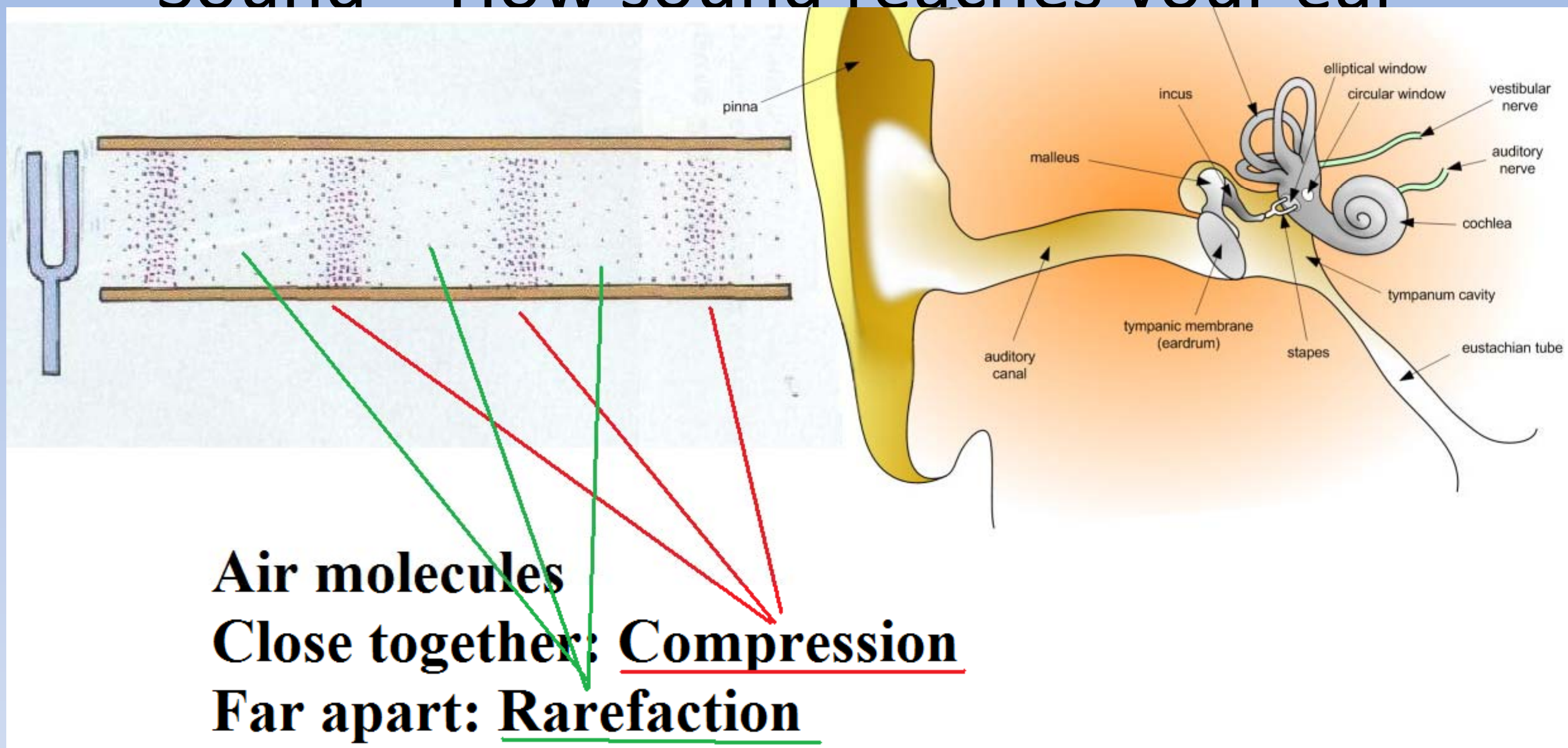
Traditional: 11-10
Themed: 01-10

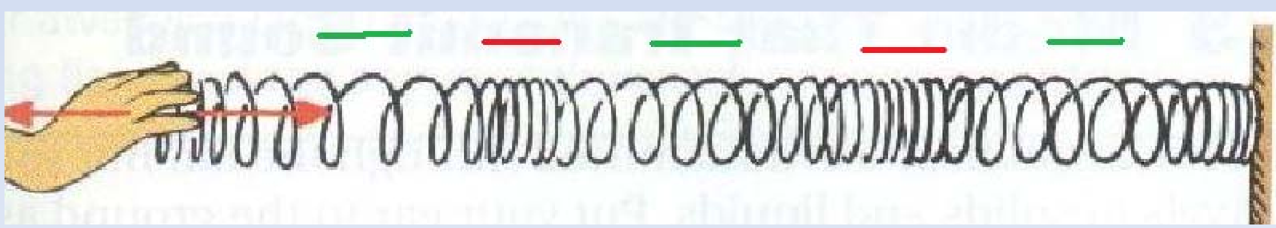
Loudness & beats

Waves Notes

Sound – How sound reaches your ear



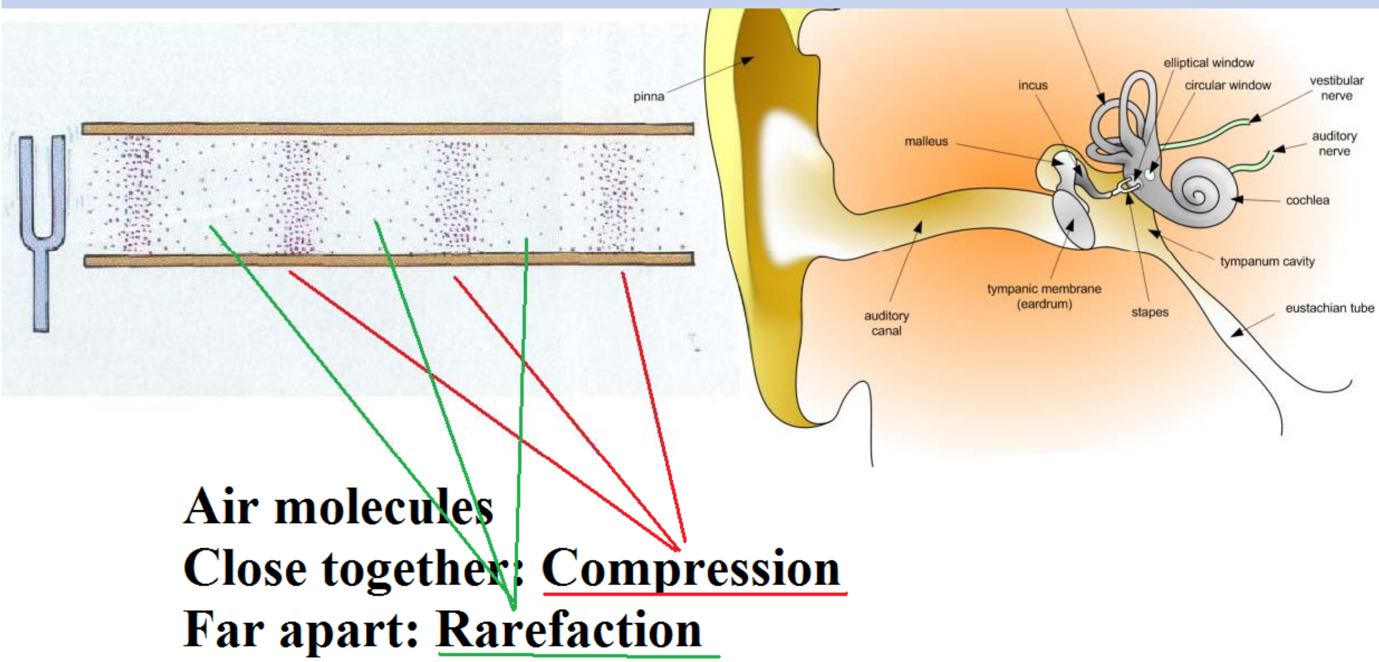
Think about when you “plucked” the slinky. Remember how the compression wave traveled along?…same thing! (Know compression and rarefaction)



Waves Notes

Sound – what it means for a sound to be “loud”

- Loud sound:
    - VERY high pressure compressions coupled with very low pressure rarefactions
    - Pushes in and pulls out on the ear drum with BIG force
- Loud sound = “Big wave amplitude” (same as above!)



Waves Notes: Sound - Loudness

- **<u>Three</u>** ways of measuring how "loud" a sound is

1. Pure Physics method: Intensity
   A. I = Amount of power/Area power is shared over
   B. $I = P/A = P/4\pi r^2$ (think how Sound energy and wave crests travel as concentric spheres)
2. dB scale
   A. A "decibel", a tenth of a bel
   B. A logarithmic scaled based on intensity
   C. 10-fold increase in I, means ADD 10 to dB value
   D. Example: Say sound intensity increases by 1000x, how much does dB go up?
3. Loudness (human perception)
   A. Humans need to tolerate extreme noise, so 10x intensity changes "don't seem" that big
   B. A 10x increase in intensity feels like a 2x change to us
   C. This is a little subjective, but treat is like it applies the same with everyone
   D. Look for key words like: "how much louder does it seem", "how does volume seem to change"
   E. Example, a sound reading goes from 63 dB to 93 dB then what much does intensity change by and how much louder does it seem?

