Syllabus: Design and engineering of musical instruments

Content:

This course will combine concepts of musical acoustics with the design and construction of musical instruments using the tools in the Center for Engineering Innovation and Design. The theoretical physical concepts will be supplemented with historical and musical perspectives on the instruments, taking advantage of expert guest performers/lecturers and resources in the Collection of Musical Instruments. The course will culminate in an innovative design project.

Instructors:

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Text:

Bart Hopkins , Making Simple Musical Instruments. Altamont Press, 1995.

Supplementary resources:

Rossing, Thomas. The Science of Sound. Addison-Wesley, 2001.

The Science of Musical Sound, Vo. 1. William Ralph Bennet, Jr.

Armstrong, Newton. An enactive approach to digital musical instrument design: Theory, Models, Techniques. AV Akademikerverlag, 2012.

Fiebrink, Rebecca. "Towards understanding human-computer interactions in composing the instrument" Proceedings of the International Computer Music Conference (ICMC), New York City, June 1-5, 2010.

Schnell, N., and Battier, M,. "Introducing composed instruments, technical and musicological implications," Proc. NIME, 2002.

Meeting Pattern

Class meets in the Center for Engineering, Innovation, and Design (Becton 107, CEID) Monday and Wednesday from 9:30-10:20am (lecture) and Tuesday from 1-4pm (lab).

Pre-requisites

Basic knowledge or interest in music or musical instruments. Solid background in math through precalculus, with knowledge of calculus preferred. Basic knowledge of physics including Newton's Laws and concepts of kinetic and potential energy. Students must become members of the CEID by the end of the first week of class.

Grades

There will be three categories of assessment: weekly labs which will include some homework problems and assigned tasks, a midterm exam and a final design project. Homework will be due in class at the beginning of class and late homework will not be accepted. The lowest scored problem set for the semester will be dropped. Students are encouraged to work together when solving problems but work that you turn in must be your own.

Weekly labs/Problem Sets: 30%

Mid-term Exam: 30%

Final Project: 40%

While collaboration and working as a group are essential to this course, all submitted material must be the student's own work. Students are expected to follow the university's code on academic honesty and plagiarism. For more information, please refer to the Yale College Undergraduate Regulations: http://yalecollege.yale.edu/content/undergraduate-regulations and the Yale College Writing Center: http://writing.yalecollege.yale.edu/advice-students/using-sources/understanding-and-avoiding-plagiarism.

Final Design Project

The culmination of the class will be team projects that produce novel musical instruments or applications. Each student will be evaluated on their individual contribution to the project as well the overall team result. Individuals will also be required to perform a quantitative analysis of some aspect of the project or a related topic and write up the results in a 3-5 page research paper.

Week 1:

1. Wed 8/27 Intro: historical contexts, overview of course, interactive learning exercise with musical instruments. Pass out sheet for documenting interest in course, with encouraged visit to Collection of Musical Instruments
2. Fri 8/29 Oscillatory systems: lumped element systems (mass on a spring) and mathematical notation. Musical scales and notation

Lab 0: Thurs 8/28 orientation session on Thursday evening mandatory for non CEID members

Week 2:

3. Wed 9/3 Intro to wave phenomena: wavelength, frequency, amplitude, longitudinal waves vs. transverse waves, constructive and destructive interference, mathematical notation

Lab 1: Tue 9/2 Construction of simple xylophone, test out beam equation (or demoed in lecture 2), cut and tune as many notes as possible, octave/chord/scale ideally, challenge to tune 1st and 2nd harmonics for one note. Laser training for all students (divide into 3 groups).

Week 3:

4. Mon 9/8 Waves on strings, reflections at boundaries, traveling and standing waves, boundary conditions, harmonics, nodes, antinodes
5. Wed 9/10 Forced vibrations on strings: plucking, bowing, fourier analysis

Lab 2: Tue 9/9 Construction of a simple stringed instrument. Explore dependence of frequency on tension, mass/length (radius of string), length.

Week 4:

6. Mon 9/15 String instruments (visit to Collection of Musical Instruments)
7. Wed 9/ 17 String instrument finish and intro to more tuning systems

Lab 3: Tue 9/16 String instrument building, continued. Measurement of sound and spectral analysis (music department)

Week 5:

8. Mon 9/22 Vibrations in air, pressure and displacement, application to tubes, boundary conditions and relation to instruments, tuning holes, conical vs cylindrical bores
9. Wed 9/24 Wind instruments, tuning the trumpet registers with a bell, more about notes in between the registers with cross fingering

Lab 4: Tue 9/23 Design and construction of a wind instrument , saxophone, finish string instruments

Week 6:

10. Mon 9/29 Mouthpieces, reeds, and orifices, trumpet valve design in excel

Wed 10/1 Intro to Solidworks for mode shapes/freq and 3D printing of instrument parts

11. **Lab 5**: Tue 9/30 Wind instrument building, continued, finish trumpet valve design in excel

Week 7:

12. Mon 10/6 SolidWorks continued, mode frequencies for bars, tuning of harmonics
13. Wed 10/8 Intro to sounds in 3D, Doppler effect, interference, radiation patterns, intro to Helmholtz resonators

Lab 6: Tue 10/7 Design and construction of a percussion instrument: Solidworks examples, midterm

Week 8:

14. Mon 10/13 Electronic generation of sound
15. Wed 10/15 Additive and Subtractive Synthesis

Lab 7: Tue 10/14 Arduinos/microprocessors/ max / midi introduced

Week 9:

16. Mon 10/20 Physical Modeling Synthesis

Week 10:

17. Mon 10/27 Hybrid Electronic / Acoustic Instruments (Guest Speaker)
18. Wed 10/29 Human Computer Interaction (HCI) and Gestural Control

Lab 8: Tue 10/28 Interfacing microprocessors to generate or process sound, leap motion

Week 11:

19. Mon 11/3 Advanced Topics I: The music of Harry Partch
20. Wed 11/5 Advanced Topics II: TBD

Lecture & Lab 11-13: Design project