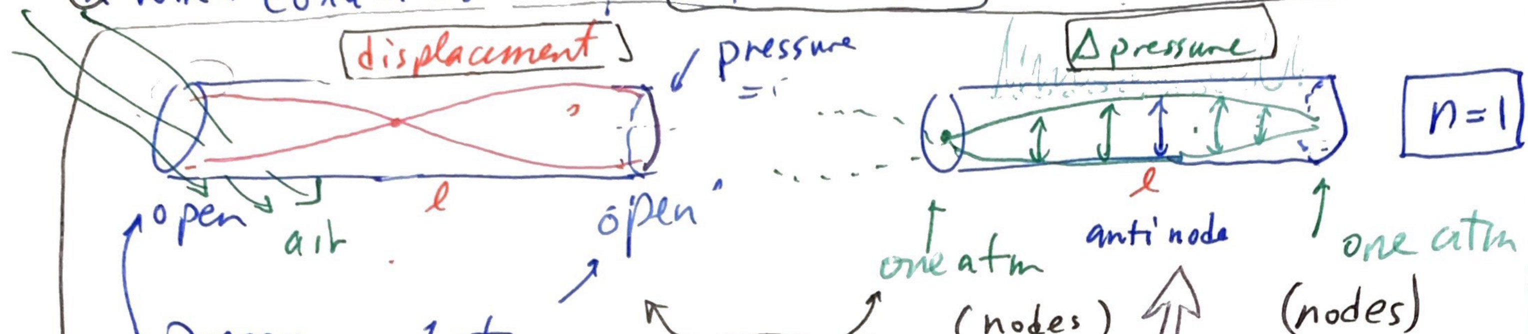
Chapter 12 B

Sound from Pipes

Open Pipe { Double open / Both ends Open }

(*) Wind columns



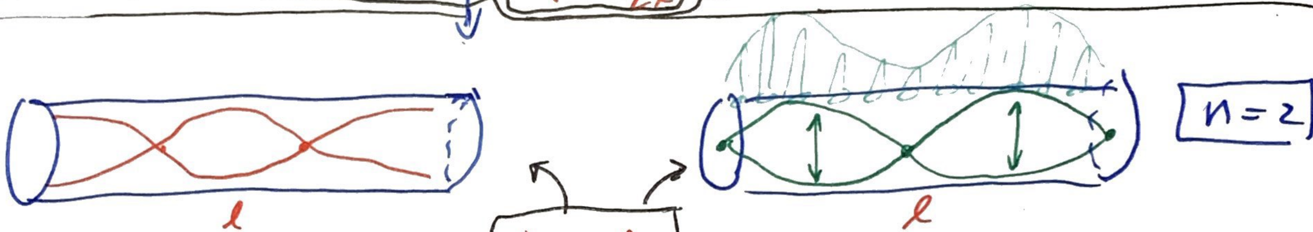
pressure = 1atm

$\lambda_1 = 2l$

$f_1 = \frac{v}{\lambda_1}$

$f_1 = \frac{v}{2l}$

Fundamental Harmonic

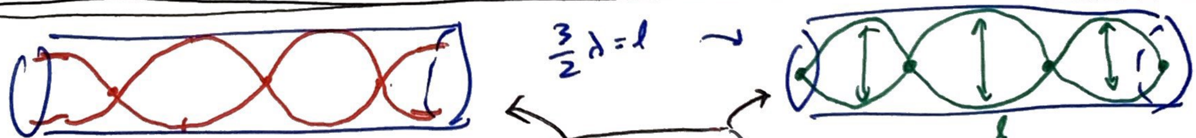


$\lambda_2 = l$

$f_2 = \frac{v}{\lambda_2}$

$f_2 = 2f_1$

2nd harmonic



$\lambda_3 = \frac{2}{3}l$

$f_3 = \frac{v}{\lambda}$

$f_3 = \frac{v}{2l/3} = \frac{3}{2}\frac{v}{l}$

$f_3 = 3f_1$

3rd Harmonic

⋮

Open – Open

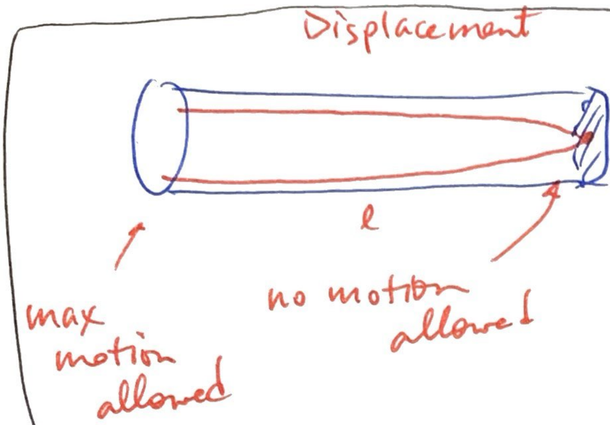
General Formulas

$\lambda_n = \frac{2l}{n}$

$f_n = nf_1$

$n = 1, 2, 3 \ldots$

Closed Pipe {half-open}



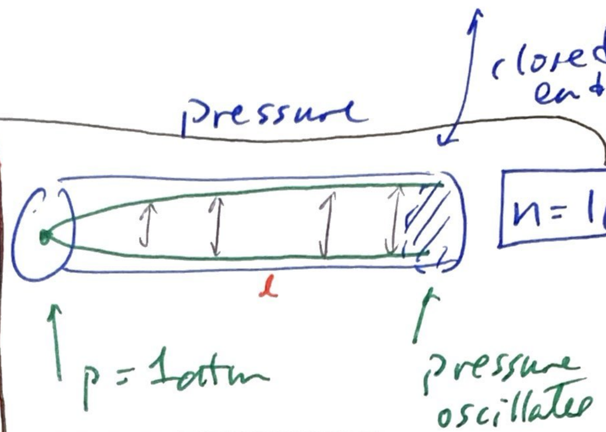