Waves Notes: Sound - Loudness

- $I = P/4\pi r^2$: I decreases to inverse square of r

  We can relate I to dB and "Loudness/volume" **changes** using: +10 dB = 2x volume (human) = 10x I

  (dB, volume, intensity)

- We use $I = P/4\pi r^2$ This relates I to r (sound source distance to listener)
  - Examples: twice as far = 1/4th as intense, 10 times as far = 1/100 as intense, twice as close = 4 times the intensity

Sound – Loudness, solving problems

- **changes** in sound amplitude scales follow:

+10 dB = 2x volume (human) = 10x I

dB, volume, intensity

These are steps to do, but not necessarily in this order

1. Relate distance CHANGE (r) to intensity CHANGE → I changes up as r^2 changes down
2. Relate scale type CHANGES using:
   - +10 dB = 2x Vol. = 10x I
3. Add or subtract any dB change to original dB value
4. Multiply or divide any distance change to original distance (r is distance from sound source)

Did I underline CHANGE enough for you to notice?

Waves Notes
Sound/Doppler – Loudness examples

$I \propto 1/r^2$

+10 dB = 2x volume (human) = 10x I

(dB, volume, intensity)

- (1) If wave energy increases by 10 times (10 times the number of watts), how many more dB would be measured? How much louder would it “seem” to you?
- (2) If wave energy increases by 100 times (100 times the number of watts), how many more dB would be measured? How much louder would it “seem” to you?
- (3) If wave energy increases by 1000 times (1000 times the number of watts), how many more dB would be measured? How much louder would it “seem” to you?
- (4) At 2 m from loud speakers, you measure 97 dB. What (dB) would you measure at 20 m? At 6.2 m?
- (5) 400 m from loudspeakers you measure the loudness a quiet 55 dB, what would you measure 4 m from the speakers?
- (6) Sound protection is required for long term exposure to 85 dB and above. If a piece of manufacturing equipment puts out 115 dB at 0.15 m, how far away must workers be to avoid needing hearing protection?

Waves Notes

Sound/Doppler – Loudness examples

$I \propto 1/r^2$

+10 dB = 2x volume (human) = 10x I

(dB, volume, intensity)

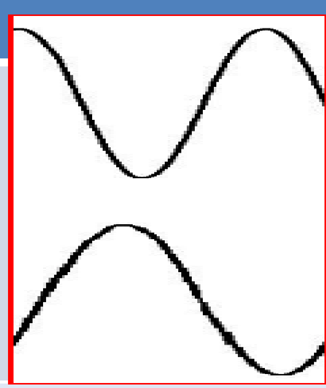
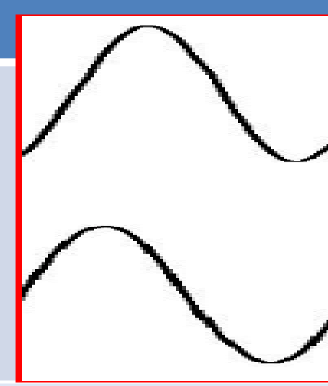
- (1) If wave energy increases by 10 times (10 times the number of watts), how many more dB would be measured? How much louder would it "seem" to you? (10 MORE dB, 2x louder)
- (2) If wave energy increases by 100 times (100 times the number of watts), how many more dB would be measured? How much louder would it "seem" to you? (100 MORE dB, 4x louder)
- (3) If wave energy increases by 1000 times (1000 times the number of watts), how many more dB would be measured? How much louder would it "seem" to you? (1000 MORE dB, 8x louder)
- (4) At 2 m from loud speakers, you measure 97 dB. What (dB) would you measure at 20 m? At 6.2 m? (77 dB (since r^2 changes by 100), 87 dB (since r^2 changes by 10))
- (5) 400 m from loudspeakers you measure sound as a quiet 55 dB, what would you measure 4 m from the speakers? (95 dB (since r^2 changes by 10,000))
- (6) Sound protection is required for long term exposure to 85 dB and above. If a piece of manufacturing equipment puts out 115 dB at 0.15 m, how far away must workers be to avoid needing hearing protection? (4.7 m (since dB changes by 30, I changes by 1,000, r^2 changes by 1,000, r changes by $\sqrt{1000}$ = 31.6, workers must be 31.6x farther than 0.15 m))

