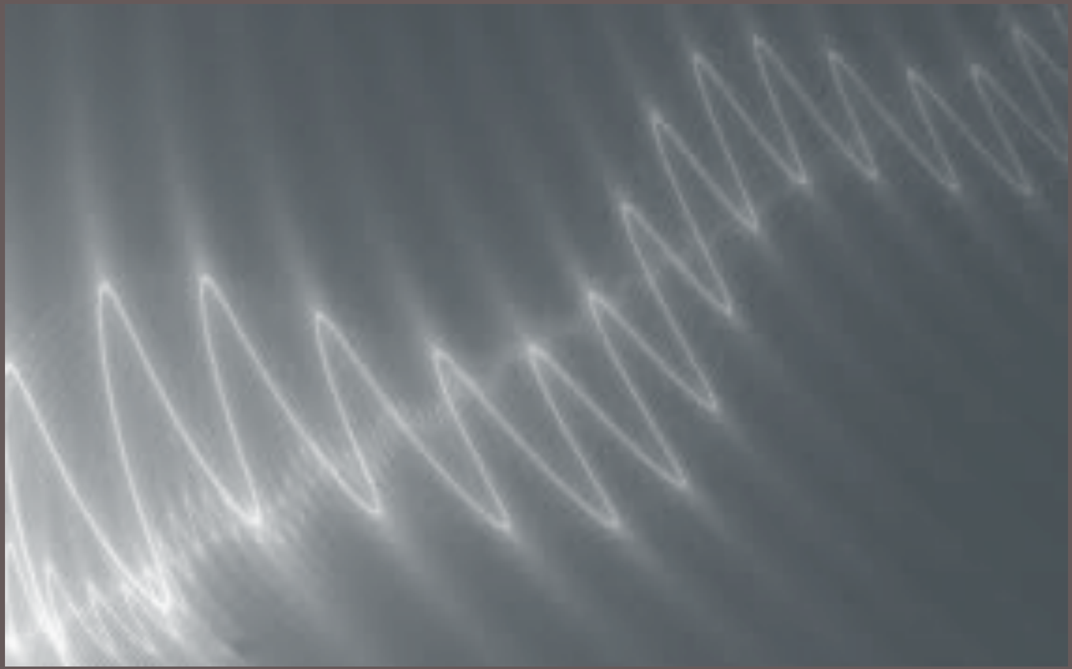
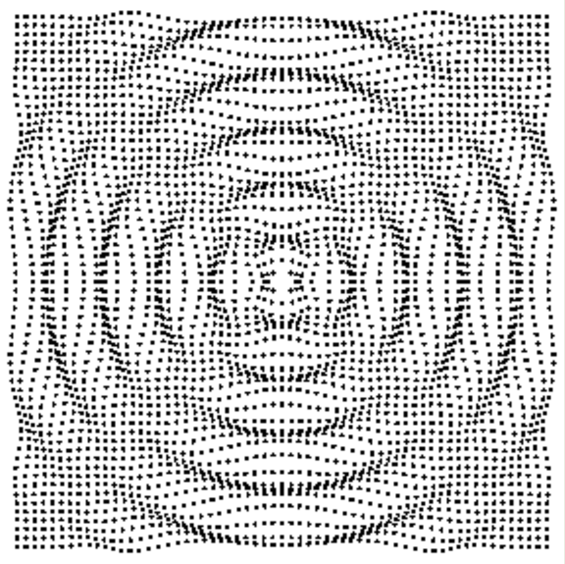
SOUND AND HEARING