$l = \frac{1}{4}\lambda$

$\lambda_1 = 4l$

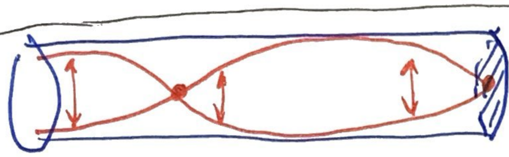
$f_1 = \frac{v}{\lambda_1}$

$f_1 = \frac{v}{4l}$

Fundamental Frequency



n = 1

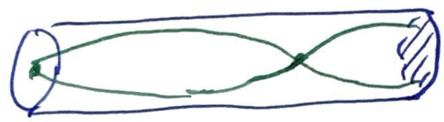


$l = \frac{3}{4}\lambda_3$

$\lambda_3 = \frac{4}{3}l$

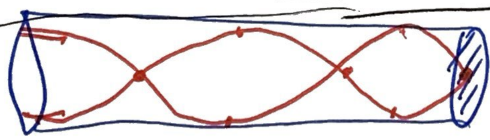
$f_3 = \frac{v}{\lambda_3}$

$f_3 = 3f_1$



n = 3

3rd Harmonic

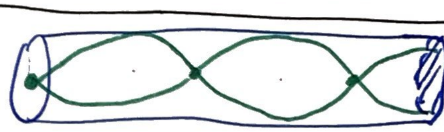


$l = \frac{5}{4}\lambda_5$

$\lambda_5 = \frac{4}{5}l$

$f_5 = \frac{v}{\lambda_5}$

$f_5 = 5f_1$



n = 5

5th Harmonic

Closed-open

Harmonic

General Formula:

$\lambda_n = \frac{4l}{n}$ $n = 1, 3, 5, \ldots$

$f_n = nf_1 = n\left(\frac{v}{4l}\right)$ $n = 1, 3, 5 \ldots$

Ex a 26 cm organ pipe @ 20°C air has which fundamental freq. ?