Waves/Sound Notes Beats

- Remember interference sound examples:
  - Constructive: loud, shock wave (sonic boom), piling waves **ADD** together for huge amplitude
  - Destructive: noise reducing headphone, dead spots, wave amplitudes **subtract** for smaller amplitude
- Sound waves in phase are LOUD, sound waves out of phase are QUIET

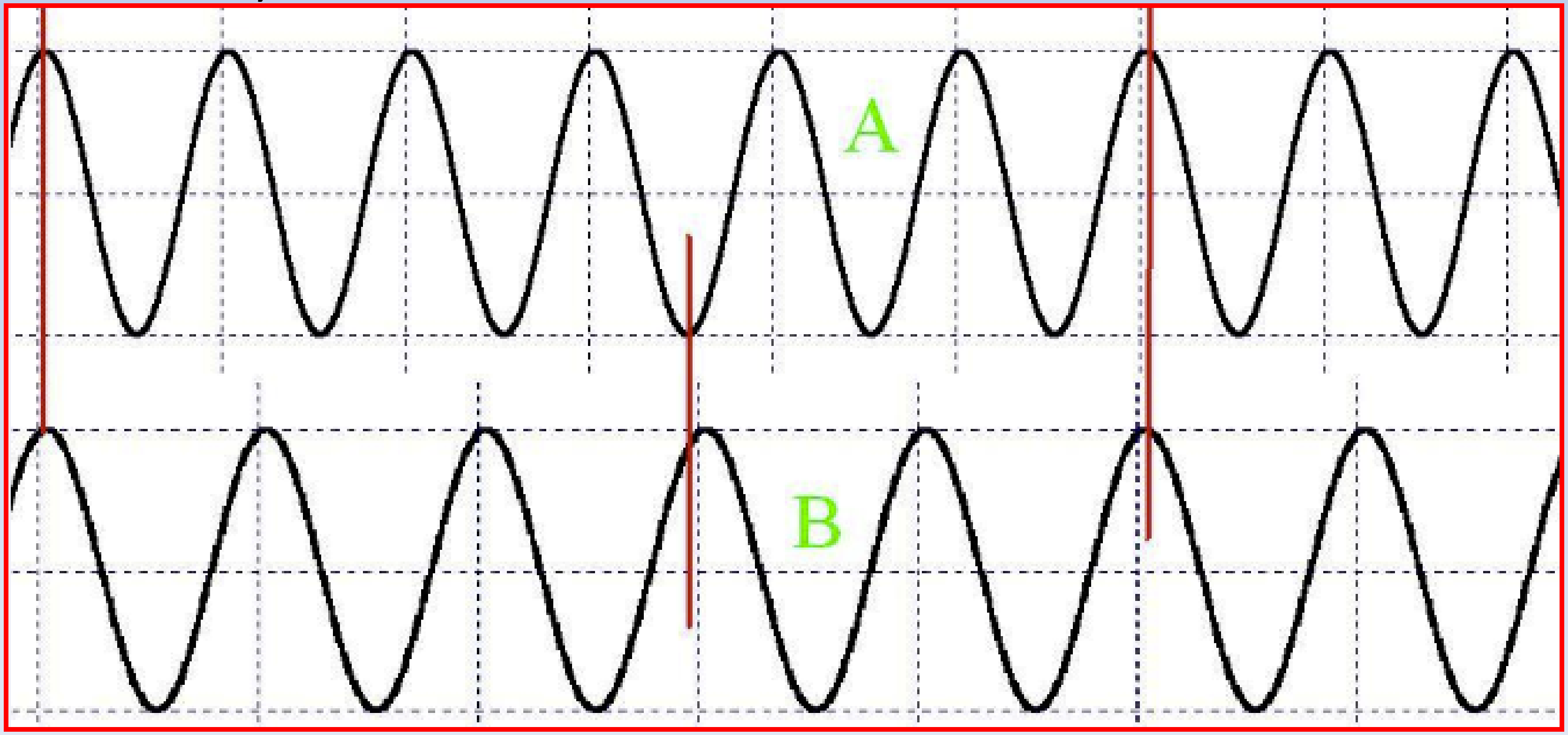
Waves/Sound Notes Beats

- Pretend A and B are Audacity waves for two separate sounds
  - Which is in phase and which is out of phase?
  - Where do you see constructive interference? Destructive?
  - Which will sound quiet? Loud?