Audio Engineering I

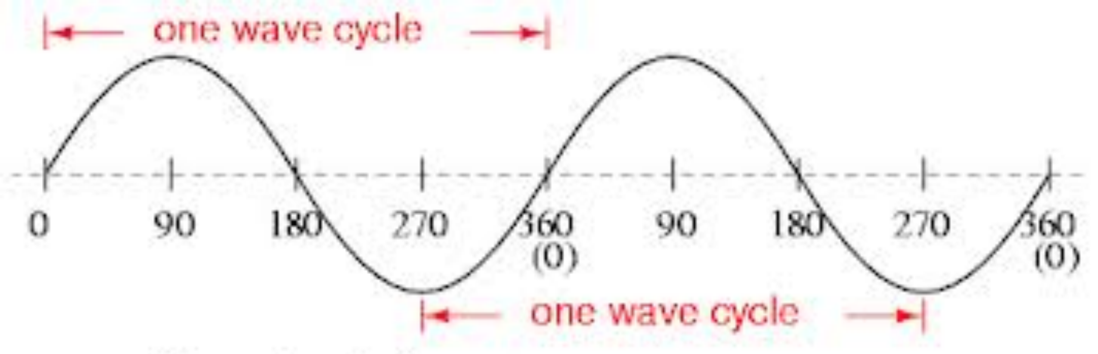
WHAT IS SOUND?



- Atmospheric Pressure
  - Compression and Rarefaction of air molecules
- Sound Waves
  - Air-pressure vibrations that have a repeating pattern are heard as having a pitch, or a musical tone.
  - Air-pressure vibrations that don't have a repeating pattern (random) are heard as noise.

FREQUENCY

- The RATE at which a sound wave repeats a cycle.

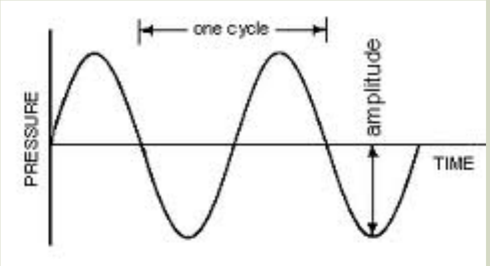


- Frequency is measured in Hertz (Hz)
  - 440 Hz = A4
  - Human hearing range: 20 – 20,000 Hz (20 Hz – 20 kHz)

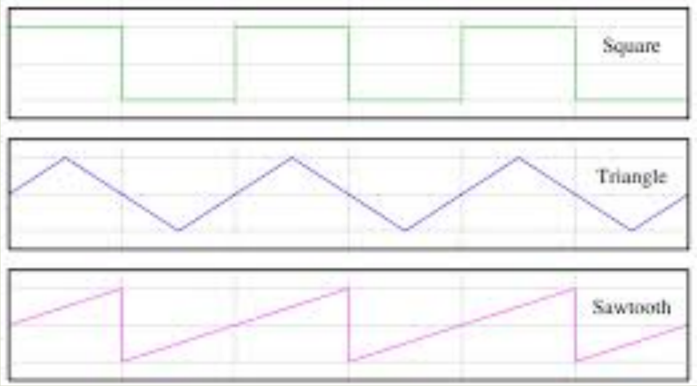
WAVEFORM

- A visual representation of a sound wave.

- Sine Wave:



- Other simple Waveforms:



TERMS:

- Amplitude
- Frequency
- Velocity
- Wavelength
- Phase
- Harmonic Content
- Envelope

WAVELENGTH

- **Velocity** of sound:

  1130 ft/sec @ 68°F (±1.1 f/s for each ° higher/lower)

- Wavelength:
  - The physical distance of one cycle at a particular frequency

$$\lambda = V/f$$

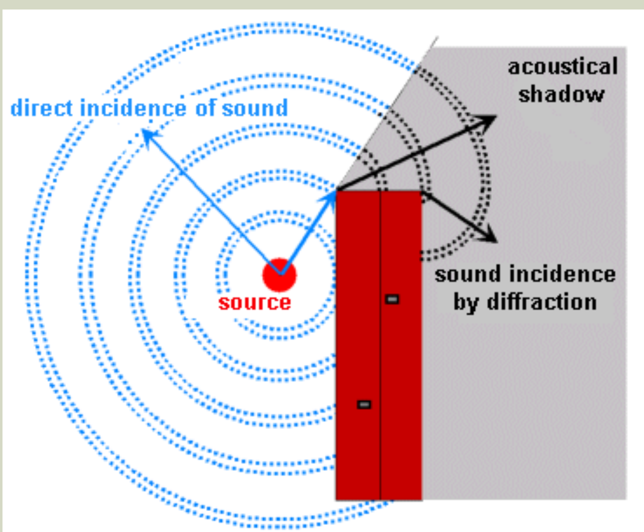
Wavelength of an 800 Hz wave: 1130 ÷ 800 = 1.4125 ft

