Department: PHYS

Course No.: 107Q

Credits: 4

Title: Physics of Music

Contact: G. Rawitscher

Content Area: CA 3 Science and Technology- Lab

WQ: Q only

Catalog Copy: 107Q. Physics of Music. First semester. Four credits. Three class periods and one 2-hour laboratory period. Recommended preparation: MATH 101 or the equivalent. PHYS 101Q and 107Q may not both be combined to satisfy the Group 8 requirement.

Basic principles of physics and scientific reasoning will be taught in the context of the production and perception of music, emphasizing the historic and scientific interplay between physics and music. Basic quantitative laboratories pertaining to sound, music, and waves. No previous knowledge of physics or music is assumed.

Course Information: a) The goal of this course is to introduce non-scientists to the concepts and methods of modern scientific
research. However, non-scientists tend to be quite apprehensive about science in general and physics in particular. Thus, this course uses a theme, music, that students enjoy and are interested in, as a context in which they can learn physics. In the end, the course attempts to show students that common, everyday experiences, like music, are based on fundamental physical principles and can be quantitatively analyzed and understood.

b) The format of the course is fairly standard: 2 in class exams and a final, weekly homework assignments and quizzes, reading from specially prepared course notes and labs. All problems on the homework, quizzes and exams are word problems with numerical answers. Most problems require at least some algebra to obtain the solution.

c)

1. Waves and the Language of Physics
   Pitch, Frequency, Timbre, Loudness/ Units, Graphs, Formulas/
   Dependencies: Qualitative and Quantitative

2. Melodic Instruments and the Origins of Music and Science
   Neanderthal flutes and Greek lyres/ Pythagorean Intervals and Scales
   Vibrating Strings/ Space-Time Connection/ Air Columns and Boundary Conditions

Music of the Spheres and the Lessons of Pythagoras
New Scales and the Development of Western Harmony

3. Non-Melodic Instruments: Non-Harmonic and 2-D systems
Vibrating Bars and Non-linear Dependencies
Overtone Series, Addition of Waves and Tone Quality
2-Dimensional Acoustic Cavities
Spectroscopy, Modern Physics and Music of the Spheres

4. Waves and Interference
General Properties of Waves/ Constructive and Destructive Interference
Interference in Reflections/ Interference Patterns/ Interference in Time: Beats
Light Waves

5. Applications: Feedback and the Doppler Effect
Gain and Feedback/ Frequency Sources and Standards
The Doppler Effect/ Sonic Booms and Shock Waves

6. Psychoacoustics: Consonance and Dissonance
Structure of the Ear and Pitch Perception
Critical Bandwidths and Just-Noticeable Differences
Pure Tones, Consonance and Dissonance
Complex Tones, Fourier Analysis and The Missing Fundamental

Meets Goals of Gen Ed: Acquire intellectual breadth and versatility. Most non-scientists have had little exposure to rigorous scientific thinking and analysis. Introducing student to the power of the scientific method will certainly extended their intellectual breadth. Moreover, this course is really about the physics of waves and whatever physics students have had previously has generally dealt with objects. The realization that all objects have a wave-like nature is the cornerstone of modern science.

Acquire critical judgement. Appreciating the fact that the physical world can be studied and understood in a quantitative mathematical framework should help students realize that there is a different between good hard science and the pseudoscience that is becoming more and more pervasive.

Acquire consciousness of the diversity of human culture and experience. The course starts with archeological artifacts that appear to be bone flute made by the Neanderthals. The musical scale is traced from its pre-Pythagorean origins, through Pythagoras mathematical explanation of the scale, the Pentatonic scale, the modern Western scale and Arabic scale showing that even a seemingly culture creation like the scale has common physical connections across different cultures.

Acquire a working understanding of the processes by which they can continue to acquire and use knowledge. This is one of the most important aspects of a science and technology course. The scientific method is one of the most successful ways of generating knowledge and applying this knowledge to problems facing society. The message is reinforced in the lecture and especially the labs, where the emphasis is on using scientific techniques to learn about different physical systems.

CA3 Criteria: 1. Explore an area of science or technology by introducing students to a broad, coherent body of knowledge and contemporary scientific or technical methods; The main physics content of the course is waves. Waves include a wide
variety of physical phenomena, such as sound waves and acoustics, and light. Indeed, with the advent of quantum mechanics, it was realized that all physical objects have wave-like properties. Thus, basing the course on waves opens the door to an understanding of quantum mechanics and modern physics.

