

Homework 7: Amplitude vs. Loudness

10 Points: Due at the beginning of class, Thursday, 2 April 2009

There are two parts to this homework assignment. Each part counts 5 points. Late homework will receive a grade of zero.

Part 1:

We must keep in mind the distinction between the physical nature of a stimulus and the psychological nature of the experience. Sound amplitude is expressed in RMS pressure units or in decibels relative to a standard pressure ($P_0 = 0.00002 \text{ N/m}^2$).

$$dB = 20 \log_{10} \left(\frac{P}{P_0} \right)$$

A psychological unit of loudness is the **sones**. By definition, 1 sone is the loudness of a 1000 Hz tone 40 dB above detection threshold. Assuming that the detection threshold for such a tone is 0 dB, then 1 sone is the loudness of a 1000 Hz tone with a sound pressure level of 0.002 N/m^2 . The relationship between perceived loudness and sound pressure level is nonlinear: a power function:

$$L = k \cdot SPL^{0.6}$$

where L is loudness, SPL is the sound pressure level in Newton per square meter, and k is a scaling constant. To compute loudness in sones, use a scaling constant $k = 41.6$:

$$Sones = 41.6 \cdot SPL_{N/m^2}^{0.6}$$

Using the above relationships, compute the loudness of a 1000 Hz sine wave tone having the following intensities: 40, 50, 60, 70, 80, 90, 100, and 110 dB and put the results in a table. Don't forget to first convert decibels into Newtons per square meter. (Hint: `db2spl <- function(db) {0.00002 * 10^(db/20)}`). Examining your table, what do you have to do to the pressure of a sound to double its loudness?

Part 2:

The critical band is an extremely important concept in hearing. It influences our ability to discriminate tones, the loudness of sounds, the ability to hear sounds in the presence of masking sounds and so forth. For example, if two tones fall into separate critical bands, they will be treated (approximately) independently of each other.

You are given two 60 dB sounds. The first sound is a simple sine wave tone having a frequency of 1000 Hz and amplitude of 60 dB. The second sound has four components: a 1st harmonic (the fundamental frequency) of 1000 Hz and a 2nd, 3rd, and 4th harmonic. Each component has an intensity of 0.01 N/m^2 . Assuming that the components of the complex sound all fall in separate critical bands and therefore their loudnesses simply add together, what is the loudness (in sones) of the simple tone and what is the loudness (in sones) of the complex tone? Are they equal? Why or why not?