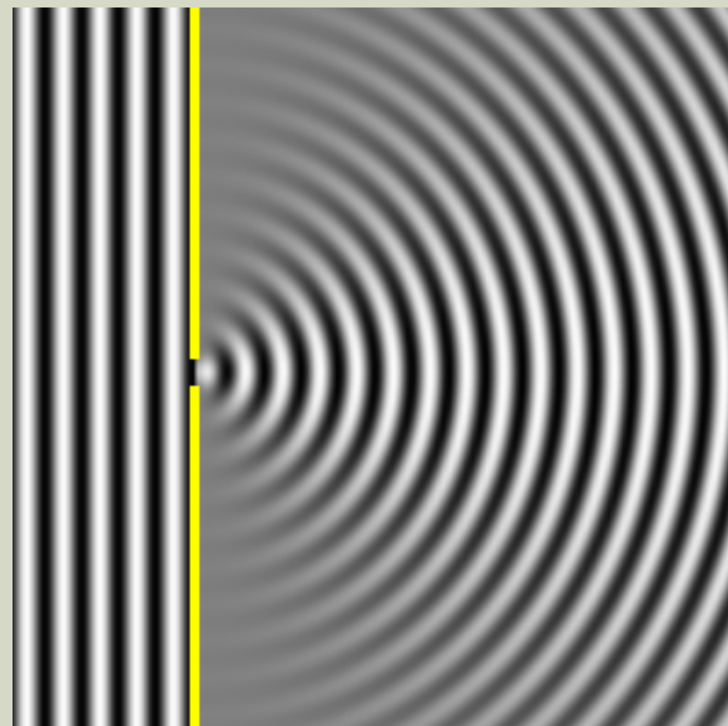
What is the frequency of a 35 ft wave?

