Demonstration Experiments in Musical Acoustics

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Abstract

Demonstration experiments are an effective way to teach acoustics principles. Musical acoustics demonstration experiments are particularly appealing to students. We briefly discuss the tradition and list a number of demonstration experiments, some of which will be illustrated in the oral presentation. Some sources for demonstrations are listed.

1. Introduction

Since the time of Pythagoras, if not before, demonstration experiments have been used by teachers to illustrate important acoustical principles and to arouse curiosity about the science of acoustics. Musical acoustics demonstrations are particularly attractive to students, because of their interest in music and musical instruments.

In this paper we will list a number of musical acoustics demonstrations that we find useful, and we will discuss a few of our favorites. Some of these will be demonstrated in the oral presentation of this paper.

2. A Cherished Tradition

We owe much to Michael Faraday, who established a rich tradition of lecture demonstrations at the Royal Institution in London. Such stalwarts as John Tyndall and Charles Wheatstone frequently illustrated their public lectures at the Institution with demonstration experiments, as did guest lecturers from other countries. Many demonstration experiments of Faraday, Tyndall, Wheatstone, and others are described in two books published by the Institute of Physics: Michael Faraday and the Royal Institution by John M. Thomas (IOP Publishing, Bristol, 1991) and The Art and Science of Lecture Demonstration by Charles Taylor (IOP Publishing, Bristol, 1988).

In addition to the Christmas lectures, a number of famous scientists, such as John Tyndall, have given lectures on sound with demonstration experiments at the Royal Institution. For one lecture, Tyndall had a hole drilled in the floor of the lecture theater through which he passed a wooden rod whose lower end rested on a grand piano in the basement two floors below. When a violin, cello, guitar, or harp was placed on the upper end of the rod in front of the lecture bench, the sound of the grand piano poured out from it!

Although some people are questioning the value of teaching by the lecture method these days, we believe that what they are really questioning is “chalk and talk” lecturing. Lecture demonstrations are as valuable as ever, we feel, in teaching the concepts of acoustics.

3. Demonstration Experiments on Vibrating Systems and Resonance

1. Dependence of frequency on mass
2. Dependence of frequency on spring constant
3. Pendulum
4. Helmholtz resonator
5. Soda bottle resonator
6. Modes of a vibrating string
7. Vibrations of rectangular bars
8. Driven vibrations of rectangular bars
9. Driven vibrations of a plate
10. Chladni patterns
11. Resonance of hand-held oscillator
12. Resonance of a driven oscillator
13. Resonance of a wire string
14. Coupled pendula
15. Wilberforce pendulum
16. Longitudinal resonances in a singing rod
17. Resonance of a closed tube
18. Tuning fork resonator
19. Smoke alarm vibrator
20. Kundt's tube
21. Impedance of an air column
22. Resonances of a tin whistle
23. Open and closed organ pipes
24. Flutes and clarinets
25. Rubens flame tube
26. Pipe excited with a Meeker burner
27. Rijke tube
28. Singing corrugated hose
29. Soda straw reed instrument
30. Waves on a rope
31. Wave machine
32. Superposition of waves
33. Standing waves on a rope
34. Standing waves on a rotating string
35. Standing waves on a wave machine
36. Wave reflection at an interface
37. Longitudinal wave model
38. Longitudinal waves on a slinky
39. Singing rods
40. Waves in a ripple tank

