
Consult the CLE Alphabetical Listing at: <a href="https://www.pathways.prov.vt.edu/cle.html">https://www.pathways.prov.vt.edu/cle.html</a> , CLE courses need to be completed prior to graduation				
CLE Area 1: Writing and Discourse (6 hrs)	<b>ENGL 1105</b>	<b>(3)</b>	<b>ENGL 1106</b>	<b>(3)</b>
CLE Area 2: Ideas, Cultural Traditions, Values Electives (6 hrs)		<b>(3)</b>		<b>(3)</b>
CLE Area 3: Society & Human Behavior electives (6 hrs)		<b>(3)</b>		<b>(3)</b>
CLE Area 4: Scientific Reasoning and Discovery (8 hrs)	<b>PHYS 2305</b>	<b>(4)</b>	<b>PHYS 2306</b>	<b>(4)</b>
CLE Area 5: Quantitative and Symbolic Reasoning (6 hrs)	<b>MATH 1225</b>	<b>(3)</b>	<b>MATH 1226</b>	<b>(3)</b>
CLE Area 6: Creativity & Aesthetic Experience elective (1 hr)				<b>(1)</b>
CLE Area 7: Global Issues Elective (3 hrs) <sup>1</sup>				<b>(3)</b>

<sup>1</sup>A total of 6 hours of Area 2 and 6 hours of Area 3 courses must be completed. Only selected courses can simultaneously satisfy both Area 2/3 & 7 requirements. Use extra care when selecting this course.

**Electives:**

The ESM PHYS degree requires 6 credits of technical electives from list. Free electives or Area 6 courses offered only on a P/F basis may be taken under the P/F grading option.

**Change of Major Requirements:** For Change of Major requirements, please see <http://www.enge.vt.edu/undergraduate-changing-majors.html>.

**Foreign Language Requirements:** Students must have had 2 years of a foreign language in high school or one year at the college level (6 credit hours) of the same language. College-level credits used to meet this requirement do not count towards the degree.

**Satisfactory Progress Towards Degree:** University Policy 91 outlines university-wide minimum criteria to determine if students are making satisfactory progress towards the completion of their degrees. The ESM Department fully supports this policy. Specific expectations for satisfactory progress for Engineering Science and Mechanics majors are as follows:

- Each student must meet the minimum University-wide criteria as described in Policy 91 and summarized in the Undergraduate Catalog (under Academic Policies)
- After having completed 72 credit hours (including transfer, advanced placement, advanced standing, and credit by examination) must have completed ESM 2014, 2104, 2204, 2304, MATH 2214, 2204, and PHYS 2305, 2306
- Maintain an in-major GPA (in-major GPA is calculated using all courses taught under the ESM designator) and an extended in-major GPA (extended in-major GPA is calculated using all ESM courses and MATH 2204, 2214, 4564, and 4574) of 2.0 or better
- Complete a minimum of 12 credits that apply toward the ESM degree per academic year (including summer and winter sessions).

**Statement of Prerequisites:**

- Pre-requisites for each course are listed after the course title. The (letter grade) notation, such as (C-), indicates the minimum grade students must earn in the pre-requisite course. There are no hidden pre-requisites in the program of study. Prerequisites may change from what is indicated. Be sure to consult the University Catalog or check with your advisor for the most current pre-requisites.

**Graduation Requirements:** Each student must complete at least 130 semester credit hours with a minimum overall GPA of 2.00 and a minimum in-major GPA of 2.00. All ESM prefix courses count towards the in-major GPA.

