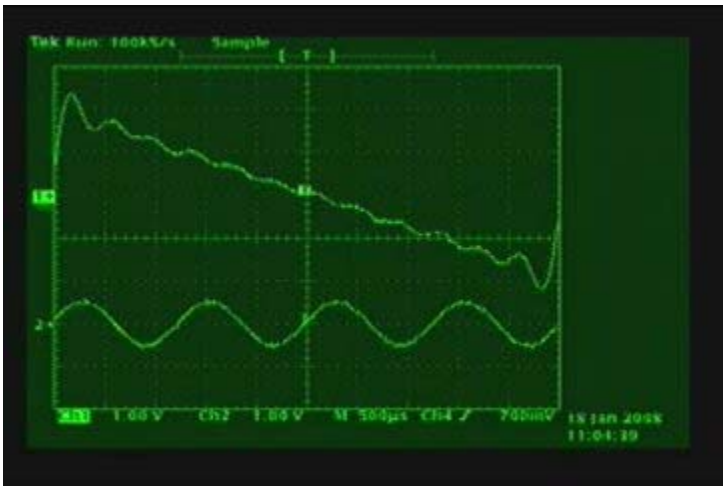
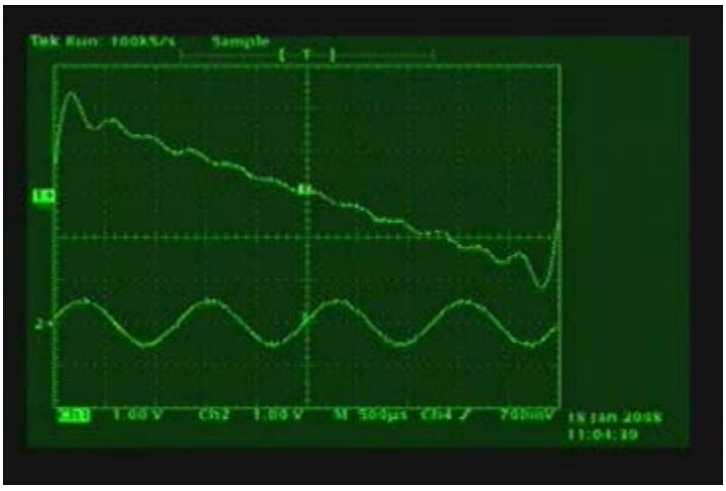
Answer #330

Part 1: The answer is (c): both the wave shape and the sound of the sum wave will change, as can be seen and heard in an mpeg video by clicking your mouse on the photograph below. The actual fourth harmonic included in the synthesized wave is shown as it changes on the lower oscilloscope trace.



Part 2: The answer is (a): only the wave shape of the sum wave will change, but not the timbre, as can be seen and heard in an mpeg video by clicking your mouse on the photograph below. Again, the actual fourth harmonic in the synthesized wave is shown as it changes on the lower oscilloscope trace.



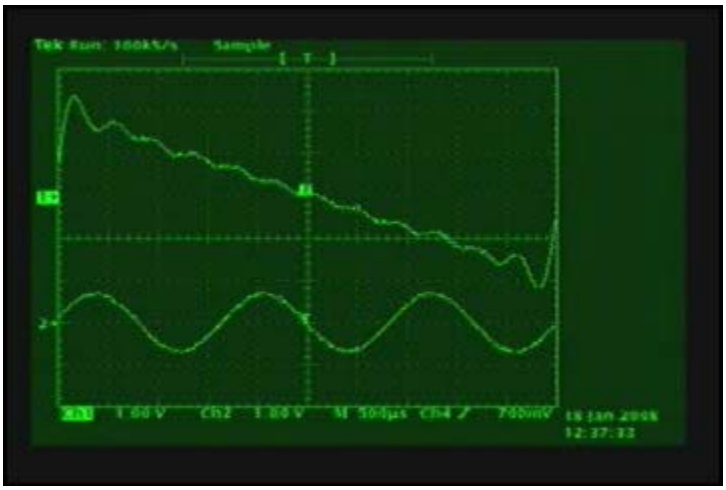
These results are consistent with an important "law" regarding how the ears hear steady-state sounds, known as *Ohm's Law of Hearing*, to distinguish it from the more common relation between electrical voltage, current, and resistance (V=IR), generally known as simply *Ohm's Law*.

According to Ohm's law of hearing and the generally accepted "place theory of hearing," which correlates the frequency response of the sensor cells along the basilar membrane with their location (place) along the membrane, the timbre, or tone quality, of a steady-state tone depends on the amplitudes of the harmonics but not on the phases. This would be consistent with the place theory because changing the phase of any harmonic would not change its frequency and would therefore not affect the position along the basilar membrane that would be stimulated by that tone. Another example would be that when you listen to a tone played on a loudspeaker, the tone quality (timbre) does not

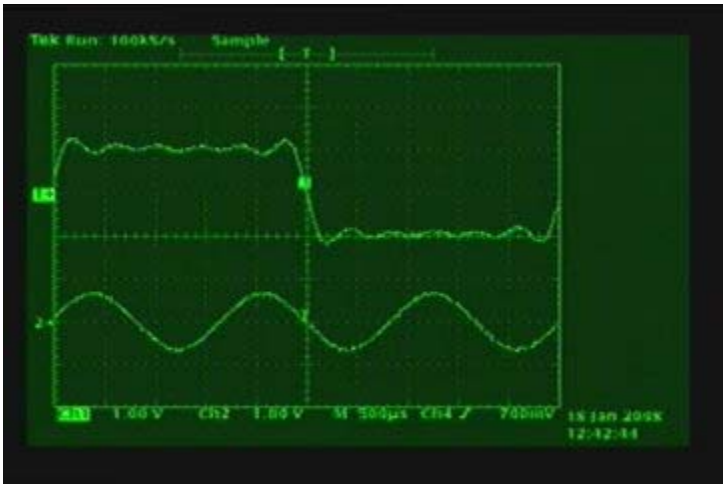
change as you move closer to or further away from the speaker. (The loudness does vary though, due to the inverse square effect.)

One simplifying result of this "law" is that the Fourier spectrum of a tone, which contains only the amplitudes of the harmonics, can tell a lot about the tone quality without the necessity of specifying the relative phases of all of the harmonics in addition to their amplitudes.

Click on the photograph below to see the effect of changing the amplitude and the phase of the third harmonic of the sawtooth on its wave shape and sound.



Click on the photograph below to see the effect of changing the amplitude and the phase of the third harmonic of the square wave on its wave shape and sound.



Question of the Week

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For questions and comments regarding the *Question of the Week* contact Dr. Richard E. Berg by e-mail or using phone number or regular mail address given on the Lecture-Demonstration Home Page.