Physics115 - The Physics of Sound and Music

Fall/Spring 20##

Description: PHY115 is a four credit-hour science course with lab, designed to meet the general education science requirements. The course examines the physical principles involved in the description, generation, detection, and reproduction of sound. Topic include oscillations and vibrations, waves and waveforms, sound, traveling waves in air, standing waves, resonance, hearing, the ear, loudness, decibels, acoustical measurements, sound-generating electronics, digital sound.

Goals of the course: This course is designed for students interested in Music and sound and can be focused toward those majoring in Music, Speech and Hearing, Audio Technology, Telecommunications, and Interior design among others. The course will answer questions like:

- What exactly is sound? How is it perceived?
- How do we quantify sound?
- How is sound produced?
- How does sound travel between a source and a receiver?
- How does the ambient environment affect sound?
- How is sound preserved and reproduced?

We will use both conceptual and quantitative approaches. Course will be taught in a lecture-lab format. This course could be worked into a learning community for student with the above listed majors.

General education Goals of course:

COURSE GOALS

1) Examine physics of waves, sounds, and the electronics that generate and detect them. Some basic ideas in the physics of electricity and magnetism will be discussed in order that students understand the electronics component of the course.
2) Students will also develop qualitative and quantitative problems solving skills.
3) Student will grow to appreciate the physical principles at work in the everyday phenomena of sound and music.
4) Practice applying the scientific method to the study and analysis of waves and electromagnetism as seen in the area of music.

Class Administration: The usual details attendance, late papers, honor code, dates to remember, etc left to the discretion of the individual instructor.

Prerequisites: MAH 099

Textbook: The required textbook is one of the following or its equivalent:
Or Musical Acoustics by Donald E. Hall, 2nd edition, Brooks/Cole Publisher
Or Physics of Sound, Reichard E.Berg and David G. Stork 3rd edition, Pearson/Prentice Hall
Other readings to be posted on Blackboard as needed.

Lecture: Class meets for lecture in room### from ##:## to ##:##. Although the lectures will follow topics in the textbook, they will include important additional information and insights not in the text and may omit some information contained in the text. The student is responsible for both the assigned material in the text and what is covered in class. Example problems will be worked during lectures. Informative and
illustrative demonstrations will also be performed during lectures. Attendance will be monitored by an attendance sheet. (Note: A MWF format is assumed but can be adapted to TTH.)

**Laboratory:** The Laboratory portion of this course provides hands-on experience for many of the topics discussed in lecture. Laboratory meets in room ### from ##:## to ##:##. The lab is required and meets separately from the lecture. The same class policies apply in both lecture and lab.

**Homework:** The homework will cover material from the lectures and reading assignments and will be assigned, at the latest, on the Friday of each week, and will be due the following Wednesday. There will be approximately 10 homework assignments consisting of about 5 problems. The assigned problems will be posted on the course schedule, and also accessible from Blackboard. Homework is due on the assigned date at the beginning of class in a location described by the instructor. Solutions will be posted on Blackboard. The instructor will go over the grading criteria for assignments.

**Exams:** There will be three closed book examinations during class on: (1) date 1, (2) date 2 and (3) date three, the Third exam is the cumulative final exam. There will be no make-up exams, and a missed unexcused exam will count as a zero toward your final grade. Each exam will include a page of needed formulas and numerical constants. The material covered on each exam will follow the reading schedule and will be reviewed in lecture before the exam.

**Final Exam:** There will be a comprehensive final exam on Dec/May### in room ### fro ##:## to ##:##. Approximately 40% of the final exam will address material covered since Exam #2, and the other 60% will be comprehensive.

**Term project:** To be discussed in another handout: The project consist of a written essay and construction of a simple, non-conventional, home-made musical instrument of their own design, and based on requirements described by the instructor. The instrument will be tested in a lab at the end of the semester. Students may work together according to guidelines provided by the instructor.

**Miscellaneous:** A scientific calculator with trig and log functions is required for homework and exams.

**Final Grade:** Your final letter grade will be assigned on the basis of a numerical distribution combining scores from exams and homework. The distribution will be determined using the following proportions:

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Midterm Exam 1</td>
<td>15 %</td>
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<tr>
<td>Midterm Exam 2</td>
<td>15 %</td>
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<tr>
<td>Term Project</td>
<td>15 %</td>
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<tr>
<td>Final exam</td>
<td>30 %</td>
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<tr>
<td>Labs and Homework</td>
<td>25%</td>
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<tr>
<td><strong>Total</strong></td>
<td>100 %</td>
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Other educational and assessment tools to be added as needed.