**Approved Technical Electives:**

ESM 4014: Applied Fluids  
ESM 4024: Advanced Mechanical Behavior of Materials  
ESM 4044: Mechanics of Composite Materials  
ESM 4084: Engineering Design Optimization  
ESM 4105-4106: Engineering Analysis of Physiologic Systems  
ESM 4114: Nonlinear Dynamics and Chaos  
ESM 4194: Sustainable Energy Solutions for a Global Society  
ESM 4204: Musculoskeletal Biomechanics  
ESM 4304: Hemodynamics  
ESM 4224: Biodynamics & Control  
ESM 4245-6: Mechanics of Animal Locomotion  
ESM 4614: Probability-Based Modeling, Analysis, and Assessment  
ESM 4994: Undergraduate Research  
ESM 5014: Introduction to Continuum Mechanics  
ESM 5405 or 5406: Clinical Internship in Biomedical Engineering  
AOE 3024: Thin-Walled Structures  
AOE 3104: Aircraft Performance  
AOE 3124: Aerospace Structures  
AOE 3224: Ocean Structures  
AOE 3134: Stability and Control  
AOE 4064: Fluid Flows in Nature  
AOE 4134: Astromechanics  
AOE 4214: Ocean Wave Mechanics  
BMES 3124: Introduction to Biomechanics  
BMES 3134: Introduction to Biomedical Imaging  
BMES 3144: Biomedical Devices  
BMES 3184: Problem Solving in BME  
BMES 4134: Global, Societal, and Ethical Considerations in Biomedical Engineering  
BMES 4154: Commercialization of BME Research  
CEE 3014: Construction Management  
CEE 3104: Introduction to Environmental Engineering  
CEE 3404: Theory of Structures  
CEE 3424: Reinforced Concrete Structures I  
CEE 3434: Design of Steel Structures I  
ECE 3105-3106: Electromagnetic Fields  
ECE 4405-4406: Control Systems  
ENGR 3124: Introduction to Green Engineering  
ENGR 3134: Environmental Life Cycle Analysis  
ME 4224: Aircraft Engines and Gas Turbines  
ME 4234: Aerospace Propulsion Systems  
ME 4524: Introduction to Robotics and Automation  
MSE 4055: Materials Selection and Design I  
MSE 4164: Corrosion  
MSE 4304: Metals and Alloys  
MSE 4574: Biomaterials  
MSE 4614: Nanomaterials  
CHEM 2535-2536: Organic Chemistry  
CHEM 2545-2546: Organic Chemistry Laboratory  
MATH 3214: Calculus of Several Variables  
MATH 4234: Elementary Complex Analysis  
MATH 4445-4446: Introduction to Numerical Analysis  
PHYS 3324: Modern Physics  
PHYS 3405-3406: Intermediate Electricity and Magnetism  
PHYS 3655-3656: Introduction to Astrophysics  
PHYS 4455-4456: Introduction to Quantum Mechanics  
PHYS 4504: Introduction to Nuclear and Particle Physics  
PHYS 4714: Introduction to Biophysics

COLLEGE OF ENGINEERING  
DEPARTMENT OF BIOMEDICAL ENGINEERING AND MECHANICS  
**BACHELOR OF SCIENCE IN ENGINEERING SCIENCE AND MECHANICS**  
**BIOMECHANICS OPTION**  
FOR STUDENTS GRADUATING IN CALENDAR YEAR 2020  
130 CREDITS REQUIRED FOR GRADUATION

