Lehman College, City University of New York
PHY 141: Physics of Sound
Course Syllabus
Spring Term, 2015
Instructor: Prof. Dmitry Garanin

Classroom: Gillet Hall 226 (lecture); Gillet Hall 237 (laboratory)
Time: lecture: Monday & Wednesday, 2:00-3:13pm
Some lectures replaced by labs, see lab schedule
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Course Description:

3 hours (2 lecture; 1 lab), 3 credits. Physical phenomena in sound production, propagation, and perception. Scientific terminology of the physics of sound. Scientific foundation for more specialized courses such as speech & hearing and music theory

Required Text:

R. Berg and D. Stork, ***The Physics of Sound***, 3rd Ed. Published by McGraw-Hill. The textbook is available in the bookstore for $115 and will be on reserve in the library.

Lehman College Physics 141 lab manual. A free copy of the lab manual can be received in the Physics Office, G131

Learning Objectives:

By the end of the course students will

- **Identify and apply the fundamental concepts and methods of a life or physical science.**
  This course covers the fundamental physical concepts underlying sound production, propagation, and perception. These concepts are illustrated through applications to understanding human speech and hearing, properties of music, auditorium acoustics, and sound recording and reproduction. Through demonstrations and laboratory experiments the students will gain an appreciation of the methods used by scientists to understand sound.

- **Apply the scientific method to explore natural phenomena, including hypothesis development, observation, experimentation, measurement, data analysis, and data presentation.**
  Students will be led to understand the multitude of wave phenomena in physics in a unified framework. It will be shown how the concepts of acoustics are related to other phenomena such as water and light waves. The historical development of these concepts from observation to hypothesis to theory will be discussed. In the lab students will perform hands-on experiments, gaining experience in the measurement, analysis and presentation of quantitative data.

- **Use the tools of a scientific discipline to carry out collaborative laboratory investigations.**
  The accompanying laboratory course will give the students hands-on experience performing a wide range of experiments related to sound. Students will work collaboratively in small groups to gather data and to analyze and present their results.

- **Gather, analyze, and interpret data and present it in an effective written laboratory or fieldwork report.**
  In the laboratory part of the course, students perform experiments under the guidance of a lab instructor and using a lab manual. They are expected to make quantitative measurements, analyze and interpret the results, and prepare a lab report in an approved format.

- **Identify and apply research ethics and unbiased assessment in gathering and reporting scientific data.**
  The lab section includes a discussion of measurement errors and uncertainty. Students are asked to assess the bias and uncertainty in their experiments. They are expected to develop methods to minimize these effects, and to use quantitative statistical tools to analyze these effects in their lab reports.

Expectations:

- Regular attendance and participation in activities and discussions.
- Completing assigned readings before coming to class.
- Completing assigned homework and asking questions about what you don't understand.
- Attending all laboratory sessions, and turning in all lab reports on time.
- Studying consistently to be prepared for examinations.
- See the instructor or the tutoring center for extra help should you need it.

Lab reports:

Students will submit an individual lab report detailing the results of the previous experiment. A description of each lab, the appropriate procedure for conducting each experiment, and the steps required to analyze the data can be found in the lab manual. The exact format of the lab report will vary as appropriate to each experiment, but should include the following:

- A list of the people who worked with you in conducting the experiment
- A description of the experiment
- A record of the data as taken by your collaboration
- An analysis of the data, following the procedure outlined in your lab manual, and including an analysis of the statistical and systematic uncertainties in your results
- A summary of your results and conclusions

Attendance/Lateness Policy:

Regular attendance is required. Students should not miss class unless it is absolutely necessary. Two absences are allowed for lecture; more than two will affect your grade and may result in loss of credit. All students must sign in at the start of every class. Students who arrive late may be asked to leave class. Absences are not allowed for lab. If you miss a lab you must contact your instructor in advance to schedule a make-up.

Grading Policy

- 75 points Exams (three midterms 15 points each, plus the final exam 30 points)
- 24 points Labs (6 labs ×4 points each)
- Total 99 points
- Zone conversion into grades

Accommodating Students with Special Learning Needs

In accordance with University policy, a student who has a documented sensory and/or learning disability and, as a result, needs reasonable accommodation(s) to attend, participate, or complete course requirements, should meet with me at the beginning of the course to discuss these accommodations. Please follow up by presenting appropriate documentation regarding any physical, perceptual, or learning disabilities as addressed by the Americans with Disabilities Act to the Coordinator of Disability Services, located in Shuster Hall, in order to obtain assistance.

Academic Integrity and Plagiarism Policy

A statement may be found in the student handbook. See http://www.lehman.cuny.edu/student-affairs/documents/student-handbook-02.pdf.

Course program and tentative schedule:

1. Introduction. Oscillations – (Week 1)

Definitions of physical quantities and units. Sound: Oscillations and waves. Simple harmonic oscillatons. Amplitude, period, and frequency (pitch). Harmonic oscillations with slowly changing parameters. Perception of sound. Anharmonic oscillations. Combinations of harmonic oscillations. Beats. Phase relations and phychoacoustical Ohm's law, phase beats. Damped and driven oscillations, resonance.

Problems: Berg & Stork, Ch.1: Questions: 5,7; Problems: 1,4.

