Chapter 17

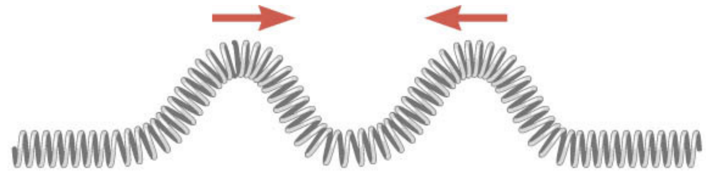
Superposition & Standing Waves

Superposition & Standing Waves

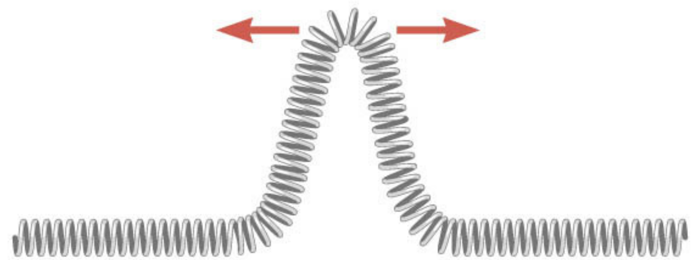
- Superposition of Waves
- Standing Waves

Wave Interference

Constructive Interference



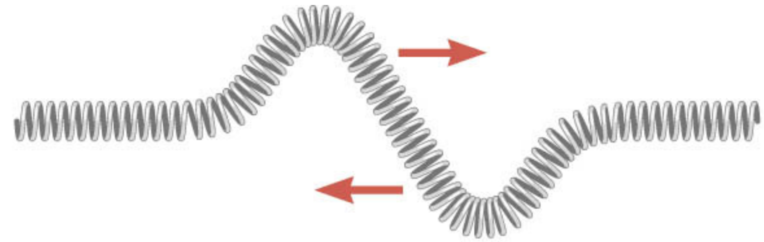
(*a*) Overlap begins



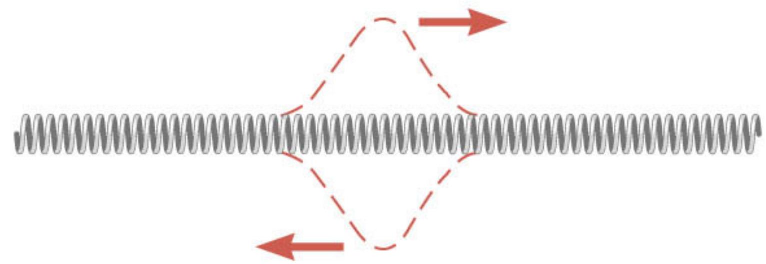
(*b*) Total overlap; the Slinky has twice the height of either pulse

