

Pearson
10.5

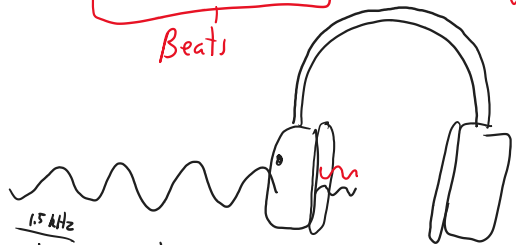
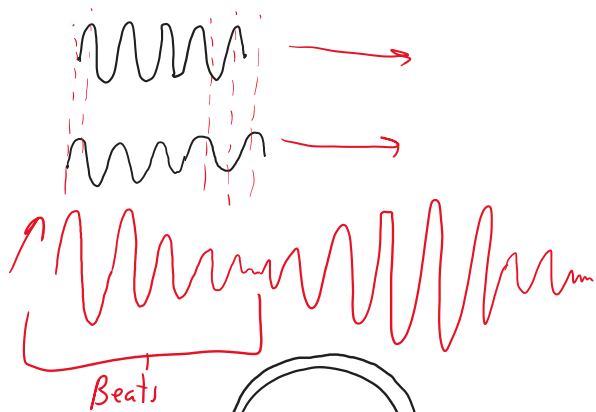
Standing Waves and Harmonics

- Standing wave
- superposition of
- two waves with
- similar amplitude
- same frequency
- opposite direction

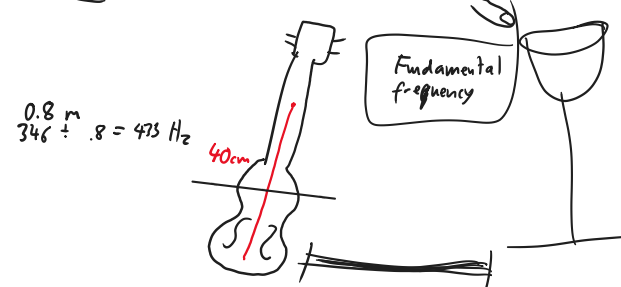
(most of time due to reflection of perpendicular surface).



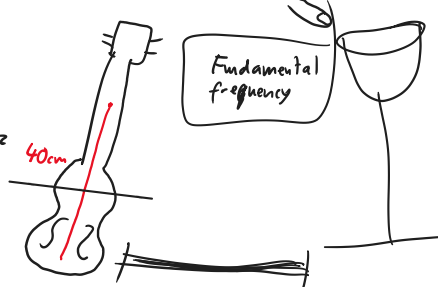
- At the nodes
- destructive interference
At the antinodes
- constructive interference



Macroscopic Example
Resonance!
Dramatic increase in amplitude (swing height)