(a) open pipe $f_1 = \frac{v}{2l} = \frac{343\ m/s}{2(0.26m)} = \underline{\underline{660 Hz}}$

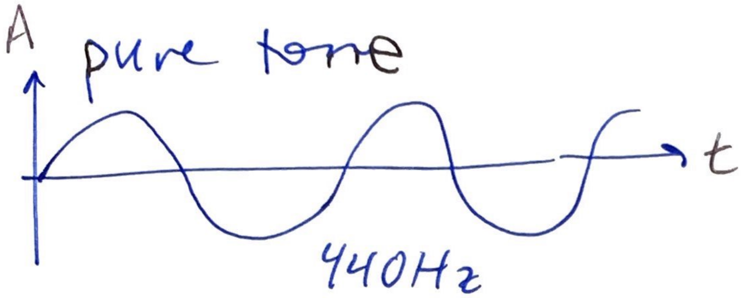
(b) closed pipe $f_1 = \frac{v}{4l} = \frac{343\ m/s}{4(0.26m)} = \underline{\underline{330 Hz}}$ ((lower note))

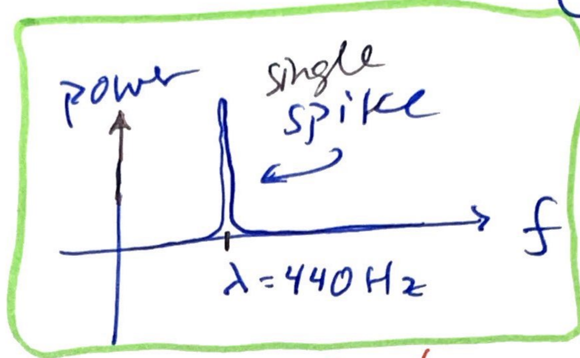
What are the harmonic of each config?

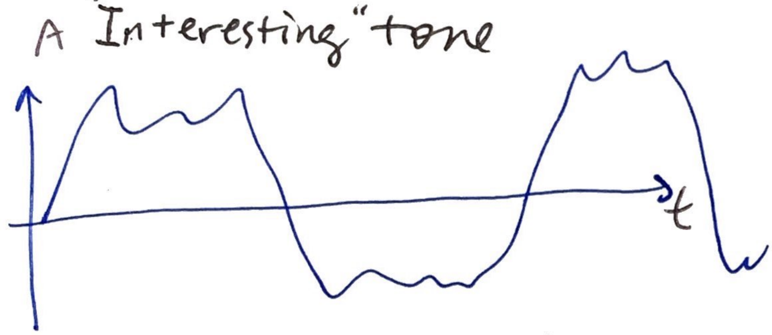
open : $f_1 = 660 Hz$, $f_2 = 1320 Hz$, $f_3 = 1980 Hz$ ...

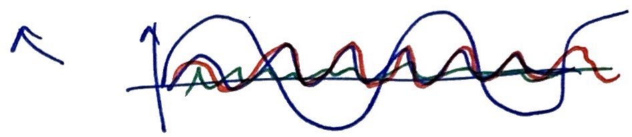
closed : $f_1 = 330 Hz$, $f_3 = 1020 Hz$, $f_5 = 1650 Hz$, ...