(*c*) The receding pulses

Destructive Interference



(*a*) Overlap begins

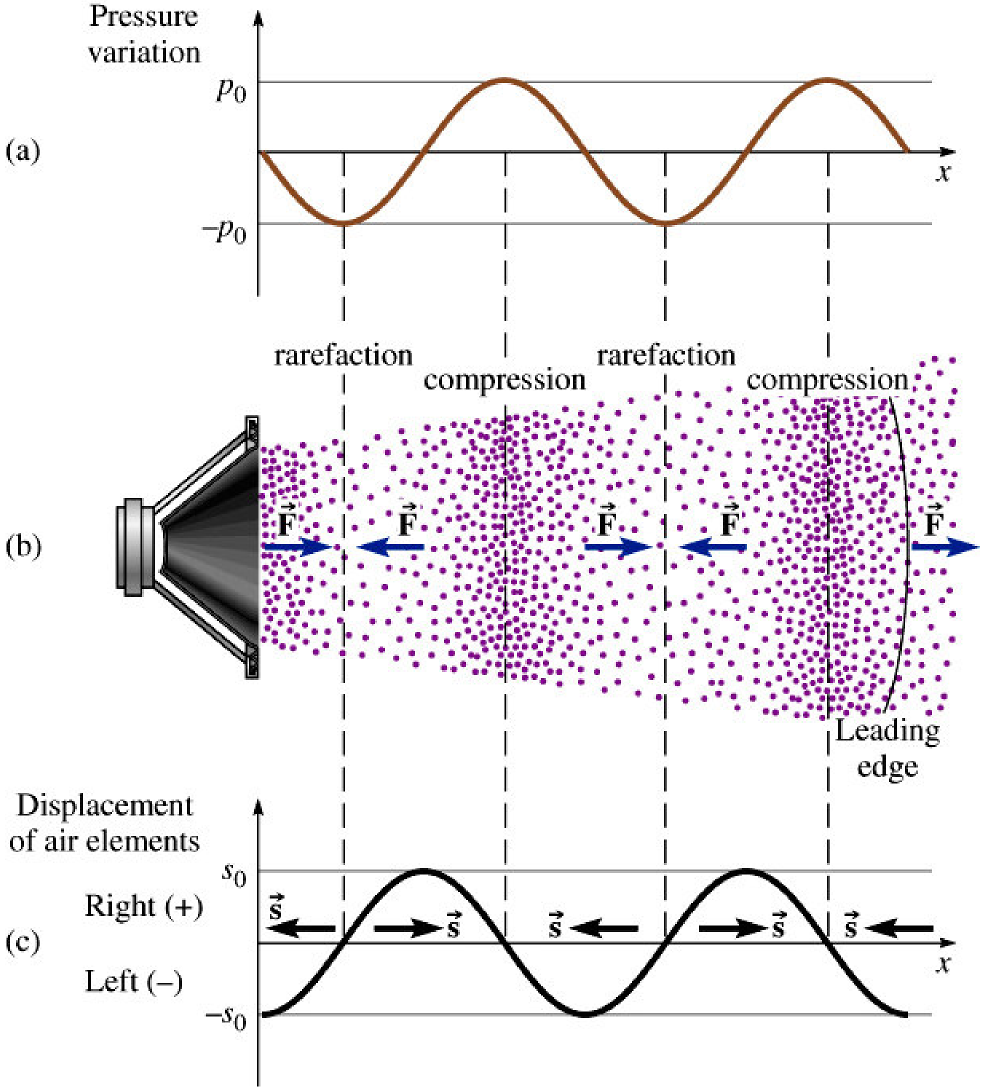


(*b*) Total overlap

(*c*) The receding pulses

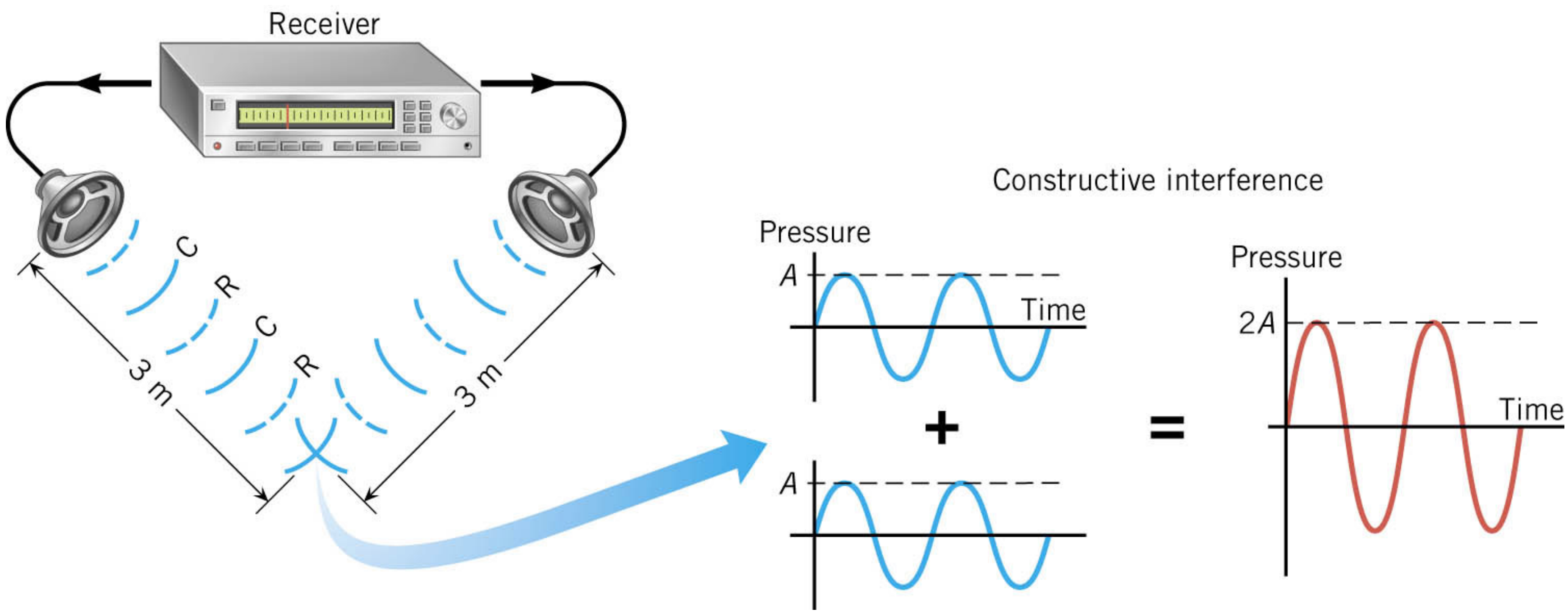