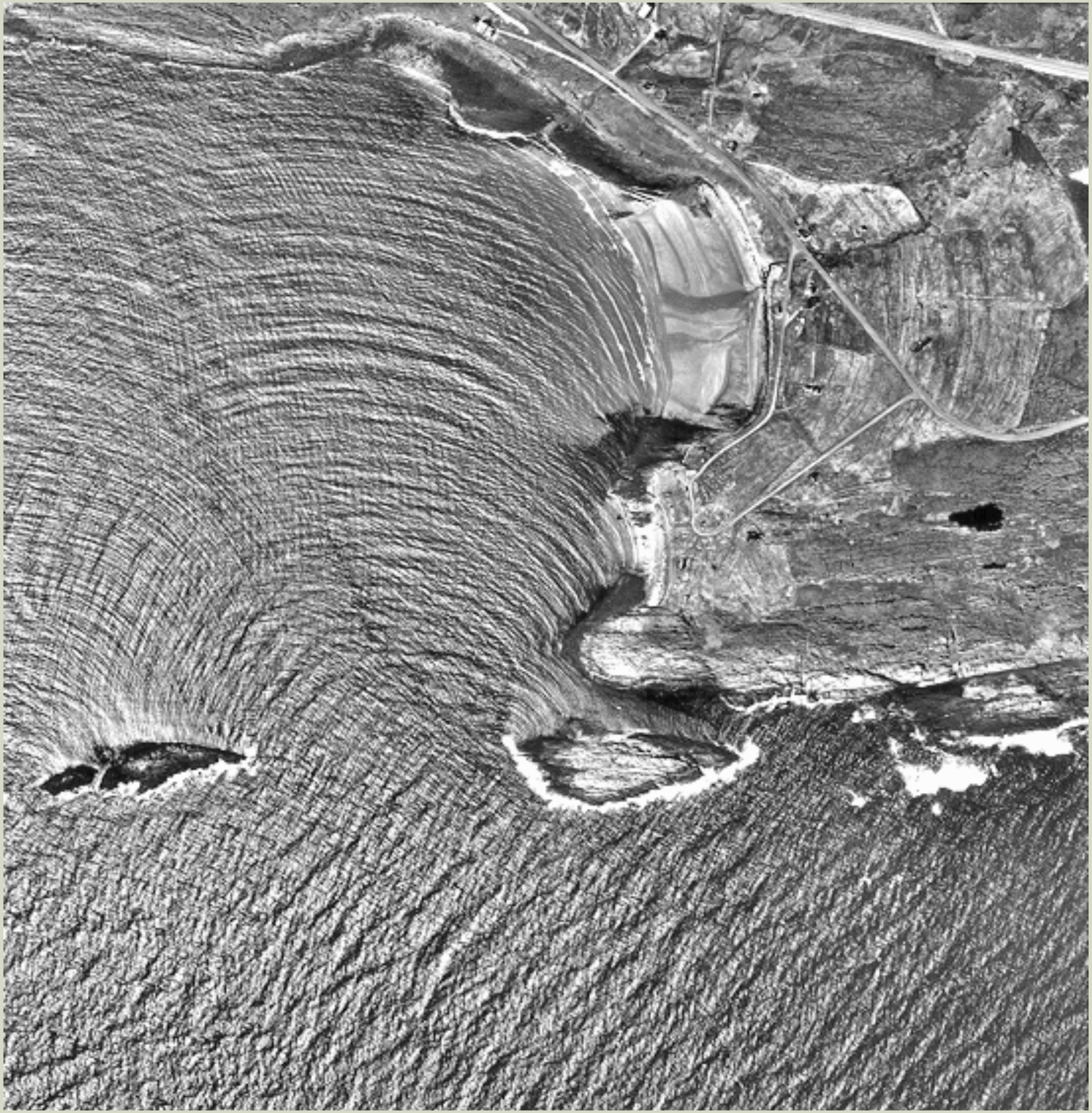
$$f = V/\lambda$$

REFLECTION AND DIFFRACTION

- Reflection
  - Sound waves reflect off a smooth, hard surface at the opposite angle.
  - Sound reflects off corners back towards the origin.
- Diffraction
  - Sound can bend around an obstacle

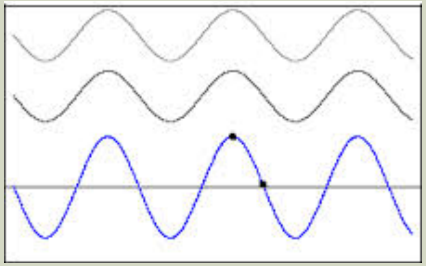






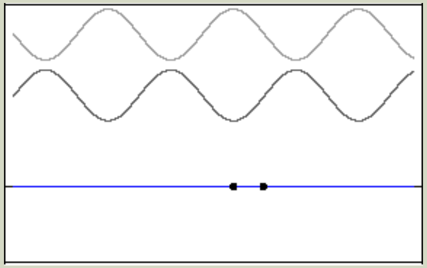
PHASE

- Imagine two sine waves of the same frequency.
- When played simultaneously, their waves are combined.
- IN PHASE