* power spectrum

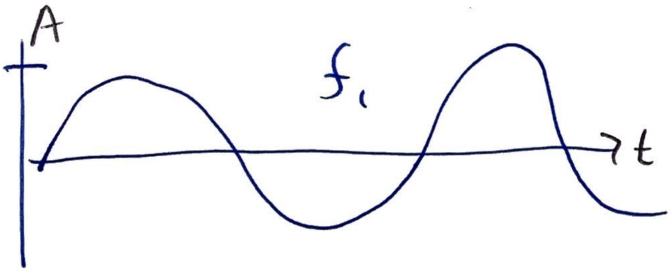


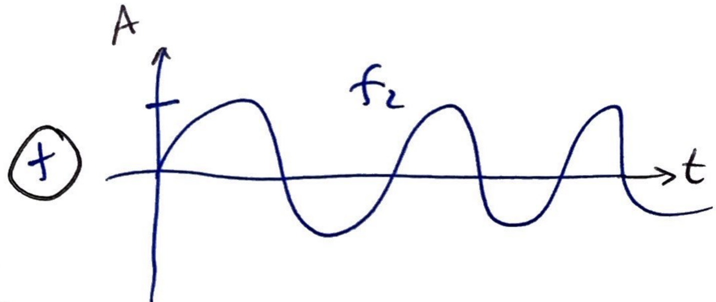


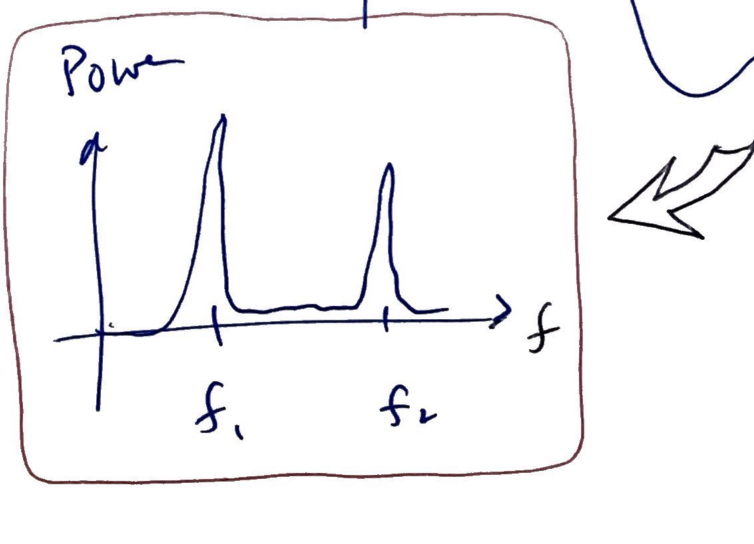




* wave addition



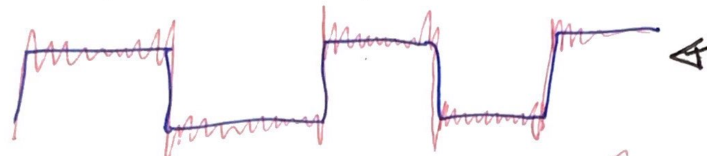




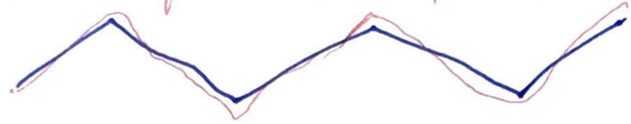
* waves can be added to create many differnt shapes...

demos.com $\left\{ y = \left(\frac{2}{\pi}\right)\sin(t) + \left(\frac{2}{3\pi}\right)\sin(3t) + \left(\frac{2}{5\pi}\right)\sin(5t) + \cdots \right.$

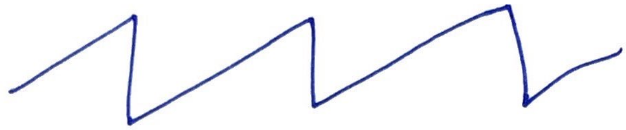
- square wave :



- triangle wave :

