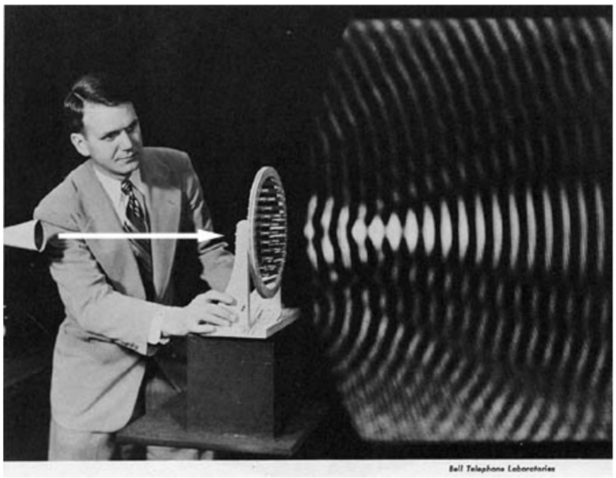
Sound waves



Sound is a wave:

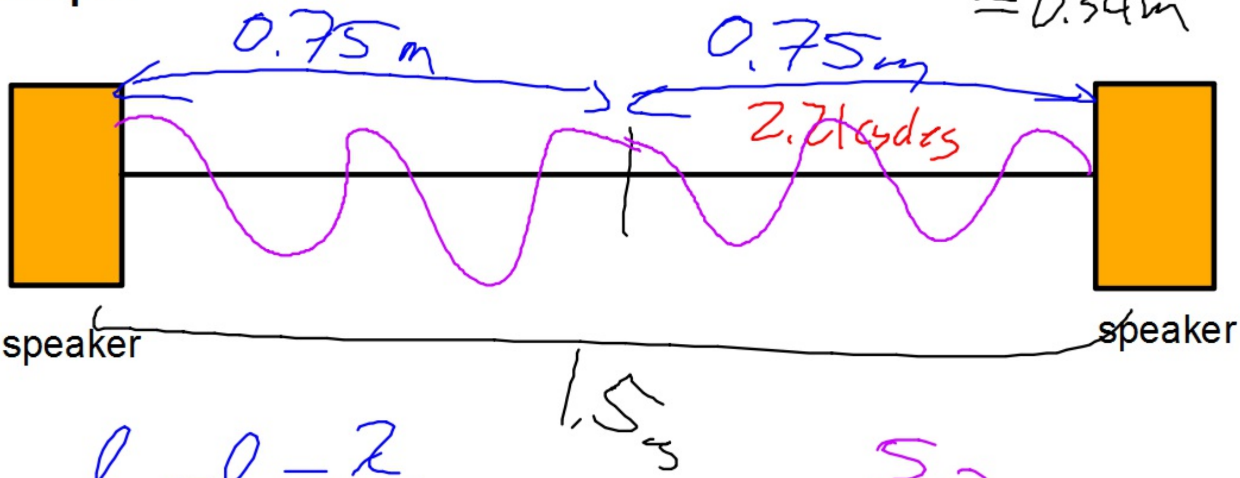
1. There is a disturbance. Disturbance in the air is pressure change

2. Sound travels and propagates (spreads) outward

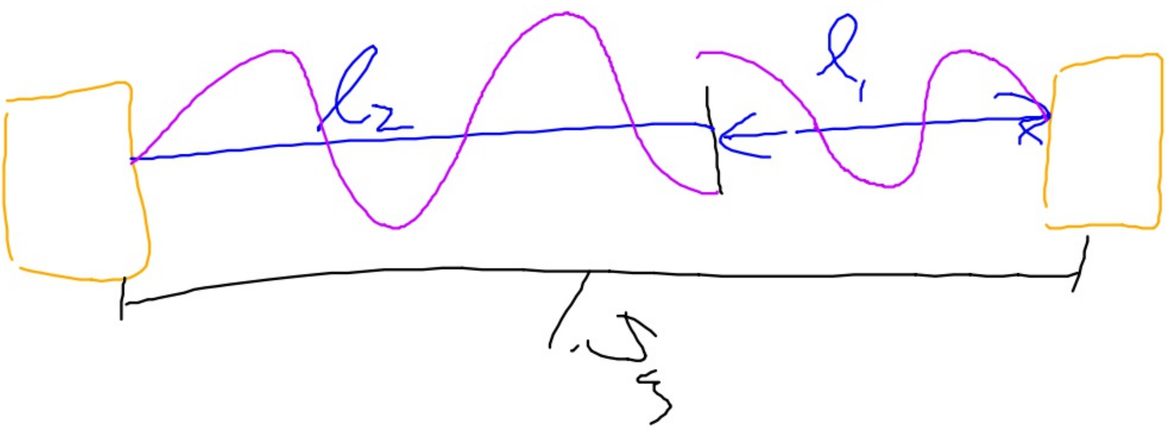
3. Sound experiences constructive and destructive interference

$$\lambda f = v \qquad \lambda = \frac{v}{f} = \frac{340\,\frac{m}{\cancel{s}}}{1000\,\frac{1}{\cancel{s}}} = 0.34\,m$$

