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SYNOPSIS: A course in introductory acoustics which stresses the basic aspects of sound generation and propagation is described. The topics include the properties of sound waves as they are evident in the voice, musical instruments, and noise sources. The factors which influence the distribution of sound and perception are included in the course. Various means of recording and reproducing sound are included. The course serves a general audience which includes music and speech pathology students for whom the course is required.
INDEX DESCRIPTORS: Acoustics course; sound generation.

The subject of sound and acoustics is moving back into the curriculum of a number of physics departments. Generally the course is designed for musicians and occasionally students of speech science, i.e. speech pathology and audiology. In such courses one has the opportunity to present physics with a minimum of mathematics. The acoustics course is often a service to other departments and has a clientele with a built-in interest in learning more about the subject.

The mathematics required is usually at the level of high school algebra. The course gives an opportunity to treat applied physics from a phenomenological viewpoint. The treatment of sounds, especially musical sounds, can be very interesting. The factors influencing noise control and room acoustics are certainly a constant problem in our lives. The present interest of most college students in stereo records, tapes, and hi fi equipment can be used as a basis for a treatment of electronic amplification and recording of sound.

The course at The University of Iowa has been taught in its present form for several years, where it has been a required course for music and speech science students. The course, however, has a long history at the University. The registration has been satisfying in areas other than music and speech sciences. Students have taken the course from departments such as engineering, mathematics, science education, and physics.

COURSE STRUCTURE

The course is conducted as a lecture course which meets three times per week. The texts are Backus: *The Acoustical Foundations of Music* and Albers: *The World of Sound*. The book *The Speech Chain* by Denes and Pinson is used as outside reference with required readings from certain areas. Alternative readings or supplemental materials are given from an extensive list of reserve library books. Class discussion is encouraged and students are encouraged to interrupt whenever the point is obscure.

The mathematics used in the lectures is high school algebra. This is used extensively in the relationship connecting wave speed, frequency, and wave length. As an example of other uses, the inverse square law for intensity is discussed mathematically. Since some of the students have not reviewed algebra for years, it is necessary to schedule extra mathematics help-sessions. Because of the logarithmic response of the ear and biological systems in general, that results in the use of logarithmic scales for intensity and frequency, the basic use of powers of ten is stressed. The expotential system of indicating large numbers is introduced early and then developed into a logarithmic system. The decibel scale is used to a very great extent in the course when referring to measures of sound intensity level. The mathematics of the decibel scale is perhaps the most frightening aspect of the course. Most students are able to grasp the idea of the logarithmic response after the ideas are used frequently in class.

The course is divided into six sections. The initial part of the course treats the basic physics of sound from the point of view of a wave propagating in air. This section treats ideal vibrating systems and resonators. The vibrating string and resonating air column are used as examples. The use of an analytic expression such as sin x or cos x for a wave is avoided with the emphasis placed on the graphical representation of a wave. A section is presented on the behavior of the ear. Because most students will either make a detailed study if they are in speech pathology or require only a discussion of the essentials, the treatment of the psychoacoustic behavior of the ear is very brief. The emphasis is placed on the physical behavior of the ear. A discussion of pitch and frequency is presented but the electrical and mechanical response of nerve endings in the inner ear is not treated in detail. The treatments found in most books written by physicists are too brief to be of great value.

A section on musical instruments is presented as an application of the ideal models and some of the problems that arise are discussed. For example, the clarinet can be compared to a tube closed at one end and open at the other. The upper partial tones of a clarinet are not those predicted by the model. The class is able to see how the real system departs from the ideal. The discussion of musical scales is limited to the pythagorean, meantone, and equally tempered scales. The instruments are treated in broad classes. The spectral analysis of the complex tones emitted by the instruments is discussed in graphic form. Such graphs of response *vs* frequency are a very convenient way to treat the applications portion of the course.

The voice is treated separately from musical instruments. Again the stress is upon graphical analysis by means of voiceprints. The vocal apparatus is treated with relation to ideal sound pressure generators and ideal resonators.

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Architectural acoustics is treated from the point of view of the home, school studios, auditoriums, and large buildings. Sound absorption and transmission is related to wall construction. Use of techniques to achieve sound control in the home or buildings is stressed. Factors contributing to reflections, dead zones, and reverberation are treated.

The electronics of sound is based on recording and amplifying sound. The behavior of all the electronic equipment is treated in graphical form on the basis of a frequency response curve. The electronic section also includes tone generators and related means for producing musical or vocal sounds.