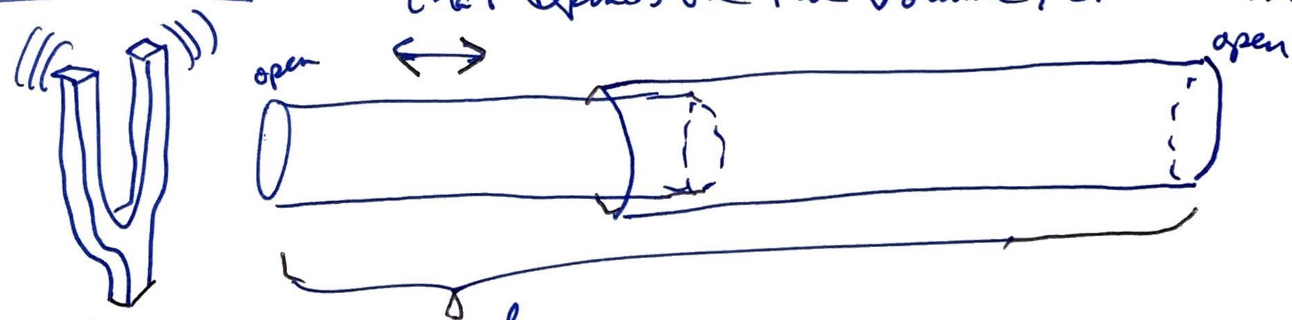


- saw tooth wave :



⊛ **Resonance**: Cavities will exhibit a "natural" frequency that depends on the volume & dimensions.

EX



Tuning Fork:

l_{TOTAL}

Here move the collar until we hear maximum amplitude, then we have a harmonic. Is it the fundament frequency?

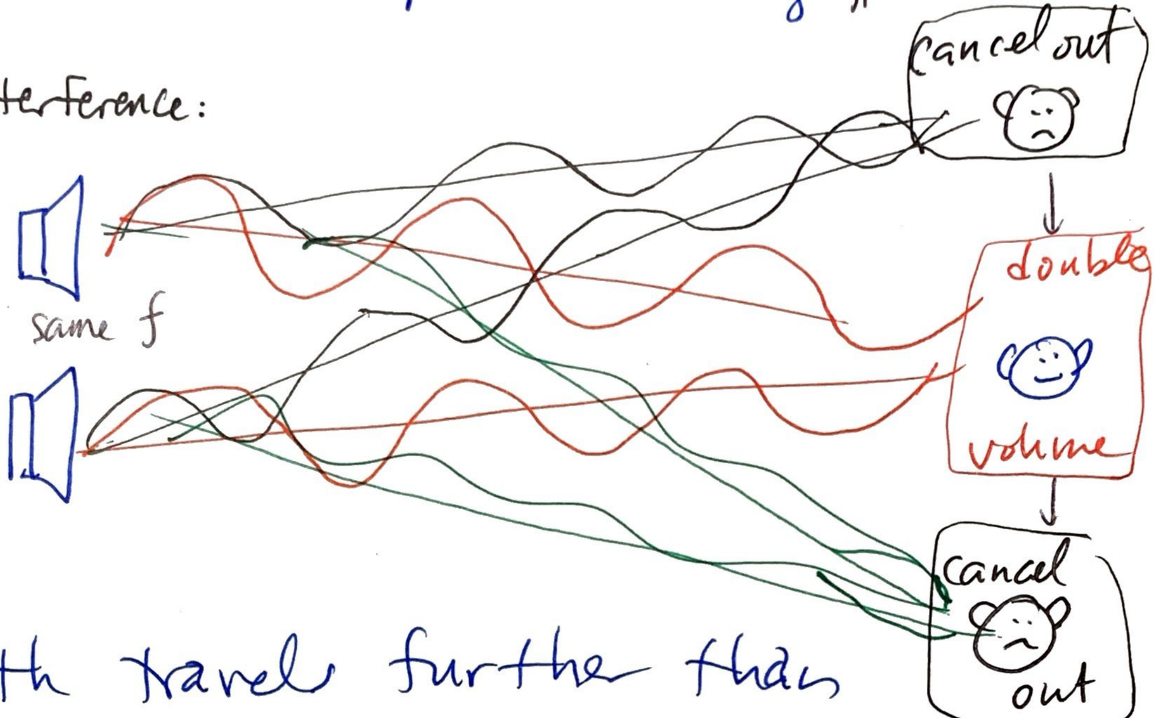
Future Lab.