**Possible Reserve Books:**


*The Speech Chain; the Physics and Biology of Spoken Language*, P.B. Denes and E.N. Pinson
Physics and the Sound of Music, John S. Rigden

Physics of Musical Sounds, John Askill

Overcoming Math Anxiety, Succeed with Math, Both by Sheila Tobias


Tentative Unit Overview:

I. Physics of Waves and Sound
We begin with a scientific description of what occurs when sound is made. Look at the quantitative description of a wave (ex: distance, speed, frequency, pressure, etc . . . ). In this section we introduce ideas that introduce the nest three sections of the course. 2) Sound propagation and detection in various media; 3) harmonic content of musical sound, 3) how to make sounds and acoustics.

II. Perception of Loudness, Pitch and Timbre
How do humans react to sound? How does our hearing work? How can we quantitatively characterize those reactions? Electronics that make sounds. Concert Hall acoustics, etc.

III. Some Musical Instrument Families and Music Synthesis
Standing waves on strings and in tubes is what it’s (mostly) all about, when the sound is musical. Bars and membranes make (no less interesting but) less musical noise. Synthesizers can simulate the above, and many other things too - a great tool and toy.

Tentative Course schedule for MWF sequence

Week One - Describing sounds in time and space
Monday - Vibrations in the air
Wednesday - Movement of waves in the world of media
Friday - Seeing sound

Concepts: Scientific notation and units displacement, speed, acceleration, Force, pressure, energy, power.

Week Two – Things that shake
Monday - The harmonic oscillator as metaphor
Wednesday - Resonance and what really matters
Friday - Inside a traveling sound wave

Concepts: Simple vibrating systems Multiple modes of vibrations, resonance

Week Three – it sounds like Music
Monday - Musical sound
Wednesday - The sine wave and the Fourier way
Friday - Strings and pipes

Concepts: Vibrations in musical instruments waves, Superposition, Interference, Refraction, Doppler Effect, Standing waves

Week Four – vibrating strings and things
Monday - Collections of oscillators
Wednesday - Normal modes and boundary conditions
Friday - Standing waves and traveling waves


Week Five - Purity of sound
Monday - Vibration recipes for taut strings
Wednesday - Interlude 1: Some musician talk - The act of percussion
Friday Exam 1 this week

Week Six - Confined wave patterns
Monday - Reflection, refraction, and diffraction
Wednesday - Beats and interference
Friday - The organ pipe

Concepts: Standing waves, Overtones & resonance
Standing waves in pipes Pitch and timbre

Week Seven - Acoustics
Monday - Intervals and consonance
Wednesday - Whistles, flap jowls and squeaky wheels
Friday - Acoustics of rooms and sources

Concepts: Fourier synthesis of complex waves
Combination tones Hearing & the human ear
The human voice: speech recognition and analysis

Week Eight - Acoustics
Monday – Energy Intensity and Loudness
Wednesday - Energy, intensity, and loudness
Friday - The decibel as loudness, quantified

Concepts: Measuring sound, Concert Hall Acoustics
Room Acoustics

Week Nine - Ancient and modern music
Monday – Exam 2:
Wednesday - Examples of percussion instruments
The diatonic scale, the twelve tone scale, and all that
Friday - The violin family
The human voice: singing

Concepts: Musical scales and temperament

Week Ten - Power-chording
Monday - Eclectic and electric strings
Wednesday - Some discussion of the piano's power
Friday - The recorders, flutes and reeds

Week Eleven - Heavy metal
Monday - The brasses - their parts
Wednesday - The brasses - their sounds
Friday – Human voice

Week Twelve - Unnatural sound
Monday - The analog synthesizer
Wednesday - The digital synthesizer
Friday - Electronic Circuits, Loudspeakers, Microphones & Amplifiers

Week Thirteen - Creating a musical palette
Monday - Sound Recording: Analog (tape)
Wednesday - Digitization Electronic Music/Synthesizers Digital (disc)
Friday - The pentatonic scale Diatonic scales: Pythagorean and just tuning
Present day

Week Fourteen - The Quest for perfection
Monday - Twelve tones and the circle of fifths
Wednesday various compromises in tuning
Friday – Putting it all together.

Week Fifteen – Presentations
You designed and built them. Now we’re all going to hear them! Two days for presentations and one day for review for final exam.

Week Sixteen – Final Exam

List of Possible experiments

3A00.00 - OSCILLATIONS
  3A10.00 - Pendula
  3A15.00 - Physical Pendula
  3A20.00 - Springs & Oscillators
  3A40.00 - Simple Harmonic Motion
  3A50.00 - Damped Oscillators
  3A60.00 - Driven Mechanical Resonance
  3A70.00 - Coupled Oscillations
  3A75.00 - Normal Modes
  3A80.00 - Lissajous Figures
  3A95.00 - Non-Linear Systems

3B00.00 - WAVE MOTION
  3B10.00 - Transverse Pulses and Waves

3B20.00 - Longitudinal Pulses and Waves
3B22.00 - Standing Waves
3B25.00 - Impedance and Dispersion
3B27.00 - Compound Waves
3B30.00 - Wave Properties of Sound
3B33.00 - Phase and Group Velocity
3B35.00 - Reflection & Refraction (Sound)
3B39.00 - Transfer of Energy in Waves
3B40.00 - Doppler Effect
3B45.00 - Shock Waves
3B50.00 - Interference and Diffraction
3B55.00 - Interference AND Diffraction Of Sound
3B60.00 - Beats
3B70.00 - Coupled Resonators

