Summary from previous lecture

1) Sampling Rate and Nyquist Theorem

2) Resolution

3) Speakers

Playing: "Sombre Reptiles" from Brian Eno,
"Another Green World"
PH 331 Guidelines for Term Paper

A) The term paper is to be a factual research paper. Pick a topic that you think is interesting. Do some research on the topic. Use the reference list, the OSU library, the Internet, etc. to gather information. (See below for more information about the proper use of the Internet.) If you need help writing your paper, including help with grammar, sentence structure, paragraph structure, etc., then go to the following two websites.

http://wic.orst.edu
http://oregonstate.edu/dept/writing-center

B) **Plagiarism is a serious problem that you must avoid.** Please go to the following website and learn what plagiarism is and how to avoid it.

http://www.orst.edu/admin/stucon/plag.htm

C) **If any part of your paper is plagiarized, then you will receive a zero for the paper and be referred to the administration for disciplinary action.** To avoid plagiarism, your paper must include footnotes or citations. The footnotes or citations must come from the sources listed in your bibliography (also called works cited). If your paper does not include any footnotes or citations, then you will have committed plagiarism.

D) The term paper **must** have a title page. The title page must be a separate page that comes at the beginning of the paper. **Two items are required:** 1) the **title** of your paper and 2) your **name**. You can include other information if you desire.

E) The term paper **must** have a bibliography (also called works cited). The bibliography must be on a separate page appended to the end of the paper. There must be a minimum of two entries in the bibliography. **You may not include the textbook in your bibliography, nor may you include the lecture notes from this class.** For each entry, you must have these four items: 1) the **author** (or **editor**), 2) the **title** , 3) the **publisher** and 4) the **year of publication**. Each entry must have been published. The publisher cannot be the same as the author (or editor). These publications can be in traditional paper form or they can be electronic.

F) **Do not include URLs anywhere in your paper!** (URLs are computer programs that find electronic documents on the Internet such as www.physics.orst.edu.) Including URLs anywhere in your paper will result in a lower score, so it will be to your own benefit to not include them. Instead of URLs, provide the four pieces of information listed above for each source.

G) The paper must be typed, double-spaced and three to five pages in length. This does **not** include captions, figures, diagrams or pictures. It **does not** include the title page nor does it include the bibliography. It **does** include the text that you write. **The text must be a minimum of three complete pages.** The paper cannot be longer than five pages.

H) **I will not accept any late papers, except for the following reasons:** 1) transportation problems, 2) illness and/or 3) an emergency such as a death in your family. If you want to turn your paper in late, then you must contact me before the paper is due, or as soon after it is due as possible. **You must get my approval. Approval is not automatic.**

I) If you have any questions or concerns, then please contact me either by phone or email, or stop by my office during office hours.
Human Hearing

1) Tone, Note or Pitch
   A) Frequency Range
   B) Frequency Just Noticeable Difference
   C) Limit of Frequency Discrimination

2) Loudness
   A) Intensity
   B) Intensity Level
   C) Thresholds
      1) Threshold of Hearing
      2) Threshold of Hearing Damage
      3) Threshold of Pain

3) Equal Loudness Curves = Fletcher-Munson Curves
   A) Intensity and Intensity Level vs. Frequency
   B) Loudness Level
Frequency Range

1) Human Ear

\[ f(\text{min}) = 20 \text{ Hz and } f(\text{max}) = 20,000 \text{ Hz} \]

\[ \text{ratio} = 1000 \approx 1024 = 2^{10} = 10 \text{ octaves} \]

2) Human Eye

\[ \lambda(\text{min}) = 400 \text{ nm and } \lambda(\text{max}) = 700 \text{ nm} \]

\[ \text{ratio} = 1.75 \approx 2 = 2^1 = 1 \text{ octave} \]
Limit of Frequency Discrimination

1) It is the smallest frequency difference that can be noticed by the average human when two frequencies are played at the same time.

\[ \text{LFD} = \Delta f \text{ (min)} = f_2 - f_1 \]

2) It depends on the average frequency.

\[ f \text{ (ave)} = \left( f_2 + f_1 \right) / 2 \]

3) \( \text{LFD} / f \text{ (ave)} = 7 \% \text{ to } 15\% \)
Frequency Just Noticeable Difference (JND)

1) It is the smallest frequency change that can be noticed by the average human when the sounds are played sequentially.

\[
\text{Frequency JND} = \Delta f \text{ (min)} = f_2 - f_1
\]

2) It depends on the average frequency.

\[
f \text{ (ave)} = \frac{(f_2 + f_1)}{2}
\]

3) Frequency JND / f (ave) = 0.5 %

Example: What is the frequency JND at 1000 Hz?
Intensity

1) Intensity is the power contained within the wave divided by the surface area over which the wave moves as it expands outward.

\[ \text{Intensity} = \frac{\text{Power}}{\text{Area}} \]

2) The intensity is proportional to the amplitude squared. For example, if the amplitude doubles, then the intensity quadruples.

\[ \text{Intensity} \propto (\text{Amplitude})^2 \]
Intensity vs. Intensity Level

1) Intensity = I \hspace{1cm} (Units = W/ m^2)

2) Intensity Level = \beta \hspace{1cm} (Units = dB)

\[ dB = \text{deci Bel} \]

(deci is the prefix meaning one tenth)
(Bel is named after Alexander Graham Bell)

How are they related?

\[ \beta = 10 \log_{10} \left( \frac{I}{I_0} \right) \]

where \( I_0 = 1.00 \times 10^{-12} \ W/ m^2 \)

is the threshold of human hearing
Change in Intensity Level $= \Delta \beta$

Let's derive a formula for the change in intensity level when the intensity changes.

It will be a useful formula in some cases.

Recall that

$$\beta = 10 \log_{10} \left( \frac{I}{I_0} \right)$$

where $I_0 = 1.00 \times 10^{-12}$ W/m$^2$

is the threshold of human hearing

Example: If the intensity doubles, then by how much does the intensity level increase?