UIUC Physics 193: Physics of Music  
Course Syllabus  
Fall Semester, 2014

Introduction to Course, Course Structure, Organization:
- Course meets once/week: Friday 10:00 - 11:50 am in 6105 ESB  
- Lecture/demo/lab/hands-on interactive/investigative-type format  
- Lecturer: Steve Errede 435 Loomis, email: serrede@illinois.edu 333-0074 (office); 333-4225 (lab), 333-4452 (sec’y)  
- P193POM TA: Nick D’Anna, email: danna2@illinois.edu  
- Course Project - of own choice (must be relevant to course), can be wide-ranging  
  * Brief oral presentations/brief written report @ midterm  
  * Final oral presentations/written report @ end of semester, substantive effort.  
  * Put final written reports on P193POM web page.  
- Web page for course, URL: http://courses.physics.illinois.edu/phys193/ 
- Final grade = mid-term & final oral presentations, final report.

Course Content:
- What is music? For humans? For other animals?  
- Why does music exist? Why is it important? For humans? For other animals?  
- Why/how did music evolve? For humans? For other animals?  
- Importance of music today in our societies. In future? Evolution of music?  
- Music in Nature/Music of the Cosmos  
  * Scientific study of music/musical instruments (history):  
    * Ancient Greeks - Pythagoras (~ 500 BC) at least. Earlier endeavors?  
    * Since then: Aristotle, Ptolemy. Huygens, Euler, Ohm, Young, Helmholtz  
- How is music made?  
  * (Collective) vibrations of atoms of matter  
  * Matter vibrations coupling to air - collective vibrations of air molecules  
  * Propagation of sound waves in air, other media, fluids & solids.  
- How/why is music heard/perceived? Human & animal hearing/sound perception  
  * Evolution - why is it beneficial to perceive sound?  
  * Psychoacoustics - study of human hearing  
  * How human ear(s) + brain work  
  * Hearing in other animals  
- Simple Vibrating Systems  
  * Simple harmonic motion - e.g. mass on a spring, tuning fork  
    + Frequency, period, wavelength, amplitude, phase, energy, energy loss/damping/dissipation, power  
  * Travelling waves and wave propagation in a medium  
    + One-dimensional medium - bead-spring system  
    + One-dimensional transverse and longitudinal waves  
    + Wave propagation in two and three dimensions  
  * One-dimensional standing waves  
    + Sum/superposition of two counter-propagating travelling waves  
    + Boundary conditions for standing waves  
    o Reflection, refraction, diffraction of travelling waves  
    o Interference effects  
    o Resonance effects
+ Transverse standing waves, e.g. on a guitar/violin/piano string
+ Longitudinal standing waves, e.g. in air - organ pipes/flutes

* Standing waves in two and three dimensions
+ Vibrating membranes - drums, musical saw

* Doppler effect - source/observer motional effects on sound waves in air.
* Beats - interference between two frequencies
* Distortion - non-linear response & generation of harmonics of fundamental
* Intermodulation distortion - non-linear response with 2 or more frequencies.

* The Human Ear/Human Hearing
+ Structure of the outer & inner human ear, and its response to sound
+ Why two ears? Phase sensitivity, source location determination.
+ Sound Intensity, \( I \) (Watts/m\(^2\))
+ Sound Intensity Level, \( L \) (decibels)
  o Threshold of hearing, threshold of pain
+ Sound Pressure Level, \( L_p \) (decibels)
+ Loudness Level (phons)
+ Loudness (sones)

* Musical Tone Quality/Timbre
+ Pure tones/simple tones - sine/cosine waves
  o have well-defined frequencies/wavelengths, amplitudes & phases
+ Partial tones (= partials) - assembly of pure tones
  o = a mix of different frequencies & amplitudes
+ Complex tone - superposition of simple tones - complex waveform
+ Periodic complex waveform - has fundamental + harmonics/overtones
  o harmonics/overtones = integer multiples of fundamental frequency
  o phase sensitivity of human ear to complex tone/tone quality/timbre
  o harmonic (Fourier) analysis of musical instrument tones
+ Formants
+ Sound Envelope - attack time/decay time

* Sound Effects
+ Vibrato, tremelo, chorus, phase shift/flanging, reverberation/echo, etc.
+ Noise
+ Subjective tones - (non-linear response/distortion in the ear)
+ Auditory sensation “tricks”

* Musical intervals, musical scales, tuning and temperament
+ Consonance/dissonance
+ Discrete frequencies = scale
+ Frequency ratios: unison, octave, fifth, fourth, third, etc.
+ Interval = separation of two notes on a scale

* Musical Scales - Pentatonic, Pythagorean, Meantone Tuning, Just, Just Diatonic, Tempered Scales
  + whole tones, semi-tones, cents
  + pitch standard(s)
  + octave notation
  + frequencies of musical notes, e.g. in tempered scale

* Acoustics
+ Acoustics of rooms and auditoriums
  o Interference, sound absorption
  o Reverberation & echo
+ Acoustics of loudspeaker enclosures
* Production of musical sounds by musical instruments
  + Stringed Instruments
    o Physics of plucked & bowed vibrating strings
    o Plucked: acoustic/classical and electric guitar(s), mandolin, ukelele, etc
    o Bowed: violin, viola, cello, bass
    o Hammered: piano, hammered dulcimer
  + Woodwind Instruments
    o Physics of whistles, reeds & organ pipes
    o Whistles: Whistle, recorder, flute
    o Reed: Clarinet, oboe, bassoon, saxophone
    o Pipe: Pipe organ, bagpipes
  + Brass Instruments
    o Physics of mouthpiece, bell
    o Trumpet, trombone, French horn
  + Percussion Instruments
    o Physics of vibrating bars, plates, membranes
    o Xylophone, glockenspiel, Fender-Rhodes piano
    o Drums (all kinds), cymbals (all kinds)
    o Musical saw
  + Electronic Musical Instruments
    o Electro-mechanical organs - e.g. Hammond B3
    o Electronic organs/keyboard instruments
    o Analog and Digital Sound Synthesizers,
    o MIDI instruments
    o Computer-generated music
  + Analog & Digital Recording of Music
    o Edison phonograph - cylinder & disk records (analog)
    o Magnetic wire and tape recorders (analog & digital)
    o Digital recording (e.g. to DR/PC, CD/DVD, etc.)
    o Analog input transducers - condenser and dynamic microphones
    o Analog output transducers - loudspeakers
  + Music in the near-term and distant future
    o Human music - culture & society. New kinds?
    o Development of new kinds of musical instruments & technology.
    o Evolution of music in animals? Human - animal music interactions?