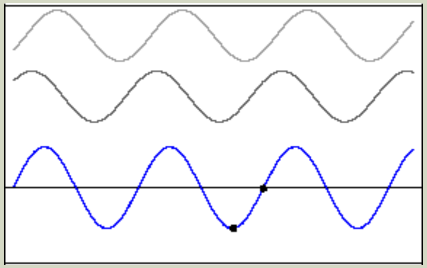
Amplitude is doubled

- 180° OFFSET



Amplitude is canceled out

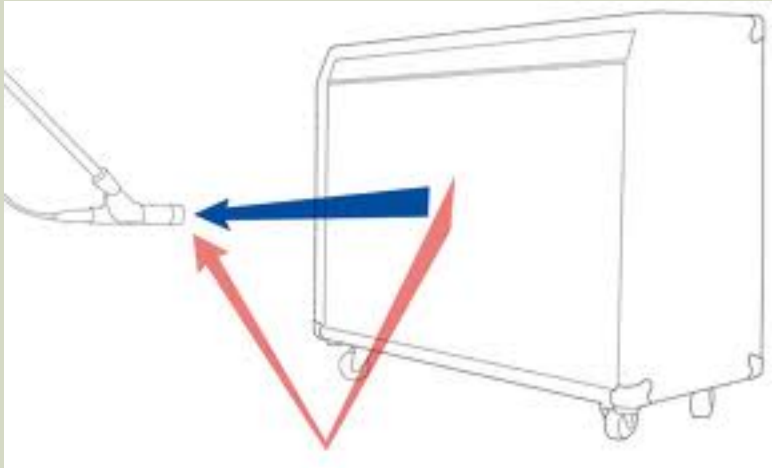
- 90° OFFSET



Amplitude is same as original

PHASE SHIFT

- A delay between two or more waveforms that causes differences in phase between them
- Example: a signal picked up by 2 microphones that are placed at different distances.
  - Some frequencies will be in phase (boosted) and some will be out of phase (cancelled).
- Example: a single microphone picking up a direct signal and a reflected signal.