Example:



$$l_2 - l_1 = \frac{\lambda}{2} \qquad \frac{5}{4}\lambda$$



Speed of sound:

$v \cong (331 + 0.60\ T)$ m/s $\qquad (331 + 12)\frac{m}{s}$

T is temperature in Celcius $\qquad = 343\frac{m}{s}$

Usually, we take T = 20°C. What is the speed of sound at 20°C?

Sound intensity: decibels

$$\text{Intensity} = \frac{P}{A} = \frac{W}{m^2}$$

$$dB = 10\log\frac{I}{I_0}$$

$I_0 = 1.0 \times 10^{-12} W/m^2$

I_0 is the quietest sound that can be heard, the threshold of human hearing

$$X = 10\log\frac{I_1}{I_0} \qquad X+5 = 10\log\frac{I_2}{I_0}$$

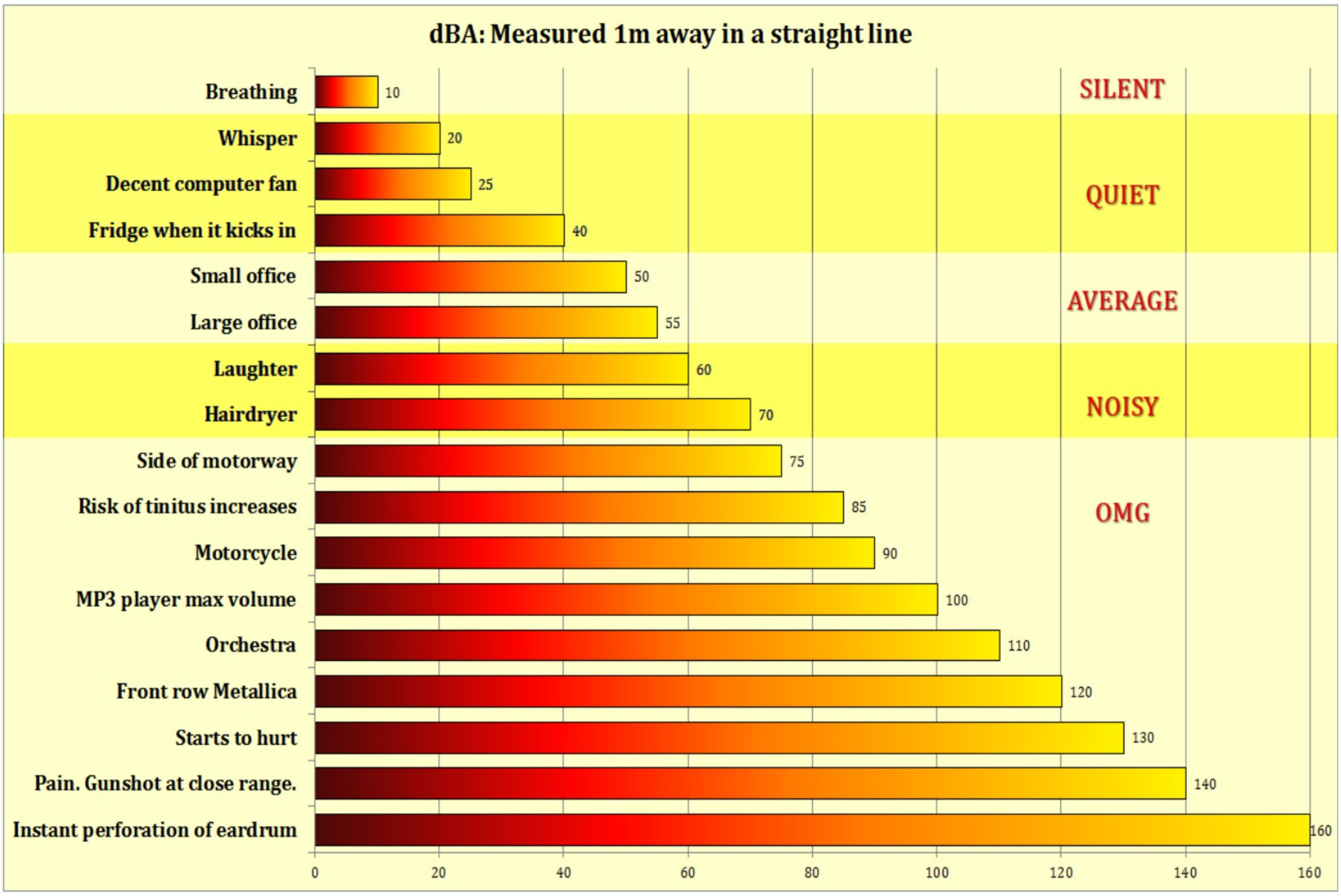
$$\log_{10} a \Rightarrow 10^{?} = a$$

$$5 = 10\left(\log\frac{I_2}{I_0} - \log\frac{I_1}{I_0}\right)$$

$$\frac{1}{2} = \log I_2 - \cancel{\log I_0} - \log I_1 + \cancel{\log I_0}$$

$$5 = 10\log\frac{I_2}{I_1} \Rightarrow 0.5 = \log_{10}\frac{I_2}{I_1}$$

$$10^{0.5} = \frac{I_2}{I_1} = \sqrt{10} \simeq 3$$


dBA: Measured 1m away in a straight line
Breathing
Whisper
Decent computer fan
Fridge when it kicks in
Small office
Large office
Laughter
Hairdryer
Side of motorway
Risk of tinitus increases
Motorcycle
MP3 player max volume
Orchestra
Front row Metallica
Starts to hurt
Pain. Gunshot at close range.
Instant perforation of eardrum
10
20
25
40
50
55
60
70
75
85
90
100
110
120
130
140
160
SILENT
QUIET
AVERAGE
NOISY
OMG
0
20
40
60
80
100
120
140
160

