

Recent Curriculum Changes in Engineering Science and Mechanics at Virginia Polytechnic Institute and State University*

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Within the last five years, the College of Engineering at Virginia Polytechnic Institute and State University (VPI&SU) has restructured the common freshman and sophomore curriculum. In addition, the Department of Engineering Science and Mechanics (ESM) has undertaken a complete overhaul of the ESM undergraduate degree. Coupled with these events have been necessary changes in service courses such as physics, an area which has a complex overlap with the basic engineering mechanics courses. The planning process for the new ESM curriculum is reviewed in this paper. Complete listings of both the old and new curricula are included.

BACKGROUND

IN 1991, the long-range planning committee of the Engineering Science and Mechanics (ESM) Department suggested that the ESM Undergraduate Curriculum Committee undertake a complete overhaul of the undergraduate degree program. This was done in the 1992-1993 academic year, and the resulting degree program was put into place in the fall of 1995. More recently, beginning in the fall of 1997, the College of Engineering embarked on a new freshman/sophomore sequence that changed the position of the mechanics service courses in all engineering curricula.

The purpose of this paper is to review both of these changes and to compare the ESM curriculum of five years ago with that of today [1]. This curriculum planning process should be of interest to any mechanics-related department.

ESM-INSTITUTED CHANGES

The ESM Undergraduate Curriculum Committee began the curriculum revision by listing the desirable characteristics of ESM graduates. The list of numbered goals below strongly follows Reference [2]. Once these goals were agreed upon, the means statements were added, and finally, the lists of specific courses were designed to implement the means statements. The goals, means, and course lists are presented together for ease of reading. (See the Appendix for an indication of course title for a given Virginia Polytechnic Institute and State University course number.)

1. Possession of a strong foundation in the basic and engineering sciences, mathematics, and fundamentals of engineering.

Means:

Three years of mathematics, engineering fundamentals sequence, physics, chemistry, engineering science content in required courses.

Courses:

MATH 1205, 1114, 1206, 1224, 2214, 2224, 4564, 4574
EF 1015, 1016
CHEM 1035, 1045
PHYS 2305-2306
ESM 2104, 2204, 2304
ME 3105
MSE 2044
EE 3054
ISE 2014

2. Understanding of the first principles in the traditional areas of mechanics: solid mechanics, fluid mechanics, and motion.

Means:

Beginning the count at the sophomore year, nine hours of required ESM courses in each of these areas, with 12 hours of electives in the area of specialty (or in a 'general background').

Courses:

Solid Mechanics and Materials: ESM 2204, 3054-3064, 4054
Fluid Mechanics: ESM 3015, 3016, 3034, 4014
Motion: ESM 2304, 3124, 4074

3. A capacity to apply these engineering fundamentals and first principles of mechanics to a wide variety of engineering problems.

* Accepted 16 October 1999.

Means:

All departmental courses.

4. Knowledge and experience in analytical, computational, and experimental methods, and an ability to critically evaluate these approaches for use in a given situation.

Means:

Stress on this point in two computational methods courses, in an instrumentation course, in all laboratory courses, and wherever possible in other conventional courses.

Courses:

ESM 2074, 4094, 4004

5. The ability to combine various areas of mechanics and other disciplines.

Means:

Senior design courses.

Courses:

ESM 4015-4016, 4614

6. Exposure to the design process throughout the undergraduate curriculum, including capstone design exercises in which both group and individual efforts are involved.

Means:

Design in the curriculum spread throughout the four years; senior design courses.

Courses:

ESM 4015-4016

7. Exposure to a curriculum that possesses flexibility to the degree that the student might concentrate in one of the traditional areas of mechanics, in a discipline such as biomedical engineering, in a discipline centered outside the ESM Department, or the student might opt to gain a more comprehensive general background in engineering science and mechanics.

Means:

Flexibility in choosing technical elective courses.

8. Effective written and oral communications skills.

Means:

Required freshman English courses along with the other social science/humanities courses, technical practice in laboratory courses and in the senior design courses.

Courses:

ENGL 1105-1106, ESM 3034, 3064, 4015-4016

9. A sense of social, ethical, and human responsibilities, including a historical perspective of the impact of technology.

Means:

Social science/humanities requirements set by the College; bits and pieces from various courses.

10. The recognition that engineering is a lifelong combination of education and achievement.

Means:

Clear indications of this necessity in all contacts with instructors and speakers.

With these goals, means statements, and course lists agreed upon by the ESM faculty, the Undergraduate Curriculum Committee proceeded to formulate the new curriculum shown in the Appendix. (Note that the new curriculum listed in the Appendix includes both ESM-instituted and College-instituted changes.) The formulation procedure was characterized by frequent progress reports and feedback invitations to the ESM faculty. The process took about one academic year. The class of 1997 was the first to graduate under the ESM-instituted changes. To date there has been no assessment study that measures how well the above goals have been achieved.