* Constructive & destructive Interference

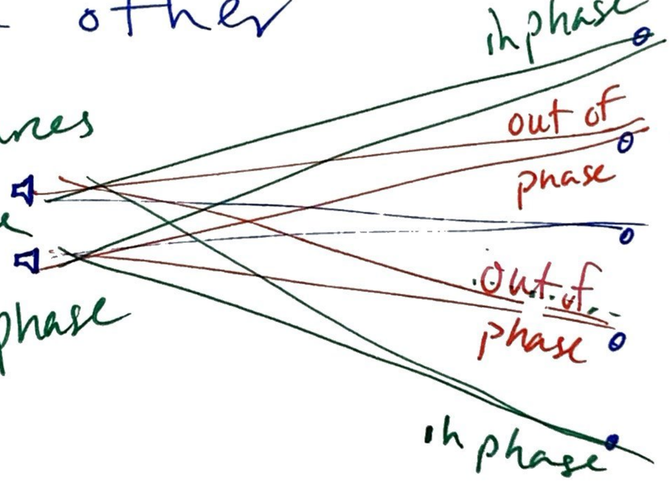
((see chpt 11 for this topic and strings))

Sound Interference:

freq symbols	
f	linear
ν	sound
ω	← angular in mechanics

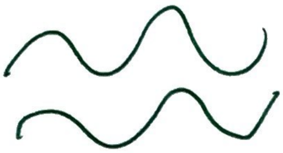


• One path travels further than the other



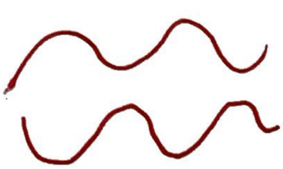
phase

Coherent sound



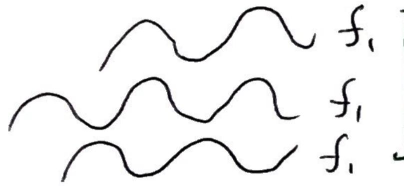
"0° in phase"

incoherent sound

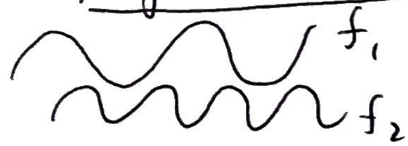


"180° out of phase"

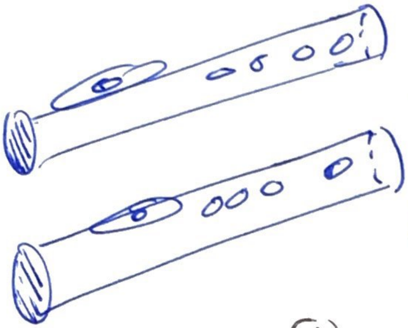
monochromatic:



polychromatic

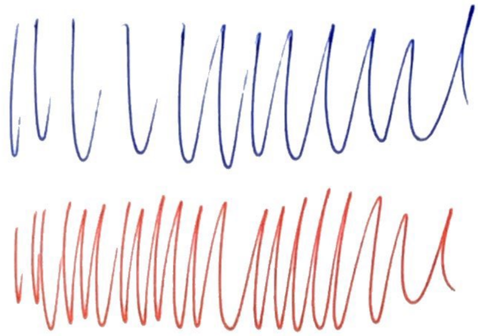


⊛ "Beat frequencies" and Tuning



$A = 440\,Hz$

$A^{\#} = 470\,Hz$



⊕

"out of tune"