Situation A	Situation B
	

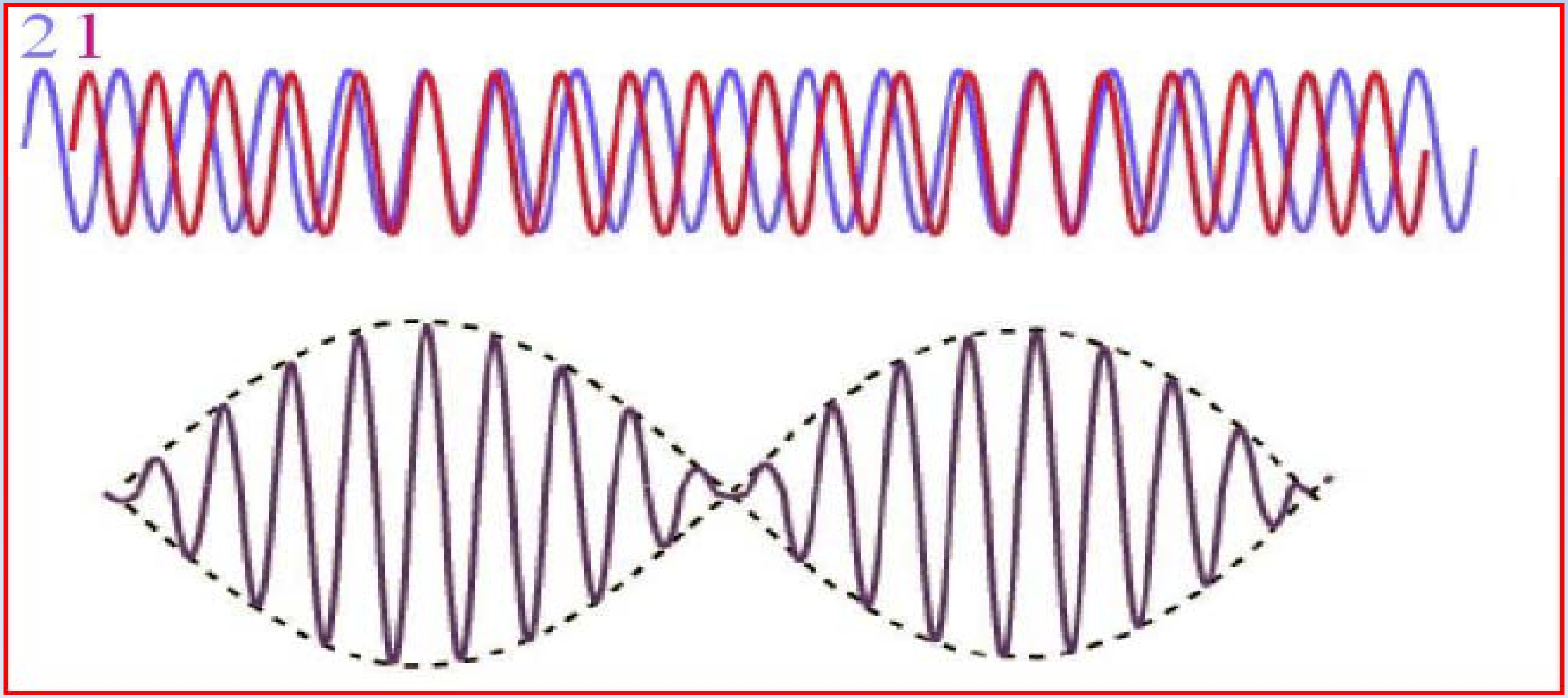
Waves/Sound Notes Beats

- Look at the waves below and recognize:
  - They are from two separate sound sources
  - The go from in-phase to out-of-phase
  - They go from LOUD to QUIET because of……….. (begins with letter I)



Waves/Sound Notes
Beats

- Look at waves 1 and 2 below. Below that the waves amplitudes of the composite wave is shown by the SUPERPOSITION PRINCIPLE
- Can you imagine the QUIET/LOUD/QUIET/LOUD/QUIET pattern you would hear? Do you want to hear it for yourself?
- Listen to the sounds of two sound waves slightly out of phase and come up with the patter of “beats”
- How could this be used to tune a piano?



Waves/Sound Notes
Beats

- Real life application: London Police Whistle
  - http://hyperphysics.phy-astr.gsu.edu/hbase/sound/london.html
- London police get people's attention using a whistle based on beats