Problem 6.1

Connect the otoscope to the video monitor. Look in your lab partner’s ear, or vice versa, and watch display on the video monitor. Find the malleus and the umbo. Is this auditory canal curvy or straight?

Problem 6.2

Listen to track 1 of the CD Audio Demonstrations by Houtsma, Rossing, and Wagenaars, prepared at IPO, published by the ASA (also available on line at http://auditorymodels.org/537/Auditory-Demonstrations/). When the complex tone is first played, are any of the harmonics separately audible, or do you, instead, hear the entire tone holistically? If you don’t hear distinct harmonics when the tone first starts, when do the distinct harmonics become audible?

Problem 6.3

Listen to track 2 of the Audio Demonstrations CD, and read the accompanying text.

(a) Based on this demonstration, would you say that a 2000Hz tone is effectively masked by noise at all frequencies, by noise in the frequency range \( f \in [1500, 2500] \)Hz, by noise in the range \( f \in [1875, 2125] \)Hz, or only by noise in the range \( f \in [1995, 2005] \)Hz?

(b) How many level steps can you hear at 250Hz? How many steps at 10Hz? What is the difference in masking threshold (in dB) between 250Hz and 10Hz?

(c) Consider that a white noise signal has a perfectly flat spectrum, \( |X(\omega)| = N \) for some constant \( N \) that is independent of frequency. A bandpass filtered white noise signal with center frequency \( f_c \) and bandwidth \( B \) has the spectrum

\[
|X(\omega)| = \begin{cases} 
N & f_c - \frac{B}{2} < f < f_c + \frac{B}{2} \\
0 & \text{otherwise}
\end{cases}
\]

\( N \) is not in units of Pascals; it is actually in units of Pascals per square-root-Hertz \( (P/\sqrt{Hz}) \). This particularly odd set of units is caused by the following fact: when you add together random noise signals at different frequencies, their amplitudes do not add, but instead, their powers (or acoustic intensities) add. Therefore the total acoustic intensity of a filtered noise signal with bandwidth of \( B \)Hz is proportional to \( BN^2 \): the spectral level squared, times the bandwidth.

To be more specific, the spectral intensity density of the noise is \( \rho c N^2 \), in units of intensity per Hertz \( (W/m^2/Hz) \), where \( \rho \) is the density of air and \( c \) is the speed of sound. Therefore the total intensity
of a filtered noise signal, propagating as a plane wave, with a level of \( N \frac{P}{\sqrt{Hz}} \), and a bandwidth of \( B \) Hz, is \( \rho c BN^2 \). The level of such a signal, in decibels, is

\[
L_N = 10 \log_{10} \rho c BN^2
\]

Most acousticians ignore the \( \rho c \) term, because it is a constant, independent of the noise spectral level or bandwidth:

\[
L_N = 10 \log_{10} B + 20 \log_{10} N + \text{constant}
\]

What is the level difference between the filtered noise signals with bandwidths of 250Hz and 10Hz? How does this answer compare with your answer to part (b)?

**Problem 6.4**

Listen to *Audio Demonstration* number 9 (CD track 22), and read the associated text. Does a high tone more effectively mask a low tone, or vice versa? Is this effect caused by properties of the auditory canal, eardrum, middle ear, basilar membrane, inner hair cells, auditory nerve, cochlear nucleus, or higher-level processing? Describe the origin of this effect.

**Problem 6.5**

Listen to *Audio Demonstration* number 27 (CD track 52). The signal that you hear is \( X(\omega) = H(\omega)E(\omega) \). The filter \( H(\omega) \) is actually a bell-shaped curve, as shown in the CD booklet, but for purposes of this problem, pretend that it is an ideal bandpass filter with cutoff frequencies of 499Hz and 1001Hz. The excitation signal is

\[
E(2\pi f) \propto \sum_{k=1}^{\infty} \delta(f - kF_0)
\]

(a) Suppose that \( F_0 = \frac{F_{\text{start}}}{2^t} \) for times \( t \geq 0 \) seconds, where \( F_{\text{start}} = 250\)Hz. Draw \( X(\omega) \) at times \( t = 0, t = 0.5s, \) and \( t = 1\)sec. Is there any upper limit on the amount of time that one could continue playing this demonstration?

(b) Even at time \( t = 0 \), the first harmonic is not present in \( X(\omega) \). Why does this not matter?

**Problem 6.6**

Listen to *Audio Demonstration* number 28 (CD track 53). If this demonstration used the vowels /i/ and /u/ instead of different musical instruments, what would you hear? Is vowel quality encoded by the pitch, rhythm, or timbre of speech?

**Problem 6.7**

If you have extra time, you may find it interesting to listen to more of the audio demonstrations!