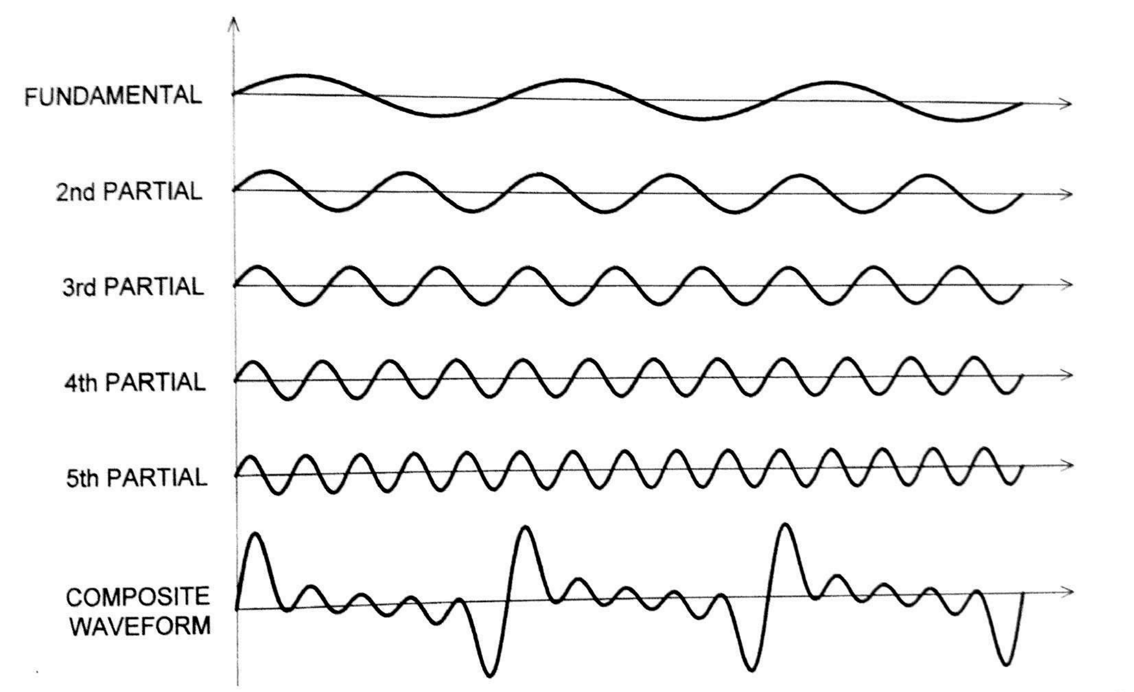


HARMONICS

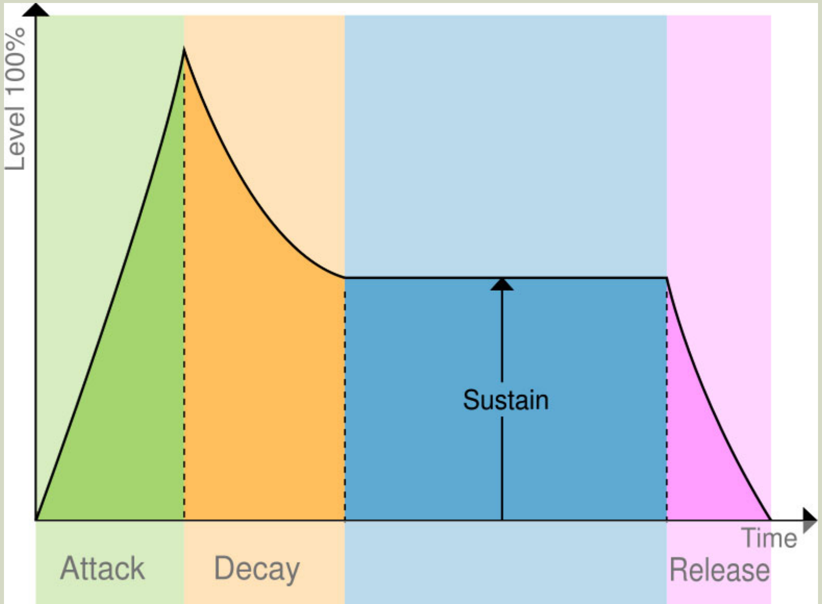
- Sine waves produce a pure tone
- Harmonics (partials, overtones)

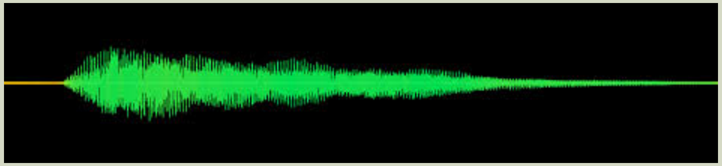
Basically, every sound besides the sine wave contains some amount of "harmonic content." This gives each different sound its own character, or "timbre."