In.terlace example: a high-quality loudspeaker advertises that it can produce frequencies from 30 Hz - 18000 Hz with a uniform (constant) sound level ±5dB. How much of a change in intensity is a difference of 5dB?

"loudspeaker response"

2113

$$10dB = 10\log\frac{I_{10}}{I_0}$$

$$-\quad 15dB = 10\log\frac{I_{15}}{I_0}$$

$$-5dB = 10\left(\log\frac{I_{10}}{I_0} - \log\frac{I_{15}}{I_0}\right)$$

$$\frac{1}{2} = -\log\frac{I_{10}}{I_0} + \log\frac{I_{15}}{I_0}$$

$$\frac{1}{2} = \log\frac{I_{15}}{I_0} - \log\frac{I_{10}}{I_0}$$

$$\frac{1}{2} = \log\frac{I_{15}}{I_{10}}$$

$$10^{1/2} = \frac{I_{15}}{I_{10}} = \sqrt{10} \simeq 3$$

$$\log\frac{a}{b} = \log a - \log b$$

$$\log a^n = n \log a$$

$$\log(a \cdot b) = \log a + \log b$$

$$\log a = 3 \Rightarrow 10^{?} = a$$

$$= \log \frac{a}{b} - \log \frac{c}{b}$$

$$= \log a - \log b - (\log c - \log b)$$

$$= \log a - \cancel{\log b} - \log c + \cancel{\log b}$$

$$= \log a - \log c = \log \frac{a}{c}$$

Example: volume increase

A single trumpet player can play at a volume of 130dB.
How loud can two trumpet players play?

$$130dB = 10 \log \frac{I}{I_0}$$

$$x = 10 \log \frac{2I}{I_0}$$

$$= 10\left(\log 2 + \log \frac{I}{I_0}\right)$$

$$= 10 \log 2 + 130dB$$

$$= 10 \cdot 0.3 + 130dB$$

$$= 3 + 130$$

$$= 133dB$$

int.erlace example: Volume increase

If 20 monkeys typing on 20 typewriters have a volume of 94dB, how loud is one monkey typing on one typewriter?

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$$94dB = 10\log\frac{I_{20}}{I_0} = 10\log\frac{20I_1}{I_0}$$

