Syllabus, Fall Quarter, 2019

FRS 002, Sec. 26--Freshman Seminar
Applications of Waves—From Music to Imaging Atoms

CRN 44410
Class Meeting: Tues. 1:10 - 3:00 p.m., 414 Physics
First Class: Oct. 1, 2019

Instructor: Shirley Chiang, 235 Physics/Geology, Tel. (530) 754-0562 (office),
e-mail: chiang@physics.ucdavis.edu
Office hour: Tues. 3:00 -4:00 p.m. in 235 Physics/Geology; and by appointment

Class web page: http://chiang.physics.ucdavis.edu/FRS2_Music.html
Supplementary information is posted under Files on Canvas: https://canvas.ucdavis.edu

Prerequisite: High school algebra is required. High school physics is helpful, but not required.
Required Textbook: *Horns, Strings and Harmony*, by Arthur H. Benade, (Dover, 1992). ISBN: 0-486-27331-8, library call number ML 3805.B33

Description:
What makes a violin sound different from a piano or a clarinet? We will explore the differences between musical pitches and timbres by using wave theory from physics. The objective of the course is for students to see how physical principles can be used to explain the world around them. Wave theory will be applied to two very different topics, one classical and one modern: music and quantum mechanics. The course will use physics to study the properties and production of musical sounds. A wide variety of physics demonstrations and musical instruments will be used to reveal physical properties and stimulate discussion. Finally, modern quantum mechanics and its dependence on wave theory will be used to explain the operation of the scanning tunneling microscope (STM), a scientific instrument which is used to image individual atoms on a surface. Atomic scale images produced by this microscope are relevant to the fabrication of small structures for integrated circuits which make possible new technological advances in computers.

Seminar Goals:
Students will work to develop effective communication skills through two presentations and the final paper. One presentation will be the description of the operation of a computer component, and the other is the presentation of the final project, which is the design and construction of a musical instrument. Students will also develop their writing skills by writing a final paper that describes the final project in detail. Students will develop high cognitive skills and prepare for lifelong learning by applying the scientific method to determine the design of the final project. They will understand the relationship of physics concepts, such as frequency, amplitude and wave shape of sound waves, to musical properties such as pitch, loudness, and timbre. They will learn why different instruments playing the same note sound different to one's ears, how musical scales relate to the mathematical ratios of frequencies of sound waves, and how the construction of different musical instruments relates to their production of varying sounds. Physical principles will also be used to understand the operation of stereo sound systems, parts of a digital computer and how they operate, digitized computer music, the operation of the STM, and how fabrication of small structures applies to high technology devices.

Grading:

Students will be graded on the quality of their participation in class discussion (1/3), on the quality of the oral presentation of their project (1/6), and on the execution of the final project and the final paper (1/2).
Traditional percentages to earn specific letter grades will be used: 100-90 (A+ to A-), 89 – 80 (B+ to B-), 79-70 (C+ to C-), 69-60 (D+ to D-), <60 (F)

Course requirements:

1. Reading assignments are listed below. Please do required reading before the class indicated so that you are prepared to discuss it in class. Class participation is also required.
2. An independent project, presentation, and paper are required. Being reading and thinking about design of the musical instrument for the final project. See instructions and dates below.

Topical Outline, Course Schedule (subject to change), and Reading Assignments:

HSH=Benade book (required). Additional references posted on Canvas under Files.

Week	Class Dates	Topics	Assignment
1	Oct. 1	What is Physics? How do physical principles explain properties of devices? Introduction to wave properties and their relationship to musical properties—pitch, loudness, timbre.	HSH Chapters 1,2,4
2	Oct. 8	Further discussion of waves and demonstration of properties such as reflection, refraction, diffraction, beats, interference, and resonance.	HSH Chaps. 7; additional information at Canvas under Files/Wave Information.
3	Oct. 15	Harmonic analysis (why do different instruments playing the same note sound different to your ear?) Discussion of musical scales and their relationship to the mathematical ratios of frequencies of sound waves. Operation of piano and tuning it.	HSH Chap. 3, 5; additional information at Canvas under Files/ Harmonics and scales.
4	**Oct. 22**	Prof. Chiang is out of town. Plans for substitute are not final yet.	HSH Chap. 6
5	Oct. 29**.**	Stringed and percussion instruments. Possibly excerpts from video lecture: *The Essence of an Instrument*, by Charles Taylor.	HSH Chap. 8.9
5	**E-mail note** to Prof. Chiang by **Fri. Nov. 1** describing proposed project.		
6	**Nov. 5, 152 Roessler**	Arduino lab. Making music with a simple computer system.	Lab writeup on Canvas under Files.
7	Nov. 12	Computers -- what's inside and how do they work? Operation of computerized music and stereo systems.	**Assignment to look up a computer part and report on it**.
8	Nov. 19	Wave theory and probability related to quantum mechanics. Operation of the STM, imaging atoms, and relevance to new advances in computer technology.	See Bohr atom and "Quantum Jumps," "Quantum Tunneling" and STM articles on Canvas, Files/Quantum Mechanics.