- Ex. Clarinet – strong odd harmonics

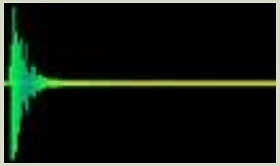


ENVELOPE

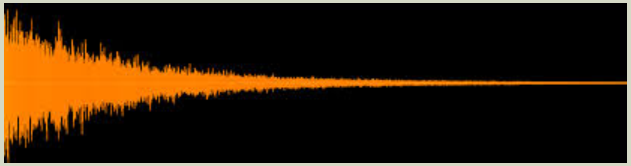




violin



snare drum



cymbal

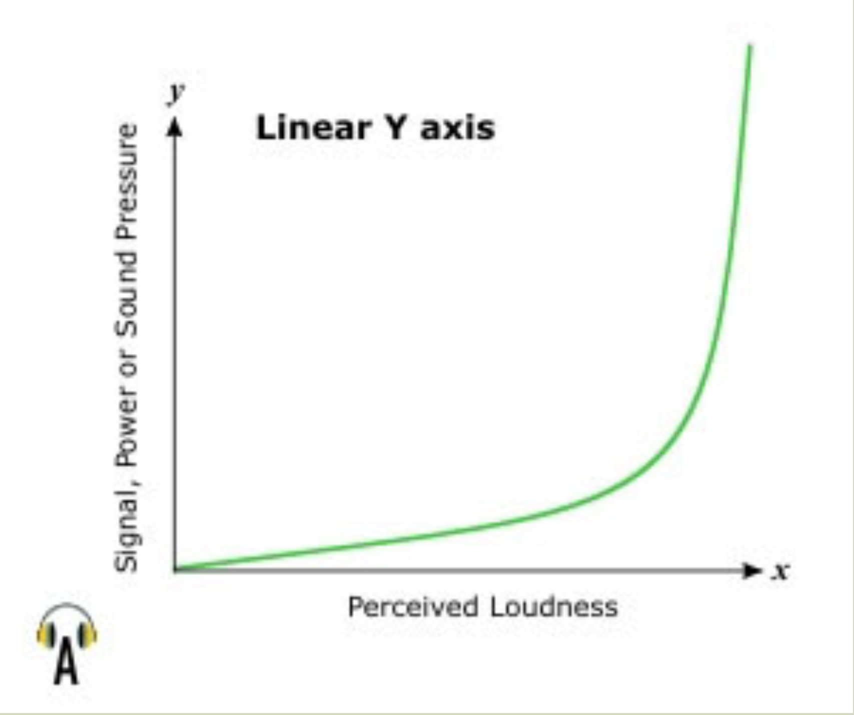
THE DECIBEL

- The decibel is a way to measure a sound's loudness, or…
- **SPL** – Sound Pressure Level

- We perceive loudness on a *logarithmic* scale

Dynamic range of human hearing:

The loudest perceivable sound is 10,000,000,000,000 (yup…10 trillion!) times stronger than the quietest perceivable sound.



LOGARITHMS

- Logarithmic basics
  - log2 = 0.3
  - log10 = 1
  - log100 = 2
  - log10,000 = 4 (the log of a power of 10 is the number of 0's)
  - log1 = 0
  - log0.1 = -1
  - log0.01 = -2 (log of a number <1 is a negative number)

DIFFERENT WAYS OF MEASURING DECIBELS

- A measurement of *difference in intensity between two levels*
  - So to measure anything in decibels, we have to first have a reference point to compare with.
    - 1 SPL$_{(ref)}$ is the threshold of hearing – the softest sound humans can perceive.

- dB SPL – Measure of sound pressure level in the air
  - *When the **distance** between a sound and a pickup is doubled, the sound pressure drops by 6 dB.*

- dBm – Measure of current through an electrical system
  - This measure is what is most often used with audio devices.
- Core idea:
  - Turning something +3 dB will *double* the signal's level. (-3 dB *halves* it)
  - +10 dB multiplies the signal's level by 10.

You don't need to know the math. Just remember: a good audio engineer knows what different dB levels sound like.