players are out of tune →

$$y = A\sin(440\cdot 2\pi\cdot t) + A\sin(470\cdot 2\pi\cdot t)$$

use a trig identity

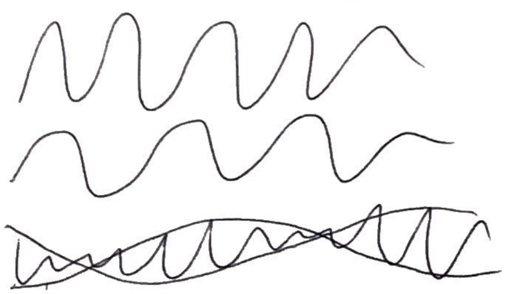
$$= A\left[\sin\left(\frac{440-470}{2}\cdot 2\pi t\right)\right]\sin\left(\frac{440+470}{2}\cdot 2\pi t\right)$$

$$= A\sin\left(\frac{30}{2}\cdot 2\pi t\right)\sin\left(\frac{910}{2}\cdot 2\pi t\right)$$

- Desmos.com — click here to turn of showing

enter

⓪ sin(10x)
⓪ sin(9x)
⓪ sin(10x) + sin(9x)

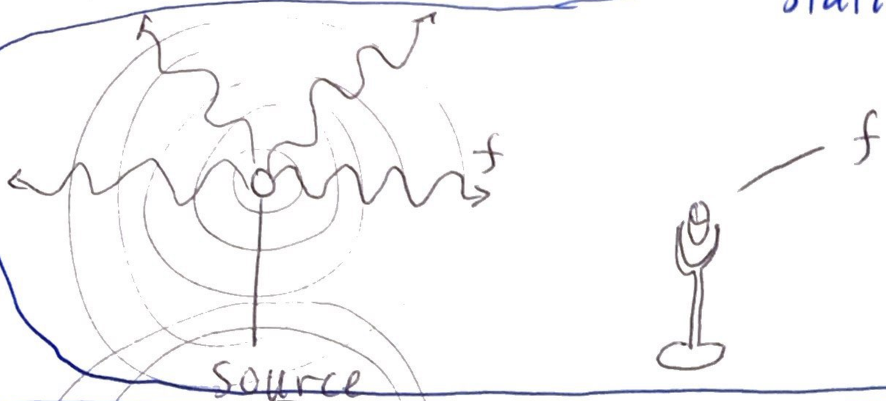


change to 9.9 later and zoom out

- See "onlinetonegenerator.com"
  ↳ binauralbeats (is sites) [play] (is -- fun) default ((Read warning 1st))

Doppler Effect

stationary source



same pitch as emitted

moving source

pitch (frequency) increases.

pitch drops

$\frac{\# + \#}{\# - \#}$ or $\frac{\# - \#}{\# + \#}$

not $\frac{\# + \#}{\# + \#}$ nor $\frac{\# - \#}{\# - \#}$

It is possible that both source and observer could be moving

Formula

$$f'_{ear} = f_{source}\left(\frac{V_{\text{sound in still air}} \pm V_{observer}}{V_{\text{sound in air}} \mp V_{source}}\right)$$

EX

V_{source} $V_{observer}$

Recall...

$V_{sound} = 343\,m/s$ @ $20°C$, $V \approx 331 + 0.60T$ (T in °C)

pick signs such that if the source and the observer are closing in to each other, the pitch is higher

EX A 5000Hz sound is emitted by a stationary source. If the source starts moving to the right, towards an observer, what is the pitch heard if the source relative to the ground is 10m/s and the observer relative to the ground is only 6 m/s.

- Diagram

$V_{sound} = 343\,m/s$

- Formula

$$f'_{observer} = f_{sour}\left(\frac{V_{sound} \pm V_{obs}}{V_{soun} \mp V_{source}}\right)$$

- pick sign so that f' is the higher pitch since the source is overcoming the observer (They are closing in on eachother)