2. Promote an understanding of the nature of modern scientific inquiry, the process of investigation, and the interplay of data, hypotheses, and principles in the development and application of scientific knowledge; The understanding of the musical scale throughout history serves as an excellent model of the scientific process in different eras and cultures. The experimental evidence that light and electrons are governed by wave equations forced a complete rethinking of classical physics and lead to the radically new theories in modern physics.

3. Introduce students to unresolved questions in some area of science or technology and discuss how progress might be made in answering these questions; and One important theme of the course is to not only teach what we know about the physical world in the context of sound and music, but how specifically we go about acquiring knowledge and finding new problems.
For example, we discuss and use spectroscopy throughout the course. By looking at the spectra of distant galaxies and starts, we know that they are made of the same substances that we are. However, between the stars and the Earth is the interstellar medium, which has a well-characterized absorption spectrum. Nevertheless, none of the absorption features have yet been identified. Thus, we actually do not know what is between us and the stars.

4. Promote interest, competence, and commitment to continued learning about contemporary science and technology and their impact upon the world and human society. The mathematical understanding of the musical scale has actually lead to great historical changes since the time of Pythagoras. Indeed, because of a poor choice of the definition of the Major Third, the use of the Major Third was actually banned by the church in the 1300s. The lack of the Major Third is a characteristic of Gregorian Chant. Only when the Major Third was redefined and allowed did more complex harmonies develop.

CA3 Lab Criteria: The labs are quantitative in that the data are used to verify every formula that is used in the course. The results are analyzed statistically. In one lab, the resonant

frequencies of a rectangular 2-D acoustic cavity are measured. The frequencies are accurate to 1%. From this, the speed of sound can be determined to this accuracy. Finally, since the speed of sound is temperature dependent, the temperature of the room can be determined. However, all of this requires accurate taking and fitting of the data on the 1% level.

The laboratory section of the course includes the following ten 2-hour labs plus a lab final. All of the labs consist of a physical apparatus that the students must adjust or reconfigure during the course of the lab. Computers are used to assist in taking and analyzing data, but do not run simulations of experiments. The labs are performed in groups, while the lab final is done individually, so that each student is required to show mastery of the experimental techniques. The students fill out worksheets that are turned in at the end of the lab section.

1. Introduction to Waves and PASCO Program
2. Vibrating String
3. Sound Waves in a Tube
4. Vibrational Modes of a Metal Bar
5. Sound Waves in a Rectangular Cavity
6. Equivalence of Standing Waves and Traveling Waves
7. Interference
8. Gain and Feedback
9. Cavity Mode Diagrams
10. Interference of Light
11. Lab Final

Q Criteria: 1. Include mathematics and/or statistics at or above the basic algebra level as an integral part of the course which is used throughout the course. All homework, quiz, and exam problems require numerical answers. The level of the problems varies considerably throughout the course, allowing the instructor to probe exactly the level of a student's quantitative skills. On the easy end are simple "plug numbers in to a formula to get an answer." The next level requires algebraic manipulation of a formula to solve for the correct variable, first. Some of the harder problems, particularly in the interference of waves require the setting up and solving of two simultaneous equations.

2. Include use of basic algebraic concepts such as: formulas and functions, linear and quadratic equations and their graphs, systems of equations, polynomials, fractional expressions, exponents, powers and roots, problem solving and word problems. Formal abstract structures used in symbolic logic and other algebraic analyses are acceptable; A large part of the course uses scaling laws, in which a student is given a formula and a special case. From this, a student must be able to scale the result when one of the parameters is changed. The types of dependencies include inverse linear, powers and square roots. Although this skill in not emphasized in math courses, so much, it is enormously important in physics.

3. Require the student to understand and carry out actual mathematical and/or statistical manipulations, and relate them to whatever data might be provided in order to draw conclusions. Merely feeding numerical data into a program on a computer or a calculator to obtain a numerical result does not satisfy this requirement. Technology should be viewed as a tool to aid understanding and not as a driver of content.

Role of Grad Students: -The grad TAs are supervised closely by the Professor of the course (G. Gibson). They participate in the grading of the Laboratory reports.