$$= 10\left(\log 20 + \log I_1 - \log I_0\right)$$

$$94dB = 10\left(1.3 + \log\frac{I_1}{I_0}\right]$$

$$94 = 13 + 10\log\frac{I_1}{I_0}$$

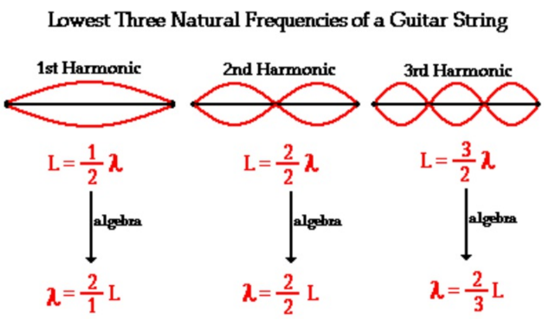
$$81dB = 10\log\frac{I_1}{I_0}$$

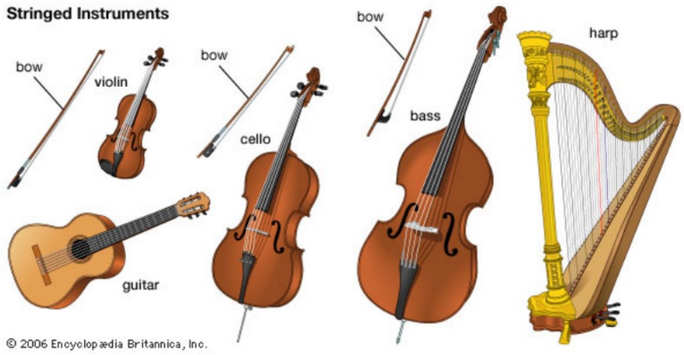
$$x = 10\log\frac{I_1}{I_0}$$

Example: airplane roar

The sound level measured 30m from a jet plane is 140dB. Estimate the sound level at 300 m.

String instruments (or closed tubes):





Int.erlace question: How do the different strings of a guitar or a violin make different notes if they are the same length?

$f = \frac{v}{\lambda}$

"different notes"

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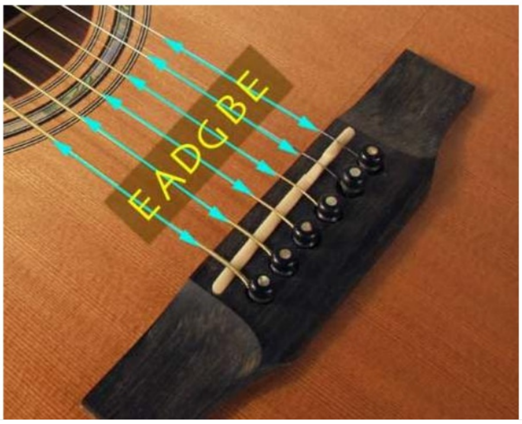


$$f \cdot \lambda = v = \sqrt{\frac{T}{\mu}}$$

μ = linear mass density

$= \frac{M}{L}$

$$f = \frac{v}{\lambda} = \frac{\sqrt{T/\mu}}{\lambda} =$$

$$f\lambda = v \Rightarrow f = \underline{\frac{v}{\lambda}}$$

$$v = \sqrt{\frac{T}{\mu}} \Rightarrow v = \underline{\sqrt{\frac{T}{\mu}}}$$

Two ways to adjust pitch (frequency):

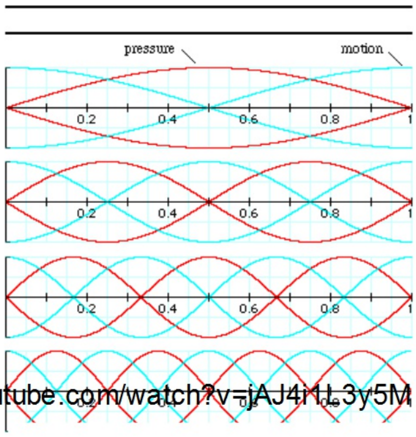
1.Change $\underline{\mu}$ thickness

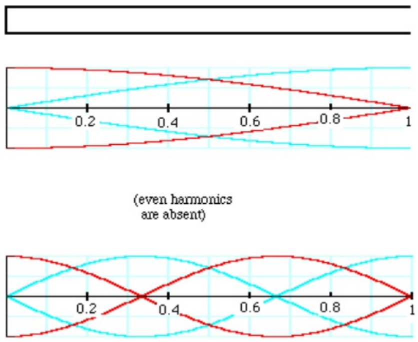
2. Change $\underline{T}$

Open tube instruments, why does a flute sound different from a clarinet:

