2.2 Sound

Complex Sound Waves
Beats
Doppler Effect.

Complex waves

- In general sound waves are a combination of different frequencies.
- The different frequencies can be determined by mathematical procedure called a Fourier Transform.

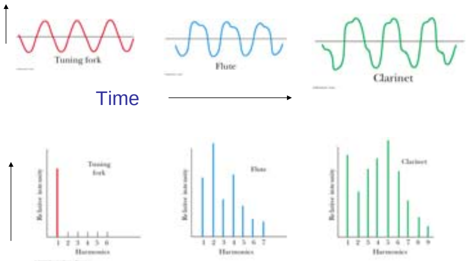
Complex waves consist of different frequency components , i.e. harmonics.

displacement

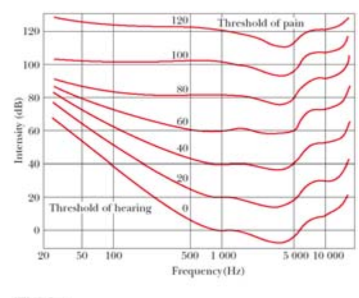
Time

relative amplitude

Frequency

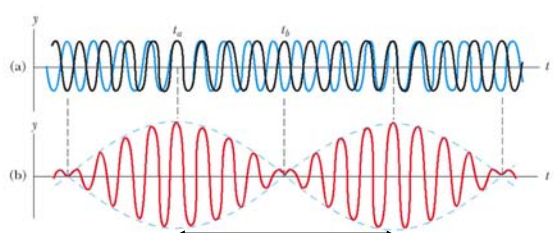


Frequency sensitivity of Hearing



Beats

Superposition of two waves with different frequencies produce oscillation in amplitude.
Due to constructive and destructive interference.



Beat Frequency $f_b = \frac{1}{T_b} = f_2 - f_1$

Tuning musical instruments

The beat frequency for two musical instruments is zero when the two are in tune. (have the same frequency)

Doppler Effect

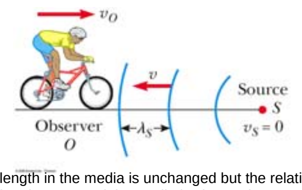
Doppler effect- the shift in frequency of a wave where the source and observer are moving relative to one another.

Two different cases:

Observer moving – source stationary

Source moving- observer stationary.

Observer moving toward a Stationary source



The wavelength in the media is unchanged but the relative velocity between the observer and the media is changed

$$f_o = \frac{v_o + v}{\lambda_s} = \frac{v_o + v}{v} f_s$$

$v_o + v$ is the relative velocity of observer and source.

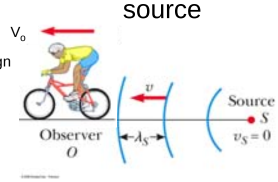
$$\lambda_s = \frac{v}{f_s}$$

When observer is moving toward source the frequency increases.

Observer moving away from a stationary source

V_o

v_o changes sign



The wavelength in the media is unchanged but the relative velocity between the observer and the media is changed

$$f_o = \frac{v - v_o}{\lambda_s}$$

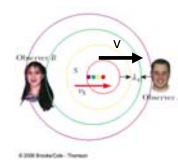
$v - v_o$ is the relative velocity of observer and waves.

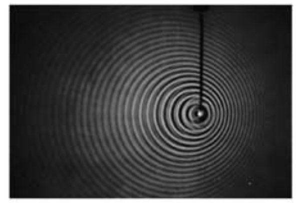
then $$f_o = \frac{v - v_o}{v} f_s$$

$$\lambda_s = \frac{v}{f_s}$$

When observer is moving away from the source the frequency decreases. (use – v_o)

Moving Source-stationary observers





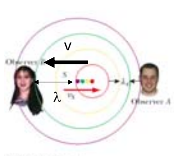
- When the source is moving the wavelength of the wave in the media is changed
- when the source approaches an observer
  - Wavelength decreases and frequency increases

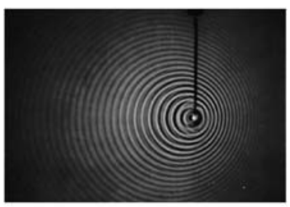
$$f_o = \frac{v}{\lambda_s - v_s T_s} = \frac{v}{vT_s - v_s T_s}$$

$$f_o = \frac{v}{v - v_s} f_s$$

f_o increases when source moves toward observer.

Moving Source-stationary observers





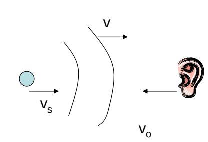
- When the source is moving the wavelength of the wave in the media is changed
- when the source moves away from an observer
  - Wavelength increases and frequency decreases

$$f_o = \frac{v}{\lambda_s + v_s T_s} = \frac{v}{vT_s + v_s T_s}$$

$$f_o = \frac{v}{v + v_s} f_s$$

f_o decreases when source moves away from observer.

General case



$$f_o = f_s \left(\frac{v + v_o}{v - v_s} \right)$$

v_o positive when observer is moving toward source

v_o negative when observer is moving away from source

v_s positive when source is moving toward observer

v_s negative when source is moving away from observer.

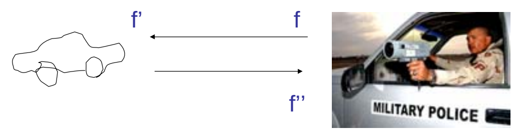
Example

A fire truck is approaching an observer with a speed of 30 m/s. The siren has a frequency of 700 Hz. What frequency does the observer hear as the truck approaches? What frequency is heard after the truck passes. speed of sound 340 m/s

Doppler Radar

Electromagnetic waves are also shifted by the Doppler effect.
Since EM waves travel in a vacuum the equations governing the shift are different.

Doppler radar is used to determine the speed of a car.



The frequency shift of the reflected waves is used to determine the speed of the car.