Section: Monday / Tuesday (circle one)

Name: ______________________________
Partners: ______________________________
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PHYSICS 107 LAB #10: THE EAR PT 1: LIMITS OF HEARING

Equipment: *2(4) headphones,1(3) headphone splitter(s),2 function generators, 2 BNC cables, banana-BNC (Male-Female), audio amplifier, Sound Intensity Level Meter(without foam microphone cover.)*

OBJECTIVES

- Experience the Just Noticeable Differences in Intensity
- Experience the Just Noticeable Difference in Frequency
- Experience the Frequency dependence of our perception of Loudness
- Experience Masking of one sound by another similar and louder sound

Overview

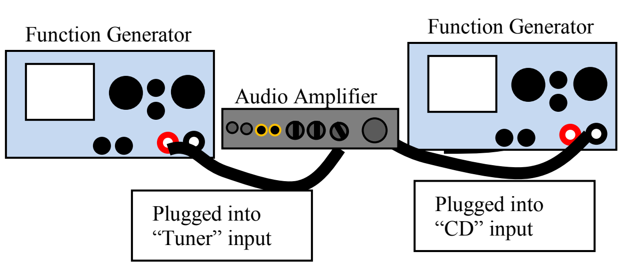
The human ear is an incredible device – it can detect signals with intensities from 10^{-12} Watts/m^2 up to 1 Watt/m^2 without sustaining damage, and it can detect from about 20 Hz to 20,000Hz. Our sound perception relies on a combination of three qualitatively different of mechanisms – varying mechanical properties of the basilar membrane allows nerves along different regions to respond to different frequencies, the stimulated nerves 'fire' at the frequency of their stimulation (i.e., the frequency of the sound stimulating them), and the brain searches for patterns to lend order to the complex messages coming its way so that when, say, you're listening to a band perform, you can associate the right signals with the guitar's complex sound and the right ones with the keyboard's. In this lab, you'll explore some of the limits of our hearing – how finely we can resolve differences in pitch or differences in loudness, how much more sensitive we are to some frequencies than to others, and how strongly a loud sound 'masks' a quieter one.

For each of these experiments, one of you should play the role of 'experimenter' and the other the role of 'test subject.' Feel free to trade back and forth. For many of these, the experimenter will vary one of two sounds that the test subject hears and the test subject will report when the variation is noticeable; when you're the experimenter, so as not to 'lead' your test subject, don't let him/her know exactly how you're varying things – don't let them see you increasing / decreasing the volume or frequency.

Readings:

Reading: Sections 6.2-6.7, 17.6

Set-up



This should already be set up by your instructor, but look it over to make sure things are as they should be.

Just Noticeable Difference - Intensity

How much stronger must one sound be than another before we notice a volume difference? With two function generators playing the same pitch, you'll vary one's strength/voltage relative to the other's to see how small a difference is noticeable.

Set-up

1. Make sure the Amplifier's "mono" button is pressed in so it will play mono.

2. Set both function generators to 200 Hz and the same voltage, around .6Volts (whatever you choose, make sure it's the same for both function generators). Adjust the amplifier's volume knob so the sound is at a pleasant enough volume.

3. Set the function generators so you can very finely control the voltage.

Experiment

4. With the test subject(s) listening through the headphones, the experimenter should switch between their listening to the "CD" and the "Tuner" function generator to make sure they're heard at the same volume.

5. Now, with the test subject(s) listening to the "CD", slightly vary the "Tuner" quieter or louder (don't say which you're doing) and switch to it, and then back, keep doing this until the test subjects report being able to hear the volume difference.

6. Now measure the sound intensity levels of the two signals by sandwiching the Sound Level Meter (SLM) between the two earphones, it's microphone pressing into one and it's bottom pressing into the other; adjust the microphone's position until you get the largest reading – record the maximum reading for the "CD" source and for the "Tuner" source.

   SIL_{CD} = ___________dB SIL_{Tuner} = __________dB

7. The 'just noticeable difference', JND in sound level is then the difference between these two:

   $JND_{intensity}$ = ________ dB

   Question: Looking at Figure 6.7, around what JND (just noticeable difference) is reported for 200 Hz in the SIL range that you were using (the ball park of your SIL_{CD} and SIL_{Tuner} values)?