Flute

Clarinet



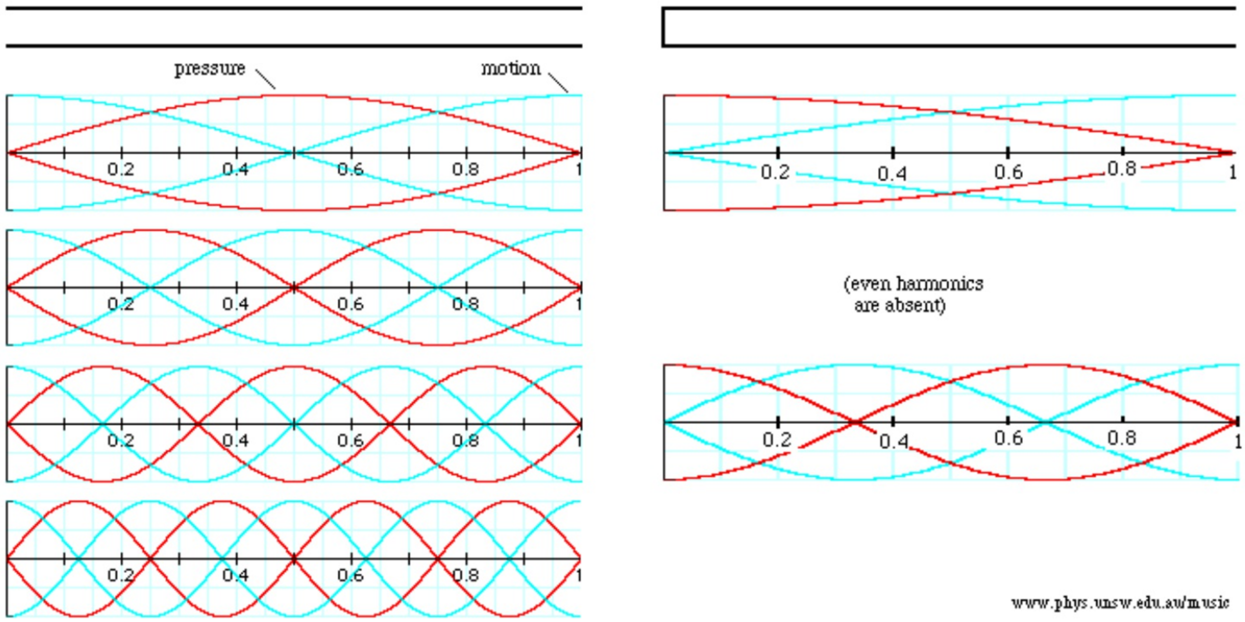


https://www.youtube.com/watch?v=jAJ4i1LL3y5M

https://www.youtube.com/watch?v=8AzV_Sz-oYw#t=40

www.phys.unsw.edu.au/music

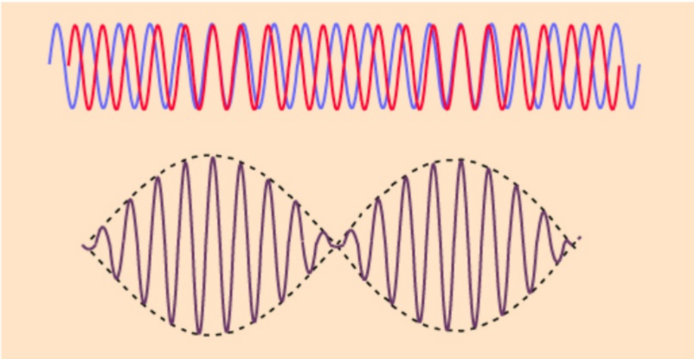
Open tube instruments:



Rules:

1. A closed end of a tube (tied end of a string) must have a ______[**node/antinode]** because motion is ____[**allowed/not allowed**]
2. A open end of a tube (free end of a string) must have a ______[**node/antinode]** because motion is ____[**allowed/not allowed**]

Beats: what happens when you add together two waves that have very close frequencies