Demonstrations: Parameters of harmonic oscillations | Damped harmonic oscillation | Interference | Beats

2. Waves and Sound (Week 2,3)

Plane waves: Periodic waves, solitary waves, wave packets. Wave length, sound velocity. Spherical and cylindrical waves. Wave intensity; Inverse square law etc. Longitudinal and transverse waves. Polarization of transverse waves. Surface acoustic waves. Reflection and refraction of waves. Refraction of sound in the atmosphere. Interference of plane waves. Interference of spherical waves. Doppler effect. Sonic booms and shock waves.

Problems: Berg & Stork, Ch.2: Questions: 6,9; Problems: 2,7.

Demonstrations: Interference of two spherical waves | Doppler-effect | Longitudinal and transverse waves

3. Standing Waves and Overtone Series (Week 4)

Standing waves in general. Role of boundary conditions in the formation of standing waves. Node-node, antinode-antinode, and node-antinode boundary conditions. Overtones series. Mersenne's laws.

Problems: Berg & Stork, Ch.3: Questions: 4,6,7; Problems: 3,5.

Demonstrations: Standing waves | Standing waves with node-node boundary conditions

4. Analysis and Synthesis of Complex Waves (Week 5)

Synthesis of complex waves. Fourier analysis and Fourier spectra. Analysis of tone quality: Attacks and decays, formants. Vibrato and tremolo. Discrete and continuous Fourier spectra. Spectrograms: Narrow-band and wide-band.

Demonstrations: Square wave | Tremolo and Vibrato

Problems: Berg & Stork, Ch.4: Questions: 2,3,7; Problems: 1,2.

5. Resonances in Sound Production (Week 6)

Role of resonances: Amplification of sound, shaping of sound (selection of particular frequency ranges), creation of sound in whistles and woodwind instruments. Helmholtz resonator and other resonators. Noise: White noise, colored noise. Filtering of noise by a resonator.

Problems: Berg & Stork, Ch.4: Questions: 8,9,10; Problems: 3,5.

6. Speech and singing (Week 7)

Structure of speech and singing apparatus. Throat and mouth as a resonator. Naive open-closed-pipe theory of the throat-mouth resonator. Resonances as formants in shaping the output sound. Production of the glottal wave by the vocal folds, Bernoulli law. Difference between singing, speech, and hoarse speech. Simplified two-formant sinthesis of vowels.

Problems: Berg & Stork, Ch.6: Questions: 10,11,12.

7. Hearing (Weeks 8,9)

Structure of the ear. Transmission of the signal through the ear parts. Place theory of hearing: Frequency response and frequency resolution. Physical sound intensity, amplitude and the intensity of the sound.. Sensitivity of the ear to the sound intensity. Logarithms. The decibel scale of sound intensity level. Decibels and phones. Nonlinearity of the ear. Aural harmonics. Combinational tones. Fundamental tracking. Masking. Binaural effects. Cochlear implants as a confirmation of the place theory of hearing.

Problems: Berg & Stork, Ch.6: Questions: 2,3,5; Problems: 1,2,3.

8. Room and auditorium acoustics (Week 10)

Direct and reflected sound. Texture of the echo. Definition of the reverberation time. Fullness and clarity. Warmth and brilliance. Formula for the reverberation time. Absorption and reflection coefficients. Resonances in room of a box. shape. General principles of constructing concert halls.

9. Sound recording and reproduction (Week 11)

History of sound recording. Acoustic vs electric recording. Phonograps. Vinyl records. Magnetic tape recorders. Digital recording. DAT and MiniDisc. CDs and their successors. Computer-based recording. Flash recorders. Legal problems with digital recordings. MIDI vs sound recording. Modern recording setup. Microphons: Dynamic and electret condenser microphons, polar pattern, frequency response. Preamplifiers and A/D converters.

10. Digital recording (Week 12)

Discretization of the wave form. Sampling frequency. Sample depth (bit depth). CD vs high-resolution audio. Dynamic range. Bit rate and file size. Bits and bytes. Storage requirements. Internet delivery of digital music. Transfer rate. Audio compression. Lossless and lossy encoding. MP3 and other lossy encoding formats. Constant, variable, and average bit rate.

Problems

11. Music temperament (Week 13)

Music sounds, notes. Pitch vs. interval. Phychological role of intervals. Temperaments. Overtone series and perfect intervals. Music scales (keys). Impossibility of a temperament using all perfect intervals. Open and close temperaments. Unequal and equal temperaments. Definition of the equal temperament. Frequency ratios in the equal temperament. Comparing wave forms of perfect and imperfect intervals. Pythagorean temperament as the simplest and historically first temperament. Wolf fifth and other problems of the Pythagorean temperament.

Midterm Test schedule:

Test 1:	We, March 4
Test 2:	We, April 8
Test 3:	We, May 13

<u>Labs</u>

No.	TITLE OF EXPERIMENT:
1	THE PENDULUM
2	SIMPLE HARMONIC MOTION
3	STANDING WAVES ON STRINGS
4	STANDING WAVES ON AIR COLUMNS
5	SOUND INTENSITY - THE DECIBEL SCALE
6	REVERBERATION TIME