Full name: ________________________________ Student ID: ______________

21M.380 · Music and Technology
Recording Techniques & Audio Production

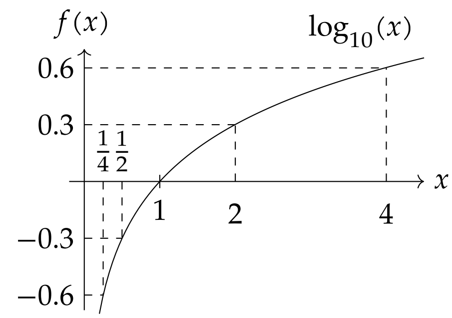
First quiz (QZ1)
Physics & perception of sound, microphones

Monday, September 26, 2016
25 minutes, 5% of total grade

1 Physics of sound

1.1 Inverse square and inverse distance law (15%)

Clearly show how you derive the answers the following two questions. In both cases, assume free-field conditions (no reflective surfaces) and a sound source that emits sound spherically in all directions.



1. By how many decibels (dB_{SPL}) does the sound pressure level p drop when you move from a distance of 8 feet from a sound source to a distance of 32 feet?

   With $L_p = 20 \cdot \log_{10}\left(\frac{p}{p_0}\right)$ and $p \propto \frac{1}{r}$ (inverse distance law):

   $$L_p = 20 \cdot \log_{10}\left(\frac{\frac{1}{32}}{\frac{1}{8}}\right) = 20 \cdot \log_{10}\left(\frac{1}{4}\right) = 20 \cdot (-0.6) = -12\,\mathrm{dB_{SPL}}$$ □

2. By how many decibels (dB_{SIL}) does the sound intensity level I rise when you move from a distance of 8 feet from a sound source to a distance of 4 feet?

   With $L_I = 10 \cdot \log_{10}\left(\frac{I}{I_0}\right)$ and $I \propto \frac{1}{r^2}$ (inverse square law):

   $$L_I = 10 \cdot \log_{10}\left(\frac{\frac{1}{4^2}}{\frac{1}{8^2}}\right) = 10 \cdot \log_{10}(4) = 10 \cdot 0.6 = +6\,\mathrm{dB_{SIL}}$$ □

1.2 Speed of sound and harmonic sounds (15%)

1. For which sound source direction(s) with respect to the listener does the *interaural time difference* reach a maximum? Describe any such direction(s) unambiguously, either in writing, or through a diagram, or through a combination of both.

   Assuming a coordinate system where the listener is facing the zero-degree direction, the interaural time difference reaches its maximum for an azimuth of $\pm 90°$ in the horizontal plane (zero elevation).

2. Quantify the maximum interaural time difference in a suitable physical unit, assuming an entirely transparent head with a diameter of 17 cm and a convenient constant for the speed of sound in air. Show how you derive your result.

   $\Delta t_{max} = \frac{d}{c} = \frac{0.17}{340} = \frac{1.7 \cdot 10^{-1}}{3.4 \cdot 10^{2}} = 0.5 \cdot 10^{-3} = 0.5\,\text{ms} \quad \square$

   where

   - Δt_{max} ... maximum interaural time difference
   - d ... distance between ears (17 cm)
   - c ... speed of sound in air ($340\,\text{m}\,\text{s}^{-1}$)

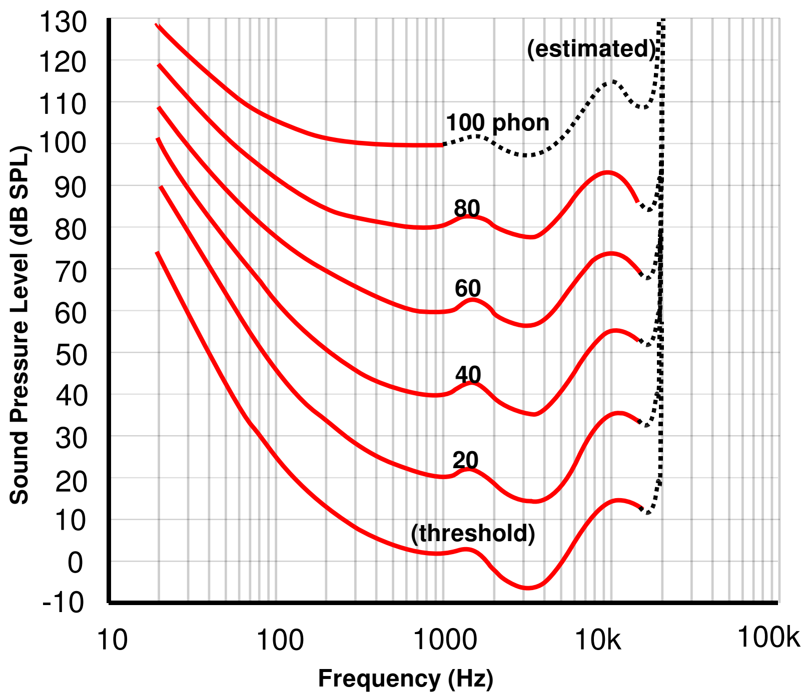
3. At which frequency will the third harmonic of a sound appear, the wavelength of whose fundamental fits exactly between the two ears of the head assumed above? Show how you derive your result.