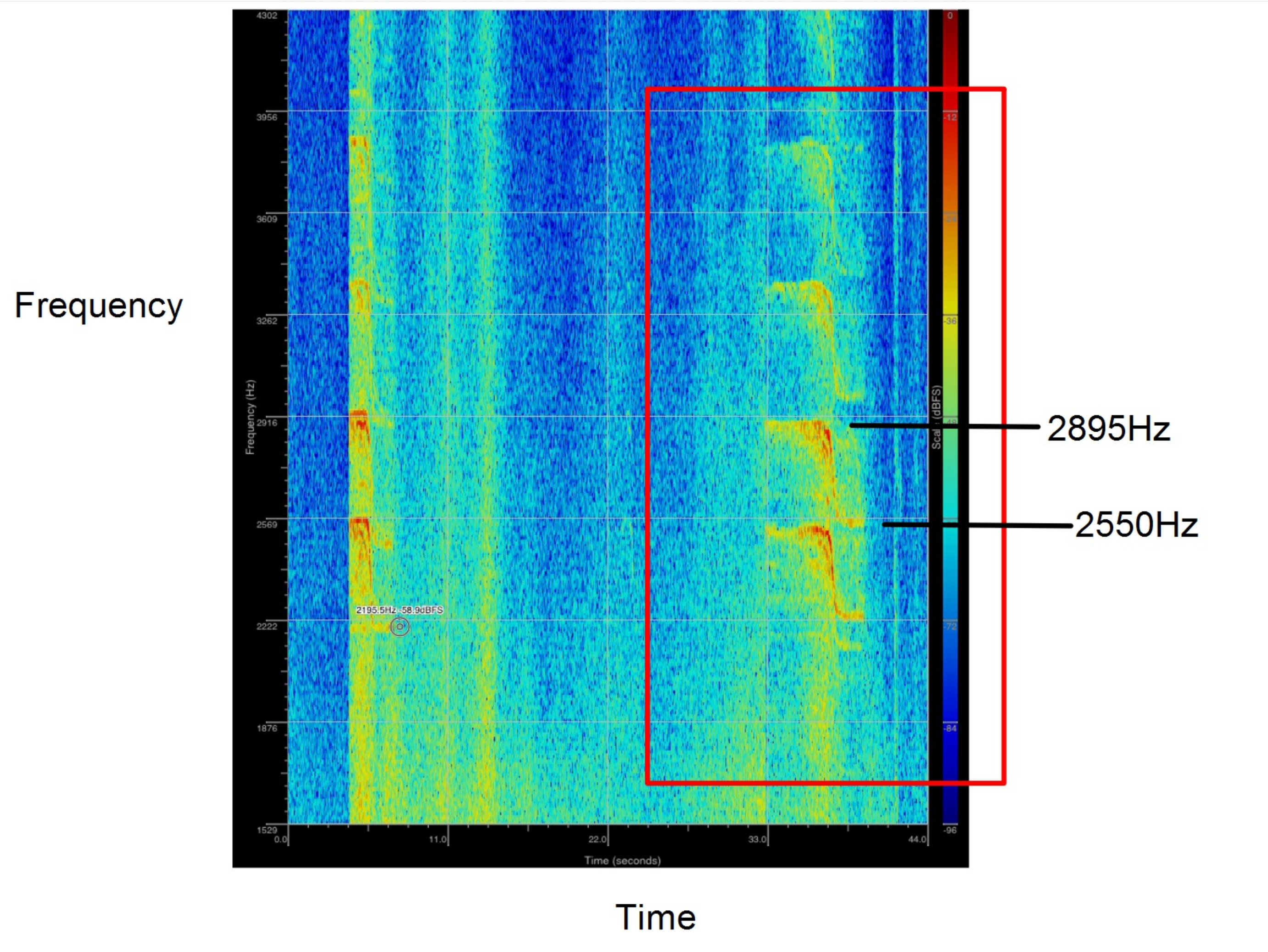


https://www.youtube.com/watch?v=V8W4Djz6jnY

$$f_{beat} = f_2 - f_1$$

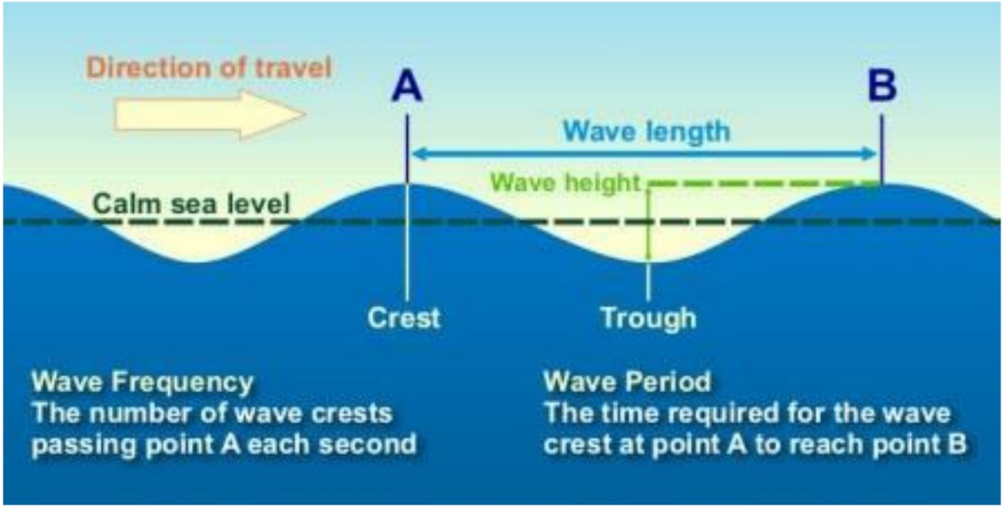
Doppler effect:

https://www.youtube.com/watch?v=0mEF9v21Dh
w

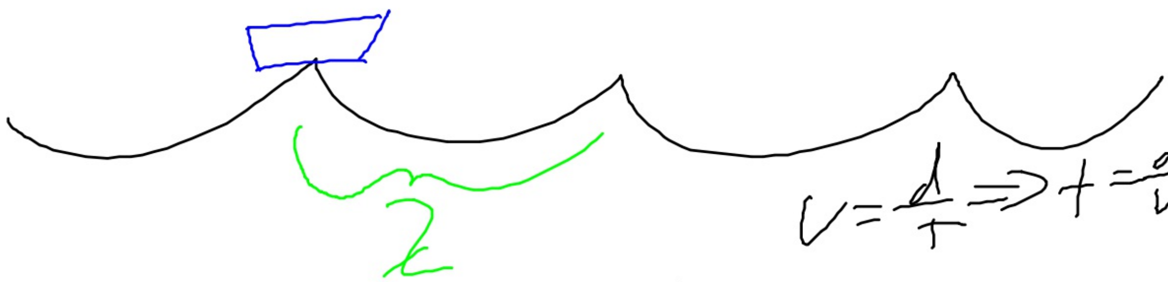


Frequency
4302
3956
3609
3262
2916
2569
2222
1876
1529
Frequency (Hz)
2195.5Hz -58.9dBFS
0.0
11.0
22.0
33.0
44.0
Time (seconds)
Scale (dBFS)
0
-12
-36
-84
-96
2895Hz
2550Hz
Time

