

THE SCIENCE OF MUSIC

EXERCISES FOR CHAPTER 5

5.1 Looking at Fig. 5.1, what is the maximum length the ear canal could have for (a) a tuna fish and (b) a bat?

5.2 On average, a human being can hear sounds up to a frequency of about 18 000 Hz when they are in their twenties, but they tend to lose hearing at the highest frequencies as they get older, and men lose more than women. A typical woman in her eighties can hear sounds up to about 10 000 Hz. A man in his eighties can hear up to about 5000 Hz.

- a) What musical notes do these three frequencies (18 000 Hz, 10 000 Hz, and 5000 Hz) correspond to?
- b) Are these notes that one would normally use when playing music?
- c) From a musical perspective, why then would it matter if you lose hearing at these high frequencies?

5.3 When two different notes are played at the same time you might hear (1) beats, (2) dissonance (a clash), or (3) consonance (a harmonious sound). Which will you hear in each of the following cases?

- a) Two sine waves with frequencies 1000 Hz and 1002 Hz.
- b) Two sine waves, the second a half-step higher than the first.
- c) Two sine waves, the second a major seventh (11 half-steps) higher than the first.
- d) Two sawtooth waves, the second a major seventh higher than the first.
- e) Two sawtooth waves, the second an octave higher than the first.

5.4 Two sawtooth waves are played at the same time. A sawtooth wave contains all harmonics.

- a) The second harmonic is an octave above the fundamental. What musical intervals separate the third, fourth, and fifth harmonics from the fundamental?
- b) If the two sawtooth waves are a (perfect) fifth apart, what are the lowest two harmonics of the two waves that will produce auditory roughness?

5.5 According to Fig. 5.14, the two most dissonant musical intervals of less than an octave are the minor second and major seventh. What is the third most dissonant interval less than an octave?

5.6 In order to increase its volume, a piano has (usually) three strings for each note, all tuned to the same frequency. Suppose one of the strings for the note A4 is out of tune by 2 cents.

- a) Is this pitch difference audible to the human ear?

- b) Nonetheless one does notice the poor tuning because it produces beats. How fast would the beats be in this case?

5.7 Two sine wave tones played together normally produce roughness only if they are less than about a minor third apart. But at lower frequencies tones further apart can produce roughness. Based on Fig. 5.9, what is the largest interval that will produce roughness when the tones are around (a) 500 Hz and (b) 200 Hz. (Note the logarithmic horizontal scale in Fig. 5.9.)

5.8 If sound from a sound source reaches your left ear 300 microseconds before it reaches the right, what direction was the sound coming from?

5.9 There are two different mechanisms the ear uses to determine the direction of a sound. What mechanism would it use for each of the following and why?

- a) The sound of a bird singing in a tree.
- b) The rumbling of distant thunder.