   With $c = \lambda \cdot f$ and $f_N = N \cdot f_1$ (harmonic sound):

   $f_3 = 3 \cdot f_1 = 3 \cdot \frac{c}{\lambda_1} = 3 \cdot \frac{340}{0.17} = 3 \cdot \frac{3.4 \cdot 10^{2}}{1.7 \cdot 10^{-1}} = 3 \cdot 2 \cdot 10^{3} = 6\,\text{kHz}$

2 Perception of sound

2.1 Loudness perception (10%)



1. What is the name of the above diagram?

   Equal loudness contours

2. At how many dB_{SPL} would a 50 Hz tone need to be played in order to be perceived as equally loud as a 1 kHz tone played at 60 dB_{SPL}?

   90 dB_{SPL} (both points on 60 phon curve)

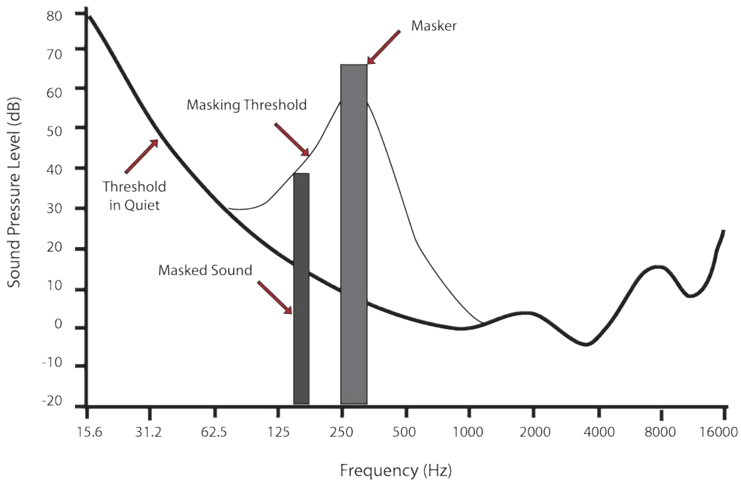
3. Mark the points that were relevant to answer the last question in the above diagram.

4. What's the difference in dB_{SPL} between two tones that are just audible, one at 8 kHz, the other at 40 Hz?

   $50 - 10 = 40\,dB_{SPL}$

5. Mark the points that were relevant to answer the last question in the above diagram.

2.2 Psychoacoustic phenomena (15%)



(🄍 Public domain image. Source: https://en.wikipedia.org/wiki/File:Audio_Mask_Graph.png)

1. Which psychoacoustic phenomenon does the figure above illustrate?

   ❍ Missing fundamental
   ❍ Cone of confusion
   ❍ Masking in the time domain
   ✗ Masking in the frequency domain
   ❍ Difference tone

2. In a few words, describe the effect this phenomenon has on the perception of concurrent sounds that are close to each other in frequency.

   'Loud' sounds tend to mask softer sounds with similar frequencies. The presence of a masking sound temporarily raises the threshold of hearing in its spectral proximity. Another sound in that frequency area, which might otherwise be perfectly audible as it lies above the threshold of hearing in quiet, might now become inaudible as it lies below the temporarily raised threshold.

3. Label the x axis as well as the four arrows in the above figure to support your description. Use the professional terms that we have learned in class.

3 Microphones

3.1 Polar patterns (15%)

1. Which polar pattern does the microphone capsule on the right have?
   ❍ Omni ❍ Cardioid ❍✗ Figure-eight

2. What is the purpose of the little red dot on this side of the capsule?

   Indicates front direction (positive phase of figure-of-eight)

3. Is the microphone capsule on the right affected by the proximity effect, i.e., does it emphasize low frequencies when positioned close to the sound source? Explain how you can tell.

   Yes, because it is *directional* microphones that exhibit a proximity effect, and a figure-eight is (not omni)directional.

4. Describe a specific recording situation for which a capsule with this polar pattern would be particularly useful.

   One-on-one interviews, where two people are facing of each other, and their voices both need to be recorded.

3.2 Electroacoustic transducer principles (8%)

1. What is the name of the physical phenomenon that allows a ribbon microphone to function? Electromagnetic induction

2. Describe how this phenomenon works in *general* terms (not limited to microphones). What happens under which physical circumstances?

   A current will be induced in a conductor that moves relative to a magnetic field.

3. How is this general principle applied to microphones? What happens when one records sound with a ribbon mic?

   Sound pressure waves move the metal ribbon (conductor), which is freely suspended in a magnetic field. This induces a current in the ribbon, whose amplitude as a function of time resembles that of the recorded sound pressure.

4. Does a ribbon microphone generally require phantom power? Explain why or why not.

   No. The primary use of phantom power is to charge the capacitor in a condenser microphone, but that capacitor is absent here.

3.3 Check all statements that are true (7%)

- [x] A pure pressure transducer is omnidirectional.
- [x] Condenser microphones tend to achieve a better sound quality than dynamic microphones.
- [ ] Large-diaphragm condensers tend to have a more frequency-neutral polar pattern than small-diaphragm condensers.
- [x] Tube condensers do not require phantom power from the mixer when they come with a separate power supply.
- [ ] A pure pressure transducer must by definition always be a condenser microphone.
- [ ] Electret condensers achieve better sound quality than any other type of microphone.
- [x] Dynamic microphones can handle larger sound pressure levels than condenser microphones.

3.4 Identify these microphones (15%)



Manufacturer:	Shure	Audio-Technica	Sennheiser
Model number:	SM58	AT4041	MD421-II
Transducer type:	dynamic	condenser	dynamic
Polar pattern:	cardioid	cardioid	cardioid
Phantom-powered?	no	yes	no