Acoustic (Sound) Wave Interference

Sound Wave



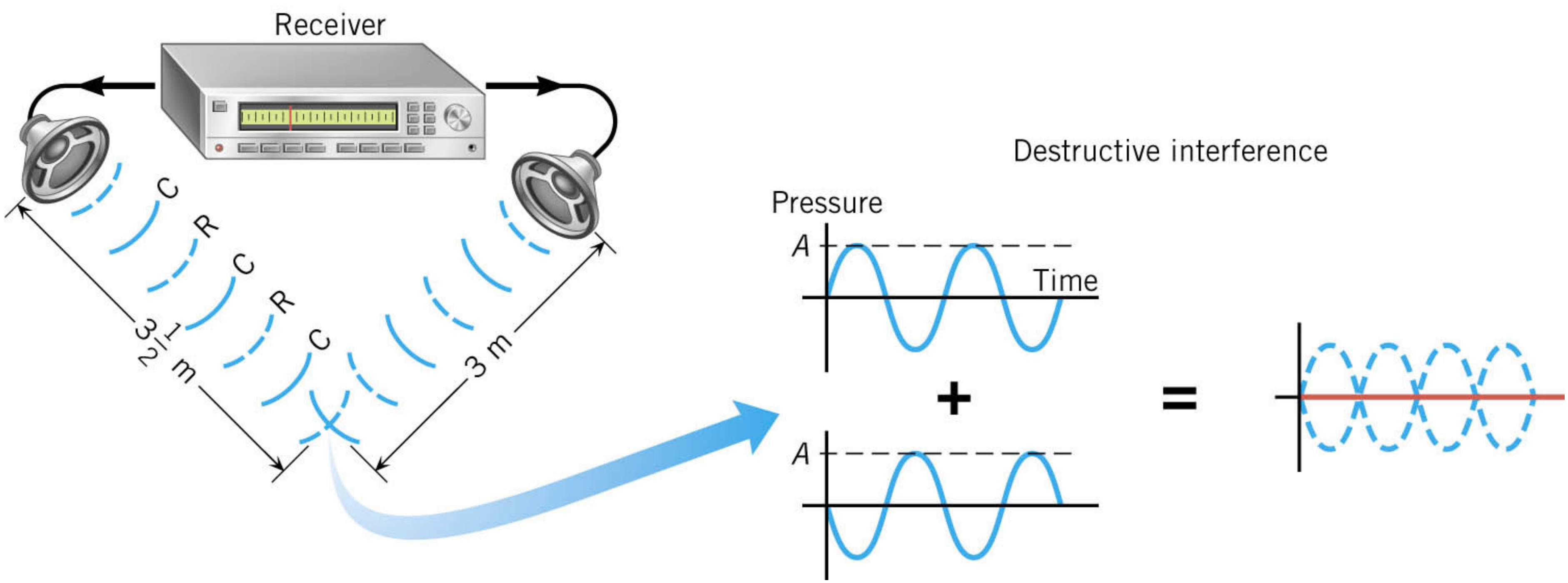
Sound waves can be considered from a pressure variation or an air displacement point of view.