There are notable differences between the old and new curricula. For example, under the old curriculum, the student was required to take certain basic courses. Then, in order to flesh out the background in the areas of solid mechanics/materials, fluid mechanics, and motion, the student was required to choose one course from each of three lists corresponding to these three areas, and then choose one more course from a general list. Finally, the student added one more course of his/her choosing. These choices (actually, 'semi-choices') added up to 15 hours of technical electives, and the student used the inherent freedom to strengthen a particular area.

Under the new curriculum, this 'multiple-list structure' for the technical courses is absent. The Department agreed on a fundamental list of courses which ensures a balance over the areas of mechanics, and then allowed for 12 hours of technical electives. Technical electives must be at the junior or higher level and be sufficiently technical so that the student can use the courses to strengthen a particular area. Alternatively, the student can use the technical electives to form a 'general mechanics background' curriculum.

A few of the above numbered goals merit further comment. In regard to Item 6, note that most of the current courses were instituted during the time when ABET mandated a total of 16 design hours spread throughout the mechanics curriculum. The course ESM 4015-4016 is a strong six-hour senior design course in which the student must complete a substantial project, including oral and written reports. In connection with Item 8, VPI&SU requires six hours of writing-intensive courses in all curricula. ESM fulfills this requirement through a combination of writing exercises in a fluid mechanics laboratory (ESM 3034), a behavior of materials laboratory (ESM 3064), and its senior design course. Goals such as those listed in Items 9 and 10 are accomplished in part beginning with common engineering fundamentals courses (EF 1015-1016) taken by all engineering students in the freshman year.

COLLEGE-INSTITUTED CHANGES

As mentioned in the Background section, the College of Engineering has recently revamped the freshman and sophomore years, resulting in required changes to the ESM curriculum. These changes are included in the new curriculum listed in the Appendix.

The history of these changes is interesting to those involved in mechanics education. In the middle 1970's, under the quarter system, the mechanics sequence and the physics sequence began simultaneously in the sophomore year. The beginning mechanics course was a five-hour combination of statics and particle dynamics, followed in later quarters by three-hour dynamics and strength of materials courses. The five-hour course was regarded as difficult for the student, so it was split into two three-hour courses, with statics beginning in the third quarter of the freshman year. At that time, VPI&SU was in the unusual situation of beginning statics before physics.

When the institution changed to the semester system in 1988, statics began in Semester 2, followed by dynamics and strength of materials in the second year (any order of these last two courses was permissible). The simultaneous treatment of classical mechanics in Semester 3 in the dynamics and physics courses, with different symbols and emphases, was very troubling to the students, so the engineering dean appointed a committee which was instructed to come up with a novel solution. The solution was to begin dynamics in the latter part of the statics course so as to remove the simultaneity. Then the main dynamics course and the first physics course were taught in Semester 3, with physics minimizing the treatment of classical mechanics. The idea was that the classical mechanics topics would be first developed in the mechanics sequence and then

applied as needed in physics, leaving physics more time for such topics as heat, light, sound, modern physics, etc. Strength of materials and the second physics course followed in Semester 4. Although instructors in both ESM and physics regarded this arrangement as pedagogically sound, the unusual configuration caused transfer and other problems, and it was recently abandoned.

The present arrangement has physics beginning in Semester 2 and statics beginning in Semester 3. Both dynamics and strength of materials are in Semester 4. This is a very conventional arrangement, and the authors believe that it is the best situation to occur at VPI&SU over the last 25 years.

CLOSURE

Given the engineering education environment over the recent past, all would agree that it is indeed a challenge to maintain an undergraduate curriculum in engineering science and mechanics. There are the coupled concerns of the mechanics degree and the service courses for the engineering school at large. Contained in this paper are a few of the considerations and curriculum changes that have recently occurred at VPI&SU.

The primary educational benefit of the new ESM curriculum is the fact that the fundamental principles in the three main areas of mechanics are delivered to the student in a straightforward manner. Indeed, the academic integrity of the mechanics discipline has been strengthened by this new core approach. In addition, the degree program meets a large number of institutional and accreditation constraints while still allowing a good amount of flexibility in regard to free electives and concentration area.

REFERENCES

1. *Undergraduate Student Guide*, ESM Department, VPI&SU, 1993 and 1998 versions.
2. E. Fromm and R. Quinn, An experiment to enhance the educational experience of engineering students, *Engineering Education*, April 1992, pp. 424-429.