Explaining it - observer moves:



When you travel against the waves the frequency of the waves seems [higher/lower?]



$$v = \frac{d}{t} \Rightarrow t = \frac{d}{v}$$

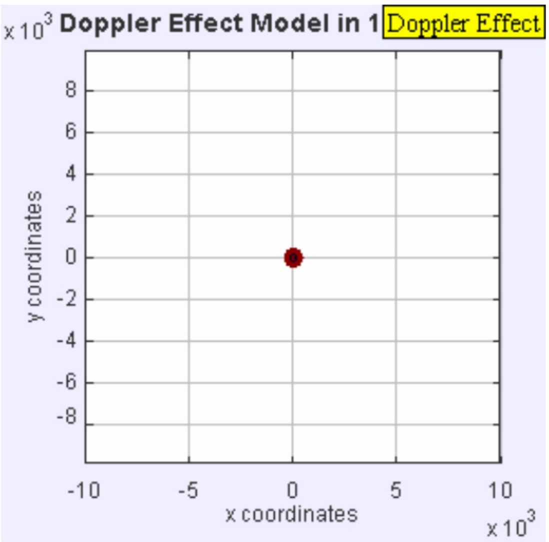
$$f = \frac{v}{\lambda} = \frac{1}{T} \qquad |T' - T| = \frac{\lambda}{v_0}$$

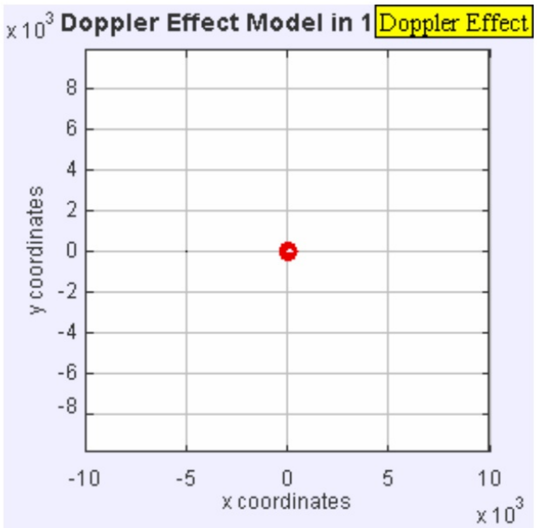
$$T' = T - \frac{\lambda}{v_0}$$

$$f' = \frac{1}{T'} = \frac{1}{T \pm \frac{\lambda}{v_0}}$$

$$f' = \frac{1}{\frac{1}{f} \pm \frac{\lambda}{v_0}} = \frac{v_0 f}{v_0 \pm f\lambda} = \left(\frac{v_0}{v_0 \pm v}\right) f$$

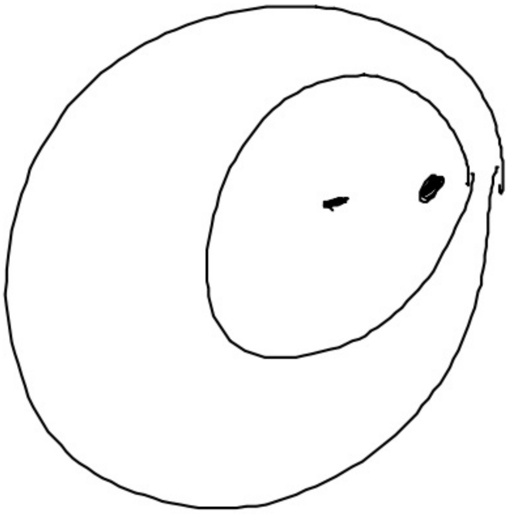
What about when source moves?





