# **Sound**

* Sound is a **longitudinal** (compression) wave
  + Start by a vibrating membrane that causes pressure changes in air (at the same frequency)
* Measure *change* in pressure because absolute pressure is very small relative to atmospheric pressure
* **Velocity of sound only depends on the medium!**
  + - where (bulk modulus) depends on the type of gas
      * measures compressibility (high is less compressible)
    - and is the pressure
* Parts of sound wave:
  + : change in pressure, amplitude, intensity
  + : pitch
  + : wavelength
* The **velocity** is the most important part, determining pitch:
  + . So the velocity is fixed by the string’s material
  + the only ways to change pitch (adjust the frequency) is to:
    - change the length
    - change the velocity of the string (tighten/loosen the string)
  + EXAM QUESTION: If you change the length or the tension force on a string, how will the resulting sound change?
  + **Velocity of sound in air is 343 m/s**
  + Or use the approximate formula where t is in degrees C
  + The velocity in Helium is faster than nitrogen/oxygen, so pitch goes up
* The **frequency of sound stays the same** no matter how many mediums a wave goes through (but the wavelength and velocity change; adjust to the same frequency!)
* Since Energy ~ , it takes much more energy to excite the second harmonic of a string, but all instruments have a combination of harmonics.
  + Different combinations of these waves make different timbres
  + **Every** sound wave is made up of a combination of sine/cosine waves ([fourier series](http://falstad.com/mathphysics.html))

## **Types of Instruments**

* String:
  + velocity depends on the string
  + depends on the length (as
  + frequency follows (with )
* Woodwind:
  + Reed/wood make a standing longitudinal wave in the tube
  + If the end is open, . If the end is closed (one octave lower),
    - To calculate possible wavelengths, use:
      * closed: where n=1,2,3...
      * open: where n = 1,3,5...
  + long tube: high , low frequency
  + short tube: short , high frequency
  + length of tube is from mouthpiece to first hole!
    - EXAM QUESTION: which is a higher pitch: all holes closed or all holes open?
  + The *open* end must have *maximum* pressure
  + The *closed* end must have *no* pressure
* Brass
  + Vibrations come from lips
  + change the length of the tube (w/ valves) to change frequency
  + *Bending of the tube doesn’t matter!*
  + In brass and woodwind, the **frequency depends on the velocity of sound in air!** In string instruments, it only depends on the velocity of a wave on a string/wood

## **Sound Intensity**

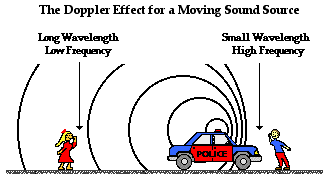
* Loudness = amplitude
* Sound is louder, close to the source:
  + It is damped as it goes further away
  + The initial energy from the wave is distributed over a sphere with increasing radius (so intensity drops as , inverse exponentially)
* Power in a wave:
* Ears:
  + large ears absorb more power
  + Ear can hear from to (pain threshold) [very large range!!]
  + Loudness doesn’t increase linearly: it is logarithmic
    - We use the
    - [conversion = good exam question!!]
      * Where is the lowest intensity we can hear () and
      * is the intensity we are looking at (in )
      * Reverse is:
    - is the lowest we can hear
  + Add means:
    - intensity goes up by a *factor* of 10 (i.e. times 10)
    - and perceived loudness increases by a factor of 2
  + If the noise is at too high a frequency, the eardrum won’t oscillate at all (won’t resonate at all; not enough time to respond)

## **Interference of Sound Waves**

* Interference creates areas that are peaks (twice the amplitude) and nothing (no amplitude).
* Some places in a room can’t hear certain frequencies due to interference
  + There are also lines of constructive and destructive interference
* Speakers only interfere if they are apart!
* If a speaker faces a wall, it creates a standing wave (with one frequency)
* Lengths between speakers ()
  + If , constructive interference
  + If , destructive (no amplitude)
* Consequences:
  + Randomly large ocean waves: from constructive interference at just the right time
  + Radio interference while driving!
  + Must build multiple towers/waves to reduce interference
* Beating
  + 2 waves with slightly different frequencies cause beating
    - The means that the maximum amplitude is twice as large as the individual waves’ maximum amplitudes (if they’re the same)
    - The sine term is the frequency: it is the average of the two waves
    - The cosine term is the beat frequency: this makes a sinusoidal amplitude. This also means that the beat frequency is a lot less than either frequency
  + The beat frequency is

## **Doppler Effect**

If the source of a sound is moving, the new waves emitted are closer together in the direction the object is moving. This makes the frequency *higher* and wavelength *lower*. (Opposite for the back)



Equation for wavelength of person in front of the moving object: (Note: )

Person in the back of a moving object:

We can also substitute and get:

or

Red-shift: moving away (same for light; just replace speed of sound with speed of light)

Travelling at speed of sound:

* Speed measured in Machs
  + The percentage of the speed f sound
  + Behind is a “mach cone” that has a large “boom” with overlapping sound waves