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Physics 3000: Acoustics and Signal Analysis, Fall 2013

Course Goal: This course provides a detailed overview of acoustics including an introduction to digital signals and their analysis. Application areas include architectural, musical, and environmental acoustics. The digital signal analysis concepts, although emphasizing the manipulation of acoustic signals, are relevant to all forms of signal processing.

Text: There is no required text. Material will be drawn from a variety of sources, including handouts given in class. Some examples of the texts used are: *Fundamentals of Acoustics* by Kinsler, Frey, Coppens, and Sanders (3rd ed.)*, Science of Musical Sounds* by Sundberg, *Science of Musical Sounds* by Pierce, and *Sound System Engineering* by Davis and Davis.

Prerequisites: Math 1220 and Physics 1600 are prerequisites (unless permission of the instructor has been given).

Grading: Your final grade for the course will be determined by the following prescription:

Homework and MATLAB work:	25%
Quiz 1	25%
Quiz 2	25%
Comprehensive final exam	25%

Because this course is perpetually in development, this prescription might be (probably will be!) altered slightly. In particular, I might substitute a special project for one or more of the quiz grades. Homework will be assigned in class with a specified due date.

Midterm Grade Reports: The University now requires us to submit an estimated grade during the semester. The midterm grade is my **best** estimate of your progress. It's not a promise or a threat; it's my honest estimate of where you stand at that point. Your final grade may be quite different.

Students with disabilities that may require assistance or accommodation, or if you have questions about accommodations for testing, note takers, readers, etc. you should see me in the first week or two of classes. Students may also contact the Office of Disabled Student Services (898-2738) with questions.

Note: It is the policy of the Department of Physics & Astronomy that no drops will be approved after the deadline posted in the university's course Schedule Book (after 8th week).
The final date for dropping a course with a W for this semester is October 29.

Do you have a lottery scholarship?
To retain Tennessee Education Lottery Scholarship eligibility, you must earn a cumulative TELS GPA of 2.75 after 24 and 48 attempted hours and a **cumulative** TELS GPA of 3.0 thereafter. You may qualify with a 2.75 **cumulative** GPA after 72 attempted hours (and subsequent semesters), if you are enrolled full-time and maintain a **semester** GPA of at least 3.0. A grade of C, D, F, or I in this class may negatively impact TELS eligibility. Dropping a class after 14 days may also impact eligibility; if you withdraw from this class and it results in an enrollment status of less than full time, you may lose eligibility for your lottery scholarship. Lottery recipients are eligible to receive the scholarship for a maximum of five years from the date of initial enrollment, or until a bachelor degree is earned. For additional Lottery rules, please refer to your Lottery Statement of Understanding form, review lottery requirements on the web at http://scholarships.web.mtsu.edu/telsconteligibility.htm, or contact the Financial Aid Office at 898-2830.

The following is an outline of the some of main topics to be covered in the course. The topics are not inclusive and they are not necessarily in sequence. In particular, the signal analysis material will be interspersed with the acoustics topics throughout the semester. A big issue that I have discovered is that most acoustics work gets very mathematical very quickly. My aim is to introduce a balance of math and physical insight, so that (hopefully) you can use a scientific approach to problem solving in acoustics and signals.

(1) Vibration: General characteristics and mathematical description of simple vibrating systems.
(2) Mechanical Resonance: driven simple harmonic motion and the concept of resonance. Resonant modes of plates (Chladni modes), rods and bars. The Helmholtz resonator.
(3) Waves in 1-dimension: General properties, wavelength, frequency, speed, longitudinal versus transverse waves, polarization. Sinusoidal nature of a traveling wave. Waves on strings: traveling and standing waves.
(3) Waves in 3-dimensions: Spherical waves and plane waves. The ray representation of wave propagation. The point source.
(4) Acoustic energy: Intensity and its relation to pressure amplitude. Decibel scales; combining intensities versus combining pressure amplitudes.
(5) Acoustic Impedance and the transmission of waves from one medium to another. Acoustic impedance as an analog to electrical impedance. Hollow pipes and cavities as waveguides.
(6) Environmental and Architectural acoustics: Reverberation time—Sabine. Reflection, and acoustic absorption of materials. Noise reduction. Direct and reverberant sound. Standing waves and normal modes of enclosures.
(7) Spectral analysis: Fourier transform: discrete and short-time Fourier transforms. Fourier time-frequency relations. Power spectra. Phase.
(8) Noise and stochastic processes. Information content of a signal.
(9) Sampling and the Nyquist criterion. Analog-to-digital conversion.
(10) Aliasing and anti-aliasing filters, word length.
(11) Resolution, dynamic range, jitter, over-sampling, and least-significant bit.
(12) Compression of digital signals.
(13) Digital effects processing.

Fall 2004 Outline

The Basics

1. Simple Harmonic Motion and oscillations.
    a. Amplitude, linear and angular frequency, phase, time
    b. The Helmholtz resonator review
2. Complex numbers and their use in representing oscillations and waves.
    a. Sine and Cosine series
    b. Exponential series
    c. Square root of -1
    d. Eulers theorem
3. Properties of Waves
    a. Wave basics: wavelength, frequency, speed, transverse and longitudinal waves, amplitude.
    b. One dimensional waves
        i. Waves on Strings
        ii. Waves in ducts
    c. Wave impedance
    d. Reflection and transmission at discontinuities
    e. Wave superposition and interference
    f. Waves in 3-dimensional
    g. Inverse square law
    h. Huygens principle
        i. Diffraction
        ii. Reflection
        iii. refraction
4. Time and Frequency Domains
    a. Period and Frequency
    b. Special status of sine waves
    c. Synthesis of complex tones—square wave example
    d. Fourier decomposition
    e. Extension to arbitrary signals (not just pure and complex tones)
    f. Basic qualitative time-frequency relations (fast time features imply broad frequency bandwidth)
    g. Why is spectrum so important?
5. Digital representation of signals
    a. Discrete versus continuous representations
    b. Sampling and Nyquists theorem
    c. Aliasing
    d. Fast Fourier Transform (FFT) and its applications
    e. Examples

Applications

1. Resonance in 1,2, and 3 dimensions
2. Room acoustics and reverb time
3. Diffusers (number theory and diffraction)
4. Bass traps and filters (Helmholtz resonators)
5. Diffractive focusing, speaker baffles, mic capsule oroentation effects, head diffraction.
6. Probability and information theory—compression.
7. Digital signal effects