When source moves away from you, space between waves (wavelength) appears ___________[larger/smaller]

When source moves toward you, space between waves (wavelength) appears ___________[larger/smaller]



$$\lambda' = \lambda \pm v_s T$$

$$= \lambda \pm v_s \frac{1}{f} =$$

$$\lambda' = \lambda \pm \frac{v_s}{f}$$

$$f' = \frac{v}{\lambda'} = \frac{v}{\lambda \pm \frac{v_s}{f}} = \frac{vf}{\lambda f \pm v_s}$$

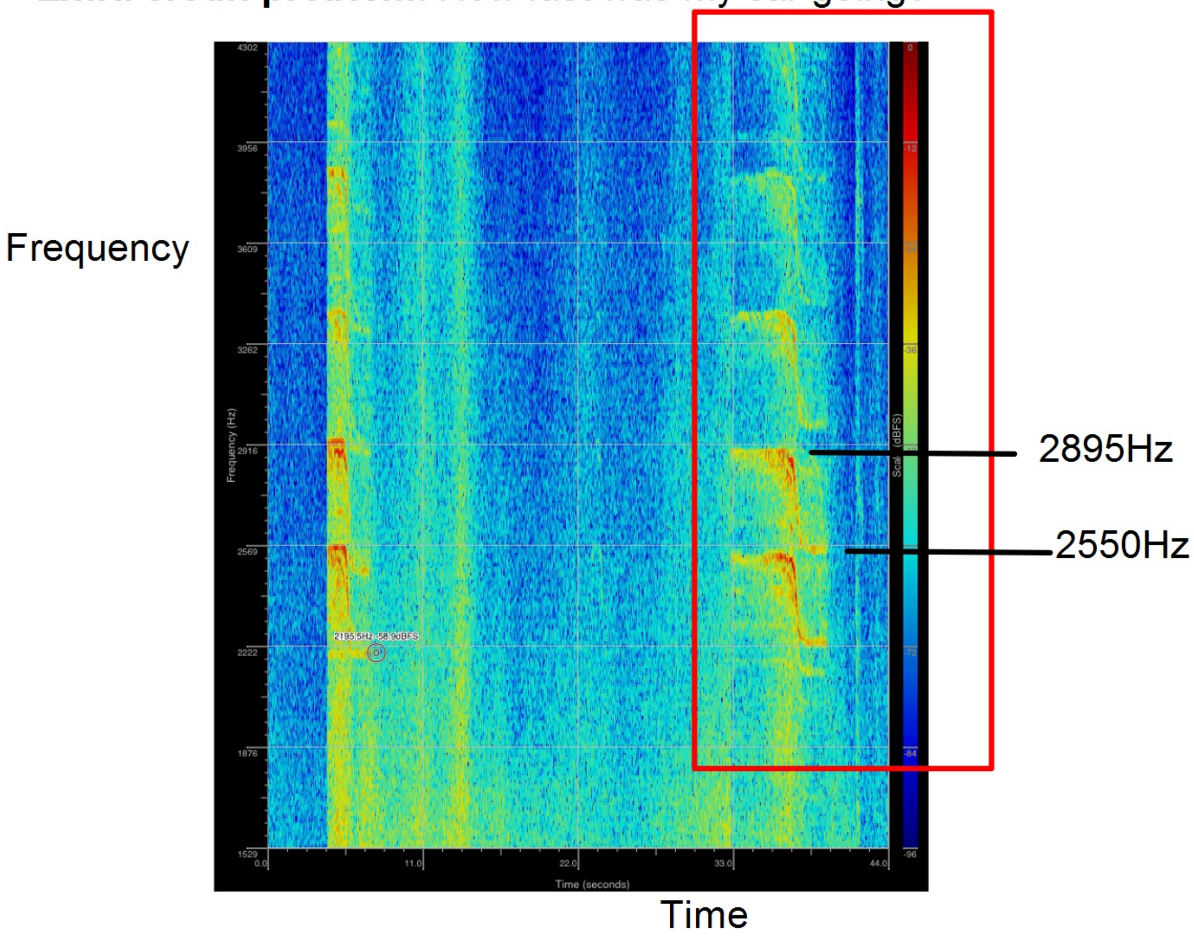
$$f' = \left(\frac{v}{v \mp v_s}\right) f$$

Full formula

$$f' = \left(\frac{v \pm v_o}{v \pm v_s} \right) f$$

where
f' = the apparent frequency
f = the original frequency
v = speed of sound (or other wave)
v_o=speed of observer (use **+** if observer is moving [toward/away from] sound source, use - if observer is moving [toward/away from] sound source
v_s=speed of source (use **+** if source is moving [toward/away from] observer, use - if observer is moving [toward/away from] observer

Extra credit problem: How fast was my car going?



If an ambulance siren has a frequency of 2000hz

(a) What is the apparent frequency when the ambulance is moving towards the observer at 60kph

$$f' = \left(\frac{v \pm v_o}{v \pm v_s}\right) f$$

$$f' = \left(\frac{V - \cancel{V_o}}{V - V_s}\right) f$$

+ makes f' smaller

$f_{beat} = 102hz$

$f' = 2102hz$

(b) What is the apparent frequency when the ambulance is moving away from the observer at 60kph?

$$f' = \left(\frac{V}{V + V_s}\right) f = 1907hz$$

$f_{Beat} = 93hz$