9	Nov. 26	Discussion of other real-space microscopes and how they are used to study surfaces. Tour of Instructor's Laboratory Room 10 Physics/Geology (basement)	Additional references or articles.
10	**Dec. 3**	Students' presentations of final project on construction of a musical instrument.	
Paper Due Fri. Dec. 13, 11:59 p.m. Please e-mail a Word or PDF file to Professor Chiang.			

Independent Project, Presentation, and Paper:

You must do a project in which you build a musical instrument. A list of suggestions will be provided. See HSH, Chap. 10 for additional ideas on homemade wind instruments. You should use the scientific method to plan and execute experiments which will aid you in building your instrument. Analyze the properties of your instrument in terms of the concepts discussed in class (e.g., frequencies produced, loudness, etc.) You will spend 5-10 minutes to present your project to the class during the last class meeting on **Tuesday, Dec. 3, 2019**. You must write a paper describing in detail the building of your instrument, including what you did and what results you obtained. The expected length of the final paper is about 1000-1500 words (4-6 pages typewritten). Your paper will be graded both on exposition and content.

You are required to send the instructor an e-mail note describing your topic and your plan of attack in several sentences by **Friday, Nov. 3, 2017.** The instructor will be happy to read a draft of your paper at any time and offer suggestions for improvement. The final paper is due **Friday, Dec. 13, 2019, 11:59 p.m. Please e-mail a Word or PDF file to Professor Chiang.**

Other books available at Shields Library (in addition to HSH):

1. Johnston, Ian. *Measured Tones: The Interplay of Physics and Music* (Institute of Physics Publishing, 2002), 2nd edition. ML3805.J63 2002 (First edition from 1986 is also acceptable).
2. Taylor, Charles. *Exploring Music: The Science and Technology of Tones and Tunes,* (Institute of Physics Publishing, 1992). ML3807.T39 1992.
3. Backus, John. *The Acoustical Foundations of Music*. New York: W. W. Norton (1969). ML3805.B245A3. (textbook)
4. Rossing, Thomas D. *The Science of Sound.* Reading, MA: Addison-Wesley Publishing Co. (1982). QC225.15.R67. (textbook)
5. Hall, Donald E. *Musical Acoustics*. 2nd Ed. Pacific Grove, CA: Brooks-Cole Publishing Co. (1991). (textbook)

About the Instructor: Professor Shirley Chiang is an experimental condensed matter physicist who specializes in surface science studies using high resolution microscopy techniques. She received her Ph.D. degree from U.C. Berkeley and was a Research Staff Member at the IBM Almaden Research Center before coming to U.C. Davis in 1994. Her current research interests include high resolutions surface imaging of metals on semiconductors, small molecules on metal surfaces, and thin metallic magnetic and alloy films. She won the UC Davis Distinguished Teaching Award in 2001. She is an advanced amateur pianist and an intermediate violinist.

PROJECT SUGGESTIONS FOR MAKING AN INSTRUMENT

The possibilities range from crude and simple versions up to concert-quality (very time-consuming!) instruments. You should think about the design and implementation problems and aim at understanding and explaining the resulting playing and sound characteristics. Also try to explain what notes the instrument plays, whether it can play a scale, and whether it can be tuned.

String: Construct your own original design or copy elements from actual stringed instruments. Possible materials for strings are nylon fishing line, wire, or purchased strings for guitars, violins, etc. Possible instrument bodies range from milk cartons, shoeboxes, wood frames, plastic boxes, etc.

Percussion: Use your imagination, and try unusual ingredients.

Flute: Plastic garden hose, bamboo, PVC irrigation pipe, or even a good piece of hardwood are all possible construction materials. The class website has a handout about where to place the holes.

References

1. Trevor Robinson, *The Amateur Wind Instrument Maker*, The University of Massachusetts Press, 1980.
2. Mark Shepard, *Simple Flutes: A Guide to Flute Making and Playing*, Shepard Publications, Los Angeles, 2003.
3. George Buchanan, *Making Stringed Instruments: A Workshop Guide*, Sterling Publishing Company, New York, 1990.
4. Bart Hopkin, *Musical Instrument Design*, See Sharp Press, Tucson, AZ 1996.
5. Arthur Benade, *Horns, Strings, and Harmony* (required text and available in library), Chapter X.

NOTE: Professor Chiang can reimburse you for $5 to $30 of expenses used for parts to build your instrument, if you keep the receipts and submit them to her with the provided form at the end of the class, i.e., after your presentation on Dec. 3, 2019 or by the end of the quarter, Dec. 13, 2019.