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Improving Undergraduate Noise Control Education at Brigham Young University

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ABSTRACT

Although BYU's acoustics heritage began over 75 years ago, noise control education and research was not a specific emphasis until the mid-1990's. Physics and engineering undergraduate students interested in acoustics and noise control typically have little or no background in acoustics before they take graduate-level courses. This creates difficulties at times because students are not introduced to many important practical topics in noise and acoustics that are not regarded as "graduate-level" topics. Undergraduate students also attempt to take the graduate courses before they are prepared. To bridge the curriculum gap and to better prepare students that enter the workforce after receiving their undergraduate degrees, a new undergraduate course in acoustics and noise control has been introduced. This course combines teaching physics-based conceptual and mathematical principles with applications-based assignments and practical laboratory exercises. In this paper, a description of the course, its objectives, and its place in the overall scope of acoustics and noise control education at BYU is given.

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1. INTRODUCTION

Since the days of Carl Eyring (beginning in the 1930's) and Harvey Fletcher (beginning in the 1950's), Brigham Young University (BYU) has had a rich tradition in acoustics research. Research topics have dealt with room acoustics, the human voice, musical instruments, and more recently, noise characterization and control.

BYU's Acoustics Research Group (ARG) consists of faculty as well as graduate and undergraduate students who are primarily from physics and mechanical engineering. The faculty involvement currently consists of three full-time, one part time, one visiting, and one emeritus faculty from the Department of Physics and Astronomy and two full-time faculty members in the Department of Mechanical Engineering. There are typically 10 to 15 graduate students at any one time, with the majority pursuing M.S. degrees. Undergraduate involvement tends to fluctuate based on short-term recruiting and advertising efforts, but average involvement during the past 5 years has been around 12 to 15 undergraduate students actively involved in research.

The purpose of this paper is to describe recent efforts to fill a gap in the acoustics/noise curriculum at BYU through the development of an advanced undergraduate course. In addition to providing an overview of the course and discussing motivations for its development, the role of the course within the overall acoustics-education framework at BYU will be provided.

2. PREVIOUS ACOUSTICS CURRICULUM AT BYU

To motivate the need for this course at BYU, principal courses within the traditional curriculum are briefly described in the following sections.

A. Physics 167: Descriptive Acoustics of Music and Speech

Physics 167 has been BYU's lone undergraduate acoustics course, but is aimed toward communications disorders (audiology, speech pathology, etc.) and music majors, and provides a foundation of principles and phenomena in acoustics without substantial mathematics. Topics such as reflection, refraction, and diffraction of waves are discussed, but, as the title of the course indicates, applications of these principles are principally for musical instruments and the human voice. Some brief noise topics in the course include OSHA guidelines, hearing risk and protection, and community noise ordinances. The long-standing text for the course has been *Music, Speech, Audio*.[1]

B. Physics 561, 660, and Mechanical Engineering 535

Three courses comprise the core of the graduate curriculum in acoustics. In the physics courses, students are treated to the rigorous mathematics of acoustics via *Fundamentals of Acoustics*,[2] *Acoustics*,[3] and internally developed sets of notes used heavily in Physics 660.[4] Topics treated in these courses include derivation of the wave equation and boundary-value problems encountered in one, two, and three-dimensional systems, acoustic ducts and mufflers, signals and systems, equivalent circuits, transducers and calibration techniques, sound sources, radiation, and propagation, and properties of human hearing. In Mechanical Engineering 535, students are introduced to structural vibration in beams and plates. Among other introductory topics, Eigenvalue and modal analysis, spectral characterization of vibrations, and numerical methods for solving vibrations problems are also covered.

C. Physics 661 and 662

The last two graduate-level courses are somewhat more of elective courses and the content varies somewhat from semester to semester. Physics 661 treats acoustics of music, speech, audio, and architecture whereas Physics 662 treats sound/structure interactions[5] and active noise control.[6]

D. Other Courses

Other courses fill out solid vibroacoustics-centered graduate programs in Physics or Mechanical Engineering. These include courses on analysis of dynamic systems, controls, fluid mechanics, digital signal processing, mathematics of signals and systems, mathematical physics, and instrumentation. The courses a student takes depends on their research project, interests, and degree program.

E. The Need for an Undergraduate Course

Although there are several courses to choose from at the graduate level, this is not the case for the undergraduate curriculum. Consequently, juniors and seniors interested in acoustics typically enroll in graduate level courses (i.e. Physics 561 and 660) after finishing the prerequisite mathematics. Although some students do quite well in these courses, the more usual two-fold outcome is first that these students survive the mathematics but do not possess the intellectual maturity to couple the mathematics with a solid physical understanding of the phenomena, implications of limiting cases, etc. In other words, they do not gain the full benefit of the course for having taken it too early in their program. Second, these students tend to slow the class down, resulting in either certain topics not being covered or an undesirable emphasis on breadth rather than depth.

These issues with undergraduate students interested in additional knowledge in acoustics beyond a descriptive level but not being quite ready for graduate-level learning strongly suggest the need for an advanced undergraduate course. This new course is intended to serve multiple purposes, including the following:

a) Bridge the gap between introductory and graduate-level material and mathematics.
b) Preserve the graduate nature of the graduate-level courses.
c) Move current material that does not belong in the graduate courses to the undergraduate level.
d) Better prepare Bachelor's degree graduates for acoustics-related jobs in industry.
e) Help train students to become effective research assistants as they learn fundamentals of acoustics and noise control and how to use equipment.