4. Waves

41. Frequency range of audible sounds
42. 42. Sensitivity to interaural time difference
43. Time resolution of the ear
44. Critical bands by loudness comparison
45. Critical bands by masking
46. The decibel scale
47. Frequency response of the ear
48. Loudness scaling
49. Loudness and sound level
50. Temporal integration
51. Asymmetry of masking
52. Backward and forward masking
53. Sound levels
54. Dependence of pitch on intensity
55. Pitch salience and tone duration
56. Influence of masking noise on pitch
57. Octave matching
58. Stretched and compressed scales
59. Difference limen or JND
60. Seebeck’s siren
61. Virtual pitch
62. Shift of virtual pitch
63. Masking spectral and virtual pitch
64. Strike note of a chime
65. Analytic and synthetic pitch
66. Repetition pitch
67. Circularity in pitch judgement
68. Fourier analysis
69. Effect of spectrum on timbre
70. Effect of tone envelope on timbre
71. Change in timbre with transposition
72. Cancelled harmonics
73. Beats
74. Difference tones
75. Difference tones from a whistle
76. Difference tones between two flutes
77. Primary and secondary beats

6. String Instruments

78. Motion of a plucked string
79. Motion of a bowed string
80. Following bow
81. Plate vibrations
82. Violin and guitar plates
83. Longitudinal string vibrations
84. Bowing at different positions
85. Violin mute
86. Fret buzz
87. Mechanical model of piano action
88. Tricords
89. Piano sound reversed

7. Wind Instruments

90. Resonances of a pipe and mouthpiece
91. Trombone slide
92. Hand stopping
93. Tuning effect of the bell
94. Lips of a brass player
95. Bernoulli effect
96. Internal sound field
97. Turning point
98. Mutes
99. Internal and external sound spectra
100. Sound spectra at various dynamic levels
101. Register holes
102. Overblowing a flute or recorder
103. Comparing open and closed end pipes
104. Open and closed end organ pipes
105. Soda straw double reed
106. Instruments with conical bore
107. Clarinet bell
108. Clarinet with flute head joint
109. PVC pipe instruments
110. Change in timbre in clarinet bore

8. Percussion Instruments

111. Modes of a rectangular bar
112. Modes of a tuned bar
113. Vibraphone resonators
114. Chimes
115. Kettledrum
116. Cymbals
117. Steel pans
118. The HANG
119. Chinese opera gongs
120. Handbells

9. Singing

121. Waveforms of vowel sounds
122. Darkened vowel sound
123. Formant
124. Identifying vowels at high tessitura
125. Scaled formants
126. Different ways of breathing
127. Vibrato rate
128. Voice source analyzed by inverse filtering

10. Electronic Musical Instruments

129. Music boxes
130. Electromechanical sound generation
131. Theremin
132. Hammond organ
133. Leslie speaker

11. Music Synthesizers and Computer

Music

134. Musique concrète
135. Elektronische Musik
136. Analog music synthesizers
137. Convolution and digital filtering
138. Sound cards
139. Computer-composed music
140. Computer sound synthesis
141. Physical modeling
142. MIDI
143. Looping
144. Pitch shifting
145. Spatialization
146. Binaural recording
147. MP3 encoding

12. Sound Recording

148. Stereo phonograph cartridge
149. Edison-type phonograph
150. Magnetization patterns on magnetic tape
151. Tape recorder bias
152. Diffraction from a Compact Disc
153. Greeting card with ChipCorder

13. Concert Halls and Recording Studios

154. Resolving time of echoes
155. Sound decay
156. Change in sound level with distance
157. Effect of echoes
158. Effect of concert halls
159. Maximum and minimum sound levels in a room
160. Standing waves in a room
161. Noise level in rooms
162. Noise criteria ratings
163. Sound field
164. Equalization
165. Loudspeaker directivity
166. Acoustic feedback
167. Combining direct and reflected sound
168. Comb filtering
169. Time-intensity trading
170. Differences in sound recording methods

13. Sources for Acoustics Demonstrations

York, 1968.


17] www.kettering.edu/drussell/demos.html

18] www.bw.edu/~phoekje


20] www.speech.kth.se

21] www.oakcroft13.fsnet.co.uk

22] www-ccrma.stanford.edu

23] www.physics.auburn.edu/demo/waves/waves.htm


25] www.acoustics.eu.com

26] www.physics.indiana.edu/~demos/sounddemo.htm