→ Lets pick $\frac{+}{-}$ so

→ then $f'_{obs} = 5000Hz\left(\frac{343+6}{343-10}\right)$

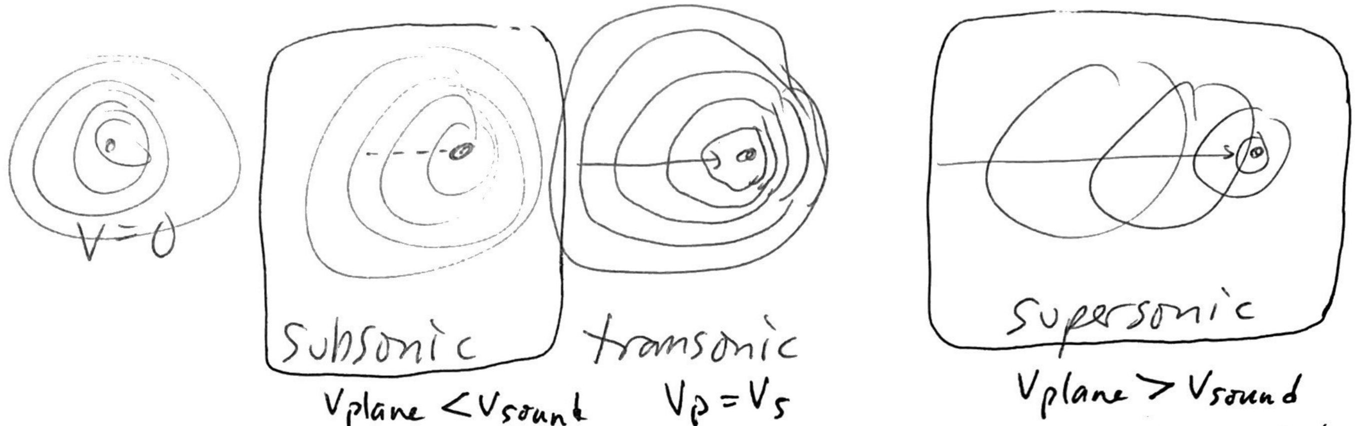
$= 5000Hz\,(1.05) = \boxed{5240Hz}$

pitch is higher so we made the correct choice of signs.

the pitch increases by 5%

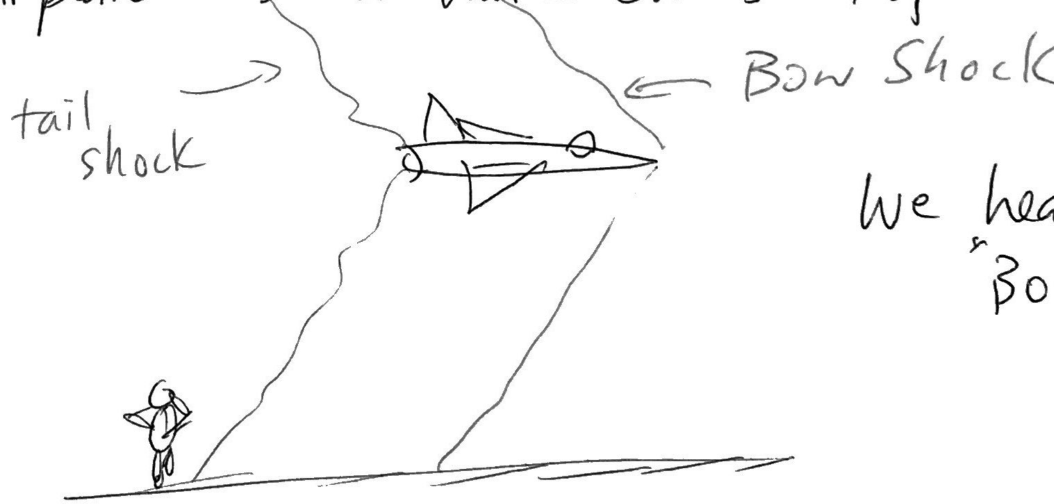
⊛ Shock Waves

If V_{source} exceeds the speed of sound, like a bullet from a rifle, or a supersonic plane, then a shock forms.



- A supersonic aircraft approaching you will not be heard until it is over you!

- Airplane shock wave comes in pairs:



We hear "Boom-Boom"

- See smarter everyday "booster landing" on youtube