The course was taught for the first time during Fall semester 2008. Interestingly enough, the students enrolled in the course had already taken or were taking Physics 561 (our introductory graduate level acoustics course), so this undergraduate course served as a test to see what the students had already learned about the fundamentals and if they could use their knowledge in an applications-based course. We found that the students generally had difficulty remembering or applying what they had previously covered in the graduate course. This suggested that they had not really understood the graduate-level fundamentals and reinforced the need for an advanced undergraduate course to serve as a bridge between the descriptive course and the graduate courses.

3. ELEMENTS OF "INTRODUCTION TO ACOUSTICS"

A. Overall Scope and Framework

Given the goals of the course outlined in the previous section, we have sought to develop a course that mixes

a) mathematical development of topics with emphasis on how the results connect with the physical phenomena, particularly limiting cases.
b) the importance of models, especially understanding the assumptions that go into these models so that they are not used inappropriately.
c) homework problems that show students how mathematical tools can be applied to "real-world" problems.
d) hands-on laboratory exercises so that they become familiar with acoustical measurement hardware and techniques.
e) analysis of data sets in order to become familiar with software tools such as Excel, MATLAB, or Mathematica.

The basic foundation for the course is that often used in tutorials on noise control, where acoustical principles related to the source, path, and receiver are developed and considered. This approach appears advantageous because the students can easily relate the specific topics back to an underlying, unifying foundation for the course.

Part of the difficulty in determining an appropriate level and scope for the course has been in deciding the prerequisite level of mathematics. At BYU, physics and engineering students take three semesters of calculus, and courses in linear algebra and ordinary differential equations from the math department. They do not generally see a coherent treatment of complex variables or partial differential equations until their junior-level field theory physics or engineering course. This is the level of mathematics generally required for an entry-level graduate course in acoustics. Although it seems unfortunate that an undergraduate course would have the same mathematics requirements, there is a wide gap in the possible level of treatment of numerous topics if students do not have a basic understanding of partial differential equations. Consequently, the current state of the course is to require at least concurrent enrollment in a course that covers complex variables and partial differential equations. This will largely restrict long-term enrollment to senior, rather than junior level students.

Determination of an appropriate text for the course has also been a challenge. In looking for something specifically "undergraduate," we found simplified versions of the widely-used *Fundamentals of Acoustics*,[2] but we wanted something that would be more practical as a resource later on during their careers. Consequently, we have settled on noise-control related texts as our primary resource. The book currently used is *Engineering Noise Control: Theory and Practice*,[7] which has a fourth edition expected in July 2009. Supplementing this text are ANSI standards, and e-books available to BYU students at no cost, including *Springer Handbook of Acoustics*[8] and *The Science and Applications of Acoustics*.[9]

B. Topics Covered

Table 1 provides a list of topics covered in the course. The balance is between solid theoretical underpinnings and practical applications. As this is still a relatively new course, its content is continually being reviewed and adapted. In particular, applications-based exercises, which are not described in this paper, will be examined for pedagogical effectiveness.

Table 1: Topics treated in a new undergraduate course on acoustics and noise control at BYU.

Topic
Introduction to acoustic waves - air as a medium - properties of waves - derivation of wave equation - planar and spherical waves
Measures of Sound - pressure, mean-square pressure - intensity, energy density, sound power - spectra and decibels - impedance
The Human Ear - physiology and response to sound - key properties of human hearing (equal loudness contours, masking, etc.) - hearing risk and protection
Fundamentals of Acoustical Measurements and Analysis - microphones - data acquisition hardware - commercial spectrum analyzers and sound level meters - narrow and fractional octave band spectral analysis - use of LabVIEW as a signal analysis package - transfer functions
Noise Criteria - weighting curves - equivalent sound exposure levels - community, environmental, and aircraft noise criteria - hearing risk criteria: continuous vs. impulse noise - noise rating (NC, RC, NCB, etc.)
Sources of Sound - monopole, doublet, dipole, quadrupole - line source, piston, plane radiator - coherent vs. incoherent sources - source directivity - sources near reflecting planes: image sources

Sound Propagation Outdoors - basic reflection/transmission theory - finite-impedance spherical wave ground reflections (including turbulence) - geometrical spreading - air absorption - shielding by barriers - attenuation by foliage - excess attenuation by ground - meteorological effects (temperature gradients, wind, turbulence)
Sound Propagation in Enclosed Spaces - modes, modal density, low vs. high frequency characteristics - diffuse field - absorption in enclosures - reverberation time - specular vs. diffuse reflections - room acoustics design criteria
Partitions, Enclosures, and Barriers - flexural waves on structures, including ribbed panels - transmission loss, STC - performance of single and double panels as a function of frequency - impact of mounting, damping, etc. of panels - noise inside and outside enclosures - effect of windows, leakage in enclosures - diffraction at barriers - outdoor barrier performance including meteorological considerations - shielding by terrain - indoor barriers including pipe lagging
Acoustic Mufflers - acoustic impedance - lumped elements - acoustic filters - equivalent circuits - side-branch resonators and expansion chambers - lined ducts

4. CONCLUSION

In this paper, we have described the development of an undergraduate physics course that emphasizes the physical principles of noise radiation, propagation, and reception. If we accomplish our aims, students should leave the course better prepared to take a job in industry or to enter a graduate program comfortable with a research-oriented role. In short, we are enthusiastic about the promise this course has in better educating and preparing our undergraduate students and improving the overall acoustics/noise program at BYU. As this course continues to evolve, interested parties should not hesitate to contact the authors for updates.

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