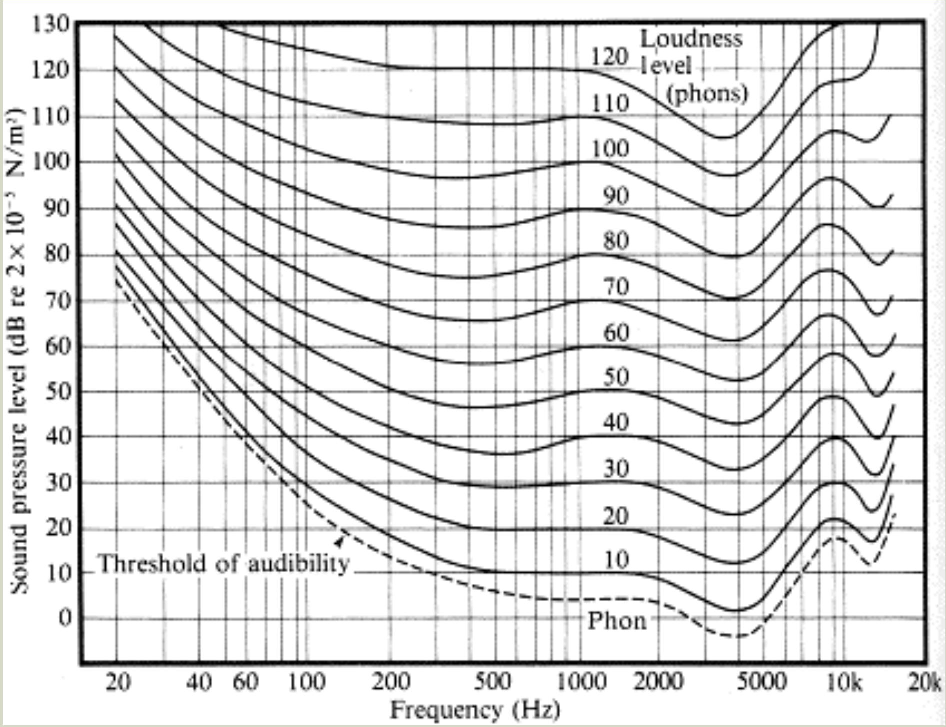
THE EAR

- Threshold of hearing = 0 dB (SPL)
- Threshold of pain ≈ 120 dB

- Protect your hearing!
  - Monitor sound at around 85 dB
    - If you have to raise your voice to be heard over it, limit your exposure.
  - Take quiet breaks when exposed to levels above 85 dB
  - Carry earplugs with you often.

THE EAR’S FREQUENCY RESPONSE

Fletcher-Munson Equal-Loudness Curve

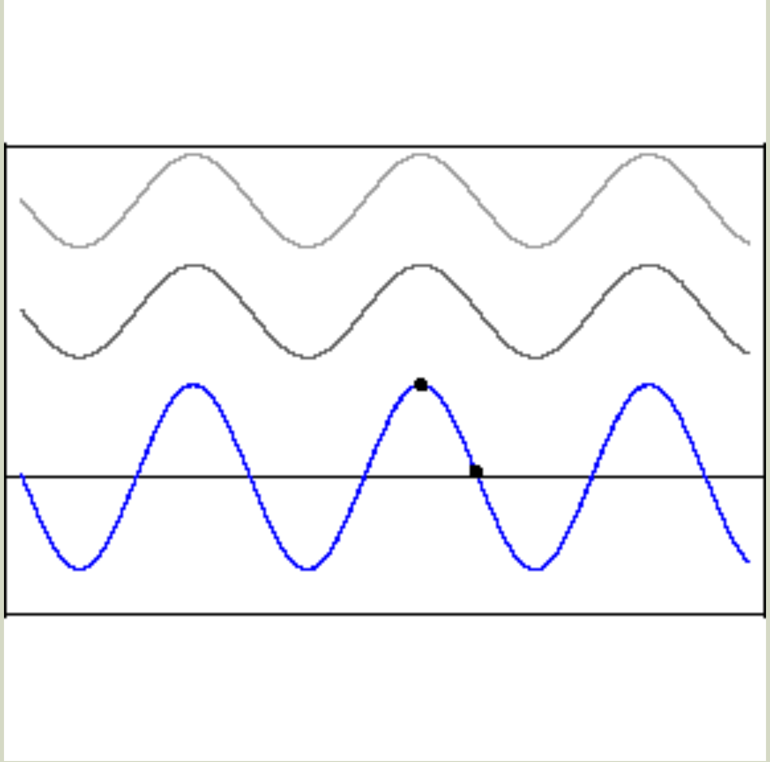


Shows the ear’s sensitivity to different frequencies at different volumes.

- Most sensitive to frequencies between 3000-5000 Hz

BEATS

Same principle as phase cancellation and amplification, but now the two sounds are slightly different in pitch



MASKING

- Louder sounds prevent us from hearing softer sounds
  - Most prominent when the frequencies of the louder and softer sounds are similar
  - This is why stereo placement (panning) and equalization (EQ) are important in the mixing process.

READING

- Huber, Modern Recording, pp. 41-66 (7th ed. page numbers) (this is most of chapter 2 – "The Basics of Sound" through "Masking")