0.8 m
346 m/s
f = 475 Hz



Overtone \neq harmonic

First harmonic
Fundamental
 $n=1$
Second harmonic
 $n=2$
1st overtone



$$l = \frac{\lambda}{2}$$

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

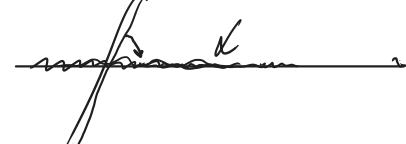
$$\lambda = \frac{2l}{2}$$

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

$$\lambda = \frac{2l}{4}$$

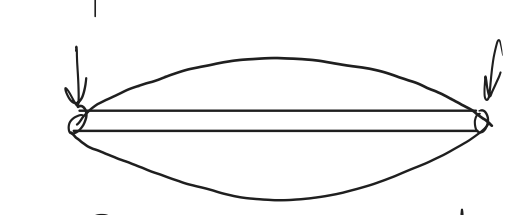
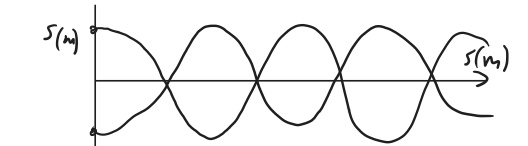
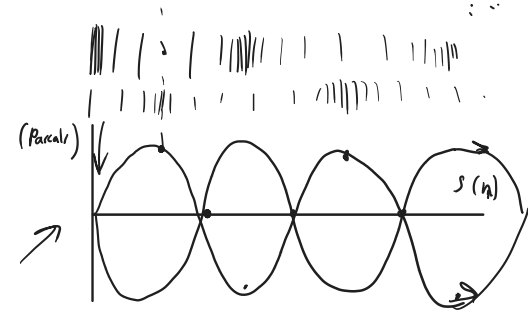
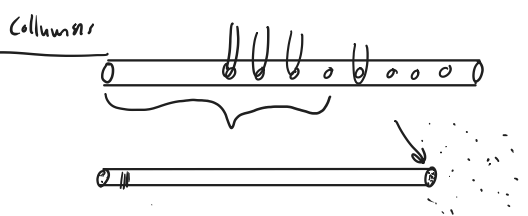
$$\lambda = \frac{2l}{5}$$

nth harmonic
has
 $\lambda = \frac{2l}{n}$
 $n \in \mathbb{N}$

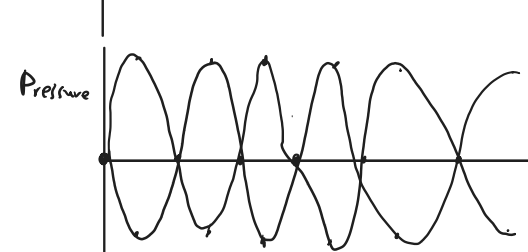
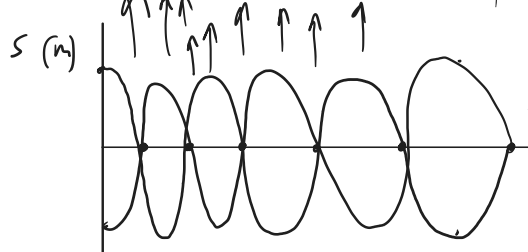
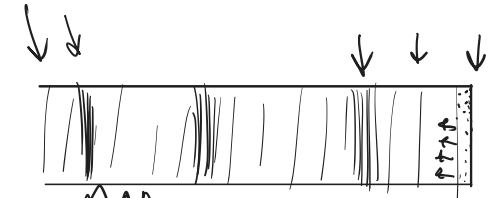


Air Columns

Open Air Columns

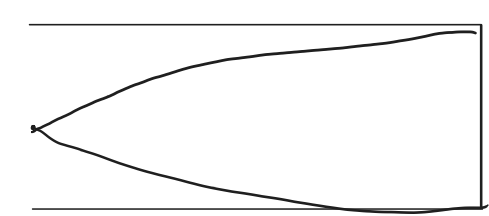


Air Columns closed at one end

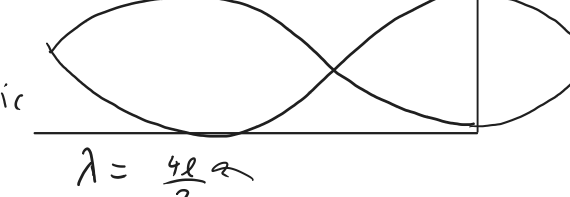


Pressure

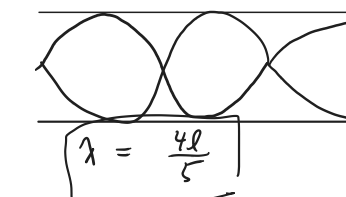
1st harmonic
1st Mode



2nd mode
3rd harmonic
2nd overtone



3rd mode
5th harmonic
4th overtone



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

open air columns
- resonant frequencies are
natural number multiples
of the fundamental frequency.

closed air column
- resonant frequencies are
odd number multiples of
the fundamental

$$\lambda = \frac{4l}{(2n-1)} \quad n \in \mathbb{N}$$

$$\lambda = \frac{4l}{h} \quad | \quad h = \text{harmonic}$$

Octave
 $A_1: 440 \text{ Hz}$
 $A_2: 880 \text{ Hz}$
+ 1 octave

1:2 2:3 3:4