APPENDIX

*Old curriculum for ESM students (136 hours)**Freshman Year*

SEMESTER 1		SEMESTER 2	
CHEM 1035, 1045 (Introductory Chemistry & Lab.)	4	CHEM 1036, 1046 (Introductory Chemistry & Lab.)	4
EF 1005 (Introduction to Engineering)	2	EF 1006 (Introduction to Engineering)	3
ENGL 1105 (Freshman English)	3	ENGL 1106 (Freshman English)	3
MATH 1205 (Calculus I)	3	MATH 1206 (Calculus II)	3
MATH 1114 (Linear Algebra)	2	MATH 1224 (Vector Geometry)	2
Free Elective	3	ESM 1004 (Statics)	3
TOTAL HOURS	17	TOTAL HOURS	18

Sophomore Year

SEMESTER 3		SEMESTER 4	
ESM 2304 (Dynamics)	3	ESM 2004 (Deformable Bodies)	3
PHYS 2175 (Physics I)	3	PHYS 2176 (Physics II)	3
MATH 2214 (Differential Equations)	3	MATH 2224 (Multivariable Calculus)	3
ISE 2014 (Engineering Economy)	2	ESM 2074 (Computational Methods)	3
MSE 2034 (Materials Science)	3	HUM/SS Elective	3
HUM/SS Elective	3	Free Elective	1
TOTAL HOURS	17	TOTAL HOURS	16

Junior Year

SEMESTER 5		SEMESTER 6	
Math Elective	3	Math Elective	3
EE 3054 (Electrical Circuits)	3	ESM 3124 (Intermediate Dynamics)	3
ME 3105 (Thermodynamics)	3	Instrumentation Elective	3
ESM 3015 (Fluid Mechanics I)	3	ESM 3016 (Fluid Mechanics II)	3
ESM 3054, 3064 (Behavior of Materials & Lab.)	3	ESM 3084 (Structures)	3
Free Elective	2	HUM/SS Elective	3
TOTAL HOURS	17	TOTAL HOURS	18

Senior Year

SEMESTER 7		SEMESTER 8	
HUM/SS Elective	3	ESM 4016 (Senior Project)	3
ESM 4015 (Senior Design)	3	ME 3304 (Heat Transfer)	3
EE 3154 (Field Theory)	2	Free Elective	4
Technical Electives	9	Technical Electives	6
TOTAL HOURS	17	TOTAL HOURS	16

*New curriculum for ESM students (136 hours)**Freshman Year*

SEMESTER 1		SEMESTER 2	
CHEM 1035, 1045 (Introductory Chemistry & Lab.)	4	Free Elective	3
EF 1015 (Introduction to Engineering)	2	EF 1016 (Introduction to Engineering)	2
ENGL 1105 (Freshman English)	3	ENGL 1106 (Freshman English)	3
MATH 1205 (Calculus I)	3	MATH 1206 (Calculus II)	3
MATH 1114 (Linear Algebra)	2	MATH 1224 (Vector Geometry)	2
Free Elective	3	PHYS 2305 (Physics I)	4
TOTAL HOURS	17	TOTAL HOURS	17

Sophomore Year

SEMESTER 3		SEMESTER 4	
ESM 2104 (Statics)	3	ESM 2204 (Deformable Bodies)	3
PHYS 2306 (Physics II)	4	ESM 2304 (Dynamics)	3
MATH 2224 (Multivariable Calculus)	3	MATH 2214 (Differential Equations)	3
ISE 2014 (Engineering Economy)	2	ESM 2074 (Computational Methods)	3
Aesthetics Elective	1	HUM/SS Elective	3
HUM/SS Elective	3	MSE 2044 (Materials Science)	3
TOTAL HOURS	16	TOTAL HOURS	18

Junior Year

SEMESTER 5		SEMESTER 6	
Math 4574 (Vector and Complex Analysis)	3	MATH 4564 (Operational Methods)	3
EE 3054 (Electrical Circuits)	3	ESM 3124 (Intermediate Dynamics)	3
ME 3105 (Thermodynamics)	3	ESM 4004 (Instrumentation and Exp. Mech. Lab.)	3
ESM 3015 (Fluid Mechanics I)	2	ESM 3016 (Fluid Mechanics II)	3
ESM 3054, 3064 (Behavior of Materials & Lab.)	3	ESM 3034 (Fluid Mechanics Lab.)	1
HUM/SS Elective	3	ESM 4054 (Mechanics of Materials)	3
TOTAL HOURS	17	TOTAL HOURS	16

Senior Year

SEMESTER 7		SEMESTER 8	
ESM 4074 (Vibration & Control)	3	HUM/SS Elective	3
ESM 4015 (Senior Design)	3	ESM 4016 (Senior Project)	3
ESM 4014 (Applied Fluid Mechanics)	3	ESM 4094 (Computational Methods in Mechanics)	3
ESM 4614 (Reliability Theory)	2	Free Elective	3
Technical Electives	6	Technical Electives	6
TOTAL HOURS	17	TOTAL HOURS	18

L. Glenn Kraige was born and received his secondary education in Roanoke, Virginia. He received his BS, MS, and Ph.D. principally in aerospace engineering from the University of Virginia. Currently Professor of Engineering Science and Mechanics at VPI&SU, his interests include dynamics, vibration and control, and engineering education.

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