FALL SEMESTER FRESHMAN 2016		Credits	SPRING SEMESTER FRESHMAN 2017		Credits
CHEM 1035 General Chemistry		3	ENGL 1106 First-Year Writing <i>Pre: ENGL 1105</i>		3
CHEM 1045 General Chemistry Lab <i>Co: CHEM 1035</i>		1	MATH 1226 Calculus of a Single Variable <i>Pre: MATH 1225 (C-)</i>		4
ENGL 1105 First-Year Writing		3	MATH 2114 Introduction to Linear Algebra <i>Pre: MATH 1225 (B) or MATH 1226</i>		3
MATH 1225 Calculus of a Single Variable (C-) <i>Pre: Math Ready</i>		4	PHYS 2305 Found of Physics I w/lab <i>Pre: MATH 1225; Co: MATH 1226</i>		4
ENGE 1215 Foundations of Engineering (C-)		2	ENGE 1216 Foundations of Engineering (C-) <i>Pre: ENGE 1215 (C-) or ENGE 1024 (C-)</i>		2
CLE (Area 2 or 3)		3			
	<b>TOTAL</b>	<b>16</b>		<b>TOTAL</b>	<b>16</b>
FALL SEMESTER SOPHOMORE 2017		Credits	SPRING SEMESTER SOPHOMORE 2018		Credits
MATH 2204 Intro Multivariable Calculus <i>Pre: MATH 1226</i>		3	ESM 2074 (AOE 2074) Computational Methods <i>Pre: ENGE 1114 or ENGE 1216 or ENGE 1434</i>		2
MATH 2214 Differential Equations <i>Pre: MATH 1226, MATH 1114 or 2114</i>		3	ECE 3054 Electrical Theory <i>Pre: PHYS 2306 Co: MATH 2214</i>		3
PHYS 2306 Foundations of Physics I w/lab <i>Pre: MATH 1226, PHYS 2305</i>		4	MSE 2034 Elements of Materials Engr <i>Pre: CHEM 1035 Co: PHYS 2305</i>		3
ESM 2014 Prof Development Seminar		1 <sup>[F]</sup>	ESM 2204 Mech of Deformable Bodies <i>Pre: ESM 2104 or 2114, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
ESM 2104 Statics <i>Co: MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H or MATH 2406H</i>		3	ESM 2304 Dynamics <i>Pre: ESM 2104 or 2114, (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3
CLE (Areas 2 or 3)		3			
	<b>TOTAL</b>	<b>17</b>		<b>TOTAL</b>	<b>14</b>
FALL SEMESTER JUNIOR 2018		Credits	SPRING SEMESTER JUNIOR 2019		Credits
ESM 3034 Fluid Mechanics Lab <i>Pre: ESM 2304, ECE 3054 Co: 3234</i>		1 <sup>[F]</sup>	MATH 4574 Vector and Complex Analysis <i>Pre: MATH 2204 or MATH 2224 or MATH 2204H</i>		3
ESM 3054 (MSE 3054) Mech. Behavior of Matrls <i>Pre: ESM 2204, MSE 2034 or MSE 2044 or MSE 3094 or AOE 3094 or CEE 3684</i>		3	ESM 3114 Problem Definition & Scoping in Engineering Design <i>Pre: Junior Standing in ESM, ESM 2014</i>		1 <sup>[S]</sup>
ESM 3064 (MSE 3064) Mech Beh Matrls Lab <i>Pre: ESM 2204; Co: ESM 3054</i>		1	ESM 3134 Dyn III Vib/Controls <i>Pre: ESM 3124, MATH 4564</i>		3 <sup>[S]</sup>
ESM 3124 Dynamics II <i>Pre: ESM 2304, MATH 2214, (MATH 2224 or MATH 2204 or MATH 2204H)</i>		3 <sup>[F]</sup>	ESM 3154 Solid Mechanics <i>Pre: ESM 2204, MATH 2214 Co: MATH 4574</i>		3 <sup>[S]</sup>
ESM 3234 Fluid Mechanics I <i>Pre: ESM 2304, PHYS 2306</i>		3 <sup>[F]</sup>	ESM 3334 Fluid Mechanics II <i>Pre: ESM 3234 Co: MATH 4574</i>		3 <sup>[S]</sup>
MATH 4564 Operational Methods <i>Pre: (MATH 2214 or MATH 2214H) or MATH 2406H or CMDA 2006</i>		3	ESM 3444 Mechanics Lab <i>Pre: ESM 3034, 3054, 3064, 3124, 3234, ECE 3054 Co: ESM 3134, 3154, 3334</i>		2 <sup>[S]</sup>
BMES/BMVS 4064 Intro to Medical Physiology		3 <sup>[F]</sup>	Biomechanics Elective		3
	<b>TOTAL</b>	<b>17</b>		<b>TOTAL</b>	<b>18</b>
FALL SEMESTER SENIOR 2019		Credits	SPRING SEMESTER SENIOR 2020		Credits
STAT 4604 Statistical Methods for Eng <i>Pre: MATH 1226</i>		3	ESM 4016 Creative Design <i>Pre: ESM 4015</i>		3 <sup>[S]</sup>
ESM 4015 Creative Design <i>Pre: ESM 3114</i>		3 <sup>[F]</sup>	Biomechanics Elective		3
ESM 4734 (AOE 4024) Intro to Finite Elements <i>Pre: (CS 3414 or MATH 3414 or ESM/AOE 2074), (MATH 2224 or MATH 2224H or MATH 2204 or MATH 2204H)</i>		3 <sup>[F]</sup>	Biomechanics Elective		3
Biomechanics Elective		3	CLE (Areas 2 or 3)		3
Thermodynamics Elective <sup>1</sup>		3	CLE (Area 2/3 & 7)		3
Free Elective		1	CLE (Area 6)		1
	<b>TOTAL</b>	<b>16</b>		<b>TOTAL</b>	<b>16</b>

<sup>1</sup> Thermodynamics Elective chosen from: BSE 3154, ME 3134, or PHYS 3704

Superscripted annotation (F, S, SI, SII) in credit column indicates terms when a course is expected to be offered.