3C00.00 - ACOUSTICS
  3C10.00 - The Ear
  3C20.00 - Pitch
  3C30.00 - Intensity and Attenuation
  3C40.00 - Architectural Acoustics
  3C50.00 - Wave Analysis and Synthesis
  3C55.00 - Music Perception and the Voice

3D00.00 - INSTRUMENTS
  3D20.00 - Resonance in Strings
  3D22.00 - Stringed Instruments
  3D30.00 - Resonance Cavities
  3D32.00 - Air Column Instruments
  3D40.00 - Resonance in Plates, Bars, Solids
  3D42.00 - Percussion Instruments
  3D46.00 - Tuning Forks
  3D50.00 - Electronic Instruments

3E00.00 - SOUND REPRODUCTION
  3E20.00 - Loudspeakers
  3E30.00 - Microphones
  3E40.00 - Amplifiers
  3E60.00 - Recorders

Numbers are PIRA standard physics equipment set-up designations.

GENERAL EDUCATION AREAS OF EMPHASIS
We will read from the text and from a diverse collection of authors on music physics ranging from the acoustics of the aboriginal didgeridoo, the vibrations in a casing of a classic violin, to the oscillations of an electronic circuit through articles posted on blackboard, on reserve in the library, or through internet links. Additional reading will also be needed when students for research for their formal project.

We emphasize critical thinking and problem solving skills through the applications of numerical and conceptual problem solving skills in physics. Laboratory work requires numerical and conceptual problems solving to succeed.

The course requires Writing and/or other forms of composition in the form of a formal paper, lab summaries in the form of abstracts, and in general, answers to conceptual questions in physics require answers in grammatically correct English in order to communicate a correct understanding of the subject. Independent, creative, and interactive learning is an important focus in the course. Much of the course work centers around group work in the laboratory, and on class projects. Lab work requires a team effort. Term project requires creative application of fundamental physics principles. The project of designing and building a musical instrument can also involve both creativity and group work.

Using the latest in physics education research, active engagement methods requiring student discussion and participation are a given in the courses in our department. This course will be taught using the same methods. Similar techniques are used in the workshop approach used in lab sessions.

In addition, the completion of the lab portion of the course requires that student teams work effectively and responsibly collaborate as they gather observations, take measurements, analyze results. The final product is a written report submitted as a group to the instructor for a grade.

Many labs involve the use of computer data acquisition and control of the experiment. Computer Simulations of physical phenomenon are also used. Blackboard and E-mail are part of the course communication. Research topics in the homework and for class projects will require Internet references and traditional references to complete. We also use the workplace standards of MS-Excel and MS Word when a spreadsheet or word processor is required.

Since students must be familiar with the effective and ethical use the information in their future careers, materials on writing reports, citing references, the honor code, plagiarism, group work, study skills, etc... are presented as needed.

The goal of the course is. Of course to learn about the physics of oscillations, waves, sound, electricity and magnetism using those examples found in the area of music. As such students will become familiar with these scientific theories and their application to everyday phenomenon.

Experiments and activities are provided where the student will evaluate the credibility or applicability of certain scientific arguments or results within the discipline of physics. Examples from basic wave mechanics and Electromagnetism will be applied to real problems. Students will measure phenomena in lab and make analyses using ideas from these theories. Other activities use standard scientific methods in making and analyzing measurements.

Sound and music are familiar examples from everyday life that allow us to study these topics. For example, to understand exactly how an electric guitar or a stereo system works requires a solid understanding of the principles of waves and Electromagnetism. In the process we also have a view into the history of the science that allows these modern developments to exist.

Finally, the very nature of a laboratory science course will allow the students to execute appropriate scientific methodology, use modern technology and test the things they learned by building an instrument of their own design out a simple household materials. They will present their work to the class and practice scientific literacy and writing skills by preparing for this presentation and by submitting a written discussion of their work. The lab weekly lab periods are where they will learn these ideas initially. Students will also read articles from...
scientific magazines in addition to the text. Guidelines and instruction for writing in a technical style will be distributed and used. The technical style will be used for both the formal report and for writing abstracts for each lab.

As with all experiments, one needs to understand how well the quantity was measured. This is where knowledge of measurement uncertainty and error are needed. Students will be instructed in proper scientific techniques as they are needed to complete the laboratory activities.

**ASSESSMENT METHODS USED TO EVALUATE STUDENT OUTCOMES:** Course grade will be based on Lab reports with 1) abstract summaries, 2) participation in groups, 3) group submitted activities from active-engagement portion of lecture, 4) term project involving a formal written paper, 5) short writings on selected topics, 6) problem solving homework assignments, both qualitative and quantitative, and 7) Exams.