The lectures include many sample calculations. Examples are selected to be as useful as possible and related to everyday occurrences.

LECTURE DEMONSTRATIONS

The number enrolled in the class is rather large and requirements of the students are such that a laboratory is not feasible. A considerable fraction of each lecture is spent in presenting demonstrations. The department is fortunate in having a substantial number of older lecture demonstration items of equipment. Also, the advanced undergraduate laboratories are well equipped with oscilloscopes, frequency generators, and wave analyzers.

These demonstrations are made available to the students for their own use. The study that is liked especially is the harmonic analysis of a musical instrument or the voice. A student usually prepares a short recording of the sound on a good quality recorder. This is then amplified and displayed on an oscilloscope and also analyzed by a tuned amplifier and null detector. In many cases the students are able to use the equipment with little help.

An interesting experiment involving a monochord is possible. The vibrations can be heard directly from the acoustical resonator. The motion of the wire can be detected with a handmade magnetic pick-up. A small coil of many turns of fine wire is wrapped on an aluminum coil form. The monochord has a steel wire and an alnico magnet in the coil provides sufficient field so that a reasonable signal can be detected. The signal can be displayed on an oscilloscope, amplified, and heard on a speaker. The monochord can be used to investigate the effects of tension on the frequency of vibration. The string may be divided into pythagorean ratios and the consonance of the intervals evaluated.

A horizontal air track is used to construct a simple harmonic system with two symmetrically-placed springs to provide a central restoring force. The spring constant can be measured and the period computed. Then the oscillations can be timed and the results compared. A spark timer is used to produce a tape record of position *vs* time. The data are given to the students so that they may graph the resulting sinusoidal vibration and compare their graph to the illustrations of a pure tone.

The other experiments relate to simpler equipment such as tuning forks, organ pipes, whistles, and sirens. The nature of microphones, amplifiers, and recorders is discussed. Most examples involve musical tones and they are not appreciated by all the students since this tends to suggest a bias toward a music emphasis.

AUDIOVISUAL AIDS

Movies and film loops are used in profusion. The short film loops are especially useful. In most cases they are used to supplement the lecture demonstrations. The class is usually too large to see the experiment in detail. The demonstration would be given and then the film or film loop is shown to emphasize the observations. The films with slow motion sections and projectors with stop-motion features are most useful. Because our projectors do not have a useful reverse-motion option it is necessary to review and film and prepare a script for many of them. This preparation is essential for the silent films.

FIELD TRIPS

At The University of Iowa we are fortunate to have an anechoic chamber which may be visited by small groups and a couple of fine auditoriums where various acoustic principles of room design may be discussed. Churches and university lecture halls are used as examples when possible of various acoustical needs for speech and music. Trips are scheduled for visits to these facilities at the time when the subject of room acoustics is treated in lecture.

TERM PAPERS

In several of the recent years that the course has been offered optional term papers have been collected and graded. The papers were used to replace the grade in a test that the student missed. Also the paper could be used to replace the lowest grade on a test.

Generally term papers were of good quality. The usual paper consisted of a literature search on some topic. Occasionally a student would conduct an experiment on the tone quality of an instrument or his voice. The term papers were difficult to judge in comparison with the tests.

EXAMINATIONS

Usually thirty multiple choice and five short answer questions are given in one class period. When forty multiple choice and five short answer questions are given few students leave early, and when thirty multiple choice and five short answer questions are given about 10% of the students leave early. It is usually not possible to detect a measurable difference between the music students and the speech and hearing science students. The class average grade in courses taken before enrollment in this course is usually slightly above B. The class performance usually gave a good distribution with about 20% in the upper division and about 23% in the lowest division.

Because of the difficulty in treating the formulas in the course an effort is made to limit mathematical questions to one-fifth of the test. Usually very few students receive grades that are seriously affected by the mathematical questions. A major difficulty with the tests is in the wording. Many students seem to insist that the tests contain trick questions, although an effort is made to avoid double meanings or unusual examples. The preparation of tests is a difficult task and requires constant review. Copies of the old tests are made available to the students as study guides. The answers are not supplied but the students could ask about particular questions in class discussion.

CONCLUSION

The course is a satisfying way to bring physics to a wider audience. It is helpful if the teacher has some interest in music and sound along with a willingness to learn. For many of the students physics will seem to be a foreign language. This is not a greater problem than the jargon of music or architectural acoustics is for the physicist. The combination of a carefully phrased definition of terms and patience in explaining the ideas can result in a very satisfying and interesting teaching experience.