<b>Curriculum for Liberal Education (CLE)</b>				
Consult the CLE Alphabetical Listing at: <a href="https://www.pathways.prov.vt.edu/cle.html">https://www.pathways.prov.vt.edu/cle.html</a> . CLE courses need to be completed prior to graduation				
CLE Area 1: Writing and Discourse (6 hrs)	<b>ENGL 1105</b>	<b>(3)</b>	<b>ENGL 1106</b>	<b>(3)</b>
CLE Area 2: Ideas, Cultural Traditions, Values Electives (6 hrs)		<b>(3)</b>		<b>(3)</b>
CLE Area 3: Society & Human Behavior electives (6 hrs)		<b>(3)</b>		<b>(3)</b>
CLE Area 4: Scientific Reasoning and Discovery (8 hrs)	<b>PHYS 2305</b>	<b>(4)</b>	<b>PHYS 2306</b>	<b>(4)</b>
CLE Area 5: Quantitative and Symbolic Reasoning (6 hrs)	<b>MATH 1225</b>	<b>(3)</b>	<b>MATH 1226</b>	<b>(3)</b>
CLE Area 6: Creativity & Aesthetic Experience elective (1 hr)				<b>(1)</b>
CLE Area 7: Global Issues Elective (3 hrs) <sup>1</sup>				<b>(3)</b>
<sup>1</sup> A total of 6 hours of Area 2 and 6 hours of Area 3 courses must be completed. Only selected courses can simultaneously satisfy both Area 2/3 & 7 requirements. Use extra care when selecting this course.				
<b>Electives:</b> The ESM degree requires 12 credits of biomechanics electives from list and 3 hours of thermodynamics electives from list. Free electives or Area 6 courses offered only on a P/F basis may be taken under the P/F grading option.				
<b>Change of Major Requirements:</b> For Change of Major requirements, please see <a href="http://www.enge.vt.edu/undergraduate-changing-majors.html">http://www.enge.vt.edu/undergraduate-changing-majors.html</a> .				
<b>Foreign Language Requirements:</b> Students must have had 2 years of a foreign language in high school or one year at the college level (6 credit hours) of the same language. College-level credits used to meet this requirement do not count towards the degree.				
<b>Satisfactory Progress Towards Degree:</b> University Policy 91 outlines university-wide minimum criteria to determine if students are making satisfactory progress towards the completion of their degrees. The ESM Department fully supports this policy. Specific expectations for satisfactory progress for Engineering Science and Mechanics majors are as follows: <ul style="list-style-type: none"> <li>• Each student must meet the minimum University-wide criteria as described in Policy 91 and summarized in the Undergraduate Catalog (under Academic Policies)</li> <li>• After having completed 72 credit hours (including transfer, advanced placement, advanced standing, and credit by examination) must have completed ESM 2014, 2104, 2204, 2304, MATH 2214, 2204, and PHYS 2305, 2306</li> <li>• Maintain an in-major GPA (in-major GPA is calculated using all courses taught under the ESM designator) and an extended in-major GPA (extended in-major GPA is calculated using all ESM courses and MATH 2204, 2214, 4564, and 4574) of 2.0 or better</li> <li>• Complete a minimum of 12 credits that apply toward the ESM degree per academic year (including summer and winter sessions).</li> </ul>				
<b>Statement of Pre-requisites:</b> <ul style="list-style-type: none"> <li>• Pre-requisites for each course are listed after the course title. The (letter grade) notation, such as (C-), indicates the minimum grade students must earn in the pre-requisite course. There are no hidden pre-requisites in the program of study. Pre-requisites may change from what is indicated. Be sure to consult the University Catalog or check with your advisor for the most current pre-requisites.</li> </ul>				
<b>Graduation Requirements:</b> Each student must complete at least 130 semester credit hours with a minimum overall GPA of 2.00 and a minimum in-major GPA of 2.00. All ESM prefix courses count towards the in-major GPA.				

**Approved Biomechanics Elective Courses (Choose 4):**

- ESM 4105-6: Engineering Analysis of Physiologic Systems
- ESM 4204: Musculoskeletal Biomechanics and Biologic Control
- ESM 4224: Biodynamics & Control
- ESM 4234: Mechanics of Biological Materials and Structures
- ESM 4245-6: Mechanics of Animal Locomotion
- ESM 4304: Hemodynamics
- ESM 5405-6: Clinical Internship in Biomedical Engineering
- BMES 3124: Introduction to Biomechanics
- BMES 3134: Introduction to Biomedical Imaging
- BMES 3144: Biomedical Devices
- BMES 3184: Problem Solving in BME
- BMES 4134: Global, Societal, and Ethical Considerations in Biomedical Engineering
- BMES 4154: Commercialization in BME Research
- BMES 5024: Biomed Engineering and Human Disease
- BMES 5174: Biomechanics Of Crash Injury Prevention
- BMES 5304: Biological Transport Phenomena
- CHE 4104: Process Materials
- CHE 4544: Protein Separation Engineering
- ECE 4580: Digital Image Processing
- ECE 4624: Digital Signal Processing and Filter Design
- ISE 3614: Introduction to Human Factors Engineering and Ergonomics
- ISE 3624: Industrial Ergonomics
- ISE 4624: Work Physiology
- MSE 4574: Biomaterials
- ME 4034: Bio-Inspired Technology
- ME 4864: Micro/Nano-Robotics