   Question: Is the JND *you* determined in the same range as what Figure 6.7 reports?

Just Noticeable Difference - Frequency

How different must two frequencies be before we can tell the difference in pitch? You'll start off listening to two identical tones (same frequency and same strength), and slowly change one's frequency until the two tones are audibly different.

Set-Up

8. Set both function generators to 400 Hz and at the same voltage of around 0.6 V and adjust the amplifier's volume so these are pleasant enough.

Experiment

9. Again, you will keep the "CD" function generator's volume and frequency constant but this time it will be the frequency of the "Tuner" function generator that you vary. While the test subjects listen to "CD", the experimenter should change the other function generator's frequency by 10^{th}'s of Hz, and then switch to "tuner" for the test subjects to hear that, turn back to "CD", adjust the frequency some more,… until the test subjects report being able to tell the difference. At that point, record the two frequencies.

f_{CD} = ____________Hz f_{Tuner} = ___________Hz

10. So the Just Noticeable (frequency) Difference for 400Hz is

$JND_{frequency}$___________________ Hz.

11. Now set both function generators to 4 kHz (you may wish to readjust the volume). You'll repeat the procedure above to identify the Just Noticeable Difference at 4 kHz.

f_{CD} = ____________Hz f_{Tuner} = ___________Hz

12. So the Just Noticeable (frequency) Difference for 4kHz is

$JND_{frequency}$___________________ Hz.

Question: Looking at Figure 6.8, around what JND (just noticeable difference) is reported for 400 Hz, and what is reported for 4 kHz?

Question: Are the differences you determined for 400 Hz and 4 kHz comparable to those reported in Figure 6.8?

Frequency-dependent Loudness Perception

Not all frequencies are heard equally well. You'll listen to two very different pitches and adjust the strength of one relative to that of the other until their equally loud.

Set-Up

13. Plug one function generator into the CD's Left input and the other into the CD's Right input.

14. Press the Amplifier's "Mono" button in – this will ensure that the signals from both function generators get mixed and sent to both ears.

15. Set one of the Function Generators to 100 Hz at 0.1V and the other to 4000 Hz at 0.1V, then dial the amplifier's Volume nob to the 5^{th} dot.

Experiment

16. Adjust the 4000 Hz voltage until the test subjects report that it's about as loud as the 100 Hz tone (you'll probably want to zero in on a good volume by adjusting identifiably too loud, too quiet,…

17. When your test subject's agree that the two tones are approximately the same volume, switch the amplifier from "Mono" to "Stereo" so each ear gets a different pitch and use the SLM as before to measure the two pitches' levels.

    100 Hz SIL: ________________dB   4000 Hz SIL: ________________dB

    Question: to which is the human ear more sensitive, the low 100 Hz or the high 4000 Hz?

18. The unit of 'perceived loudness' is the "Phon." So if two sounds are (roughly) equally loud, you'd expect them to have (roughly) the same Phon value. Look at the book's Figure 6.12; roughly, what are the Phon values (judged by which curves the points are close to) reported for these two frequencies at the measured Intensity Levels?

    100 Hz Loudness: ___________Phon   4000 Hz Loudness: _____________Phon

19. **Question:** Since we'd expect equal loudness to mean equal Phon values, what's the percent difference between these?

Masking

You probably turn up your car radio when out on the highway because the road noise obscures or partly masks the music. While listening to one loud, mid-range tone, you'll simultaneously listen to a quiet one whose frequency you'll slowly dial up from low to high and you'll listen for the range over which it gets masked by the louder tone.

Set-up

20. Dial one function generator to 400 Hz and 0.6 Volts, set the other to 200 Hz and 0.02V, and dial the amplifier's Volume to the fourth dot.

21. Plug one into the Left input and the other into the Right input for the "CD."

22. Set the amplifier to Mono so both tunes will be heard in both ears.

Experiment

You'll determine the range of frequencies for which the quieter tone is masked / inaudible.

23. With the test subject(s) listening over the headphones, slowly dial up the frequency of the quieter signal until they report that they can no longer hear it.

    frequency when first masked _______________Hz

24. Continue dialing up the frequency of the quieter signal until the test subject(s) report hearing it again.

    frequency when unmasked again ______________Hz

Question: Which way is the masking range skewed, that is, does it extend further above 400 Hz or further below?