Constructive Interference

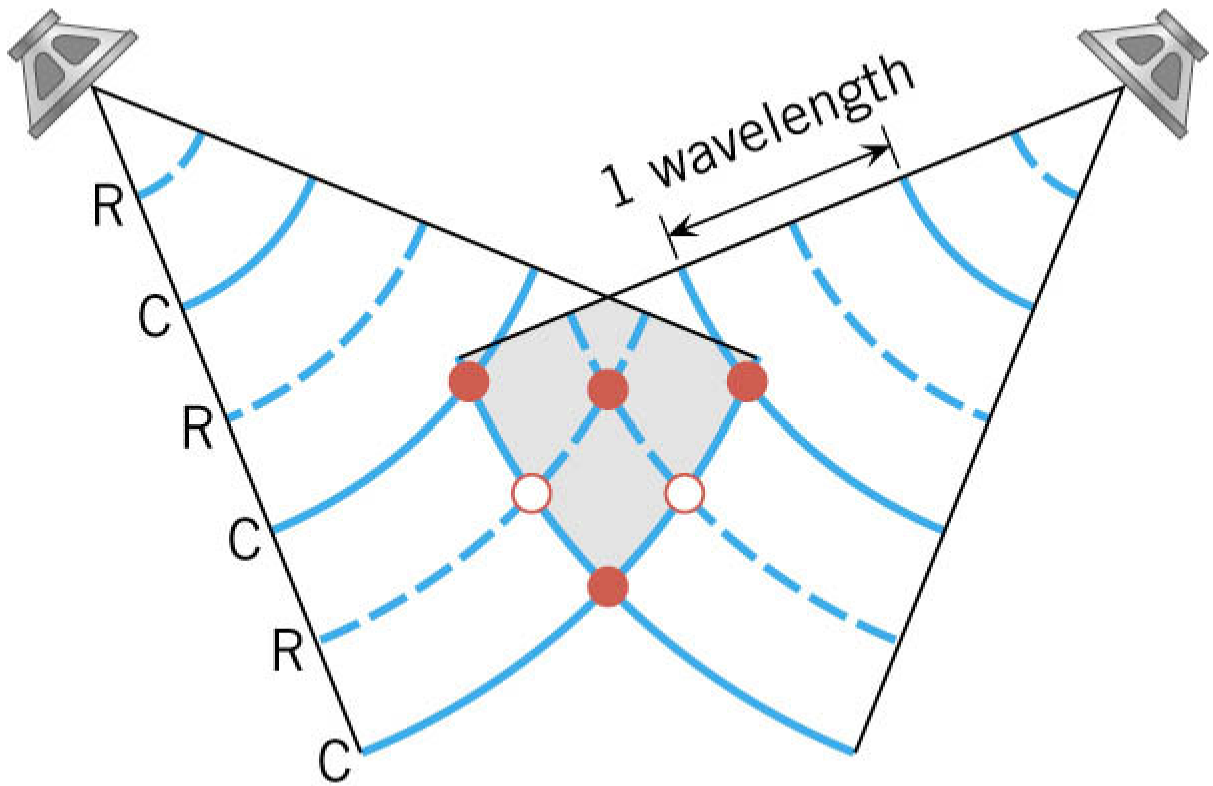


Common source to maintain phase relationship in both speakers.

Destructive Interference

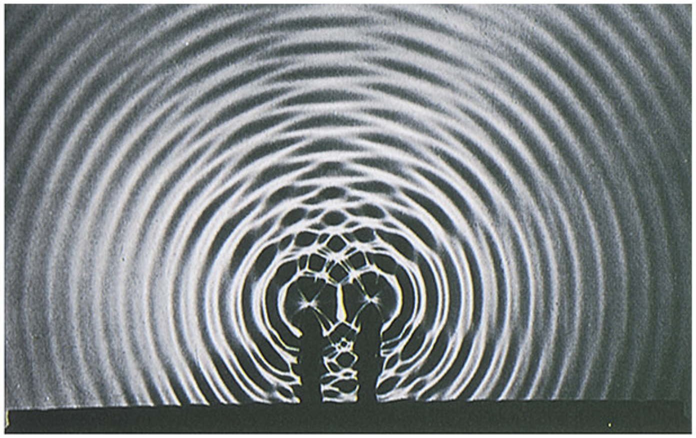


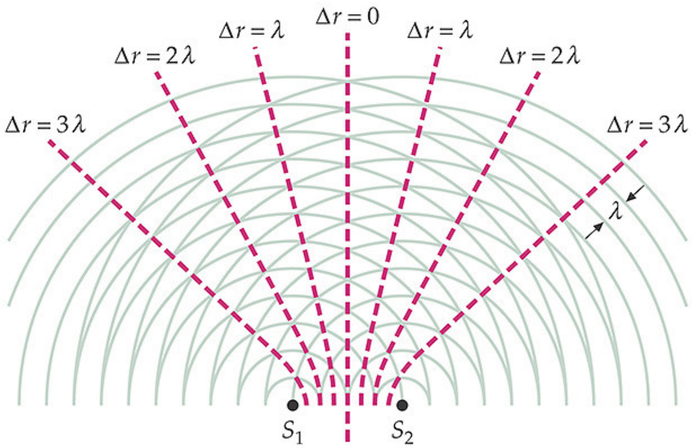
Detailed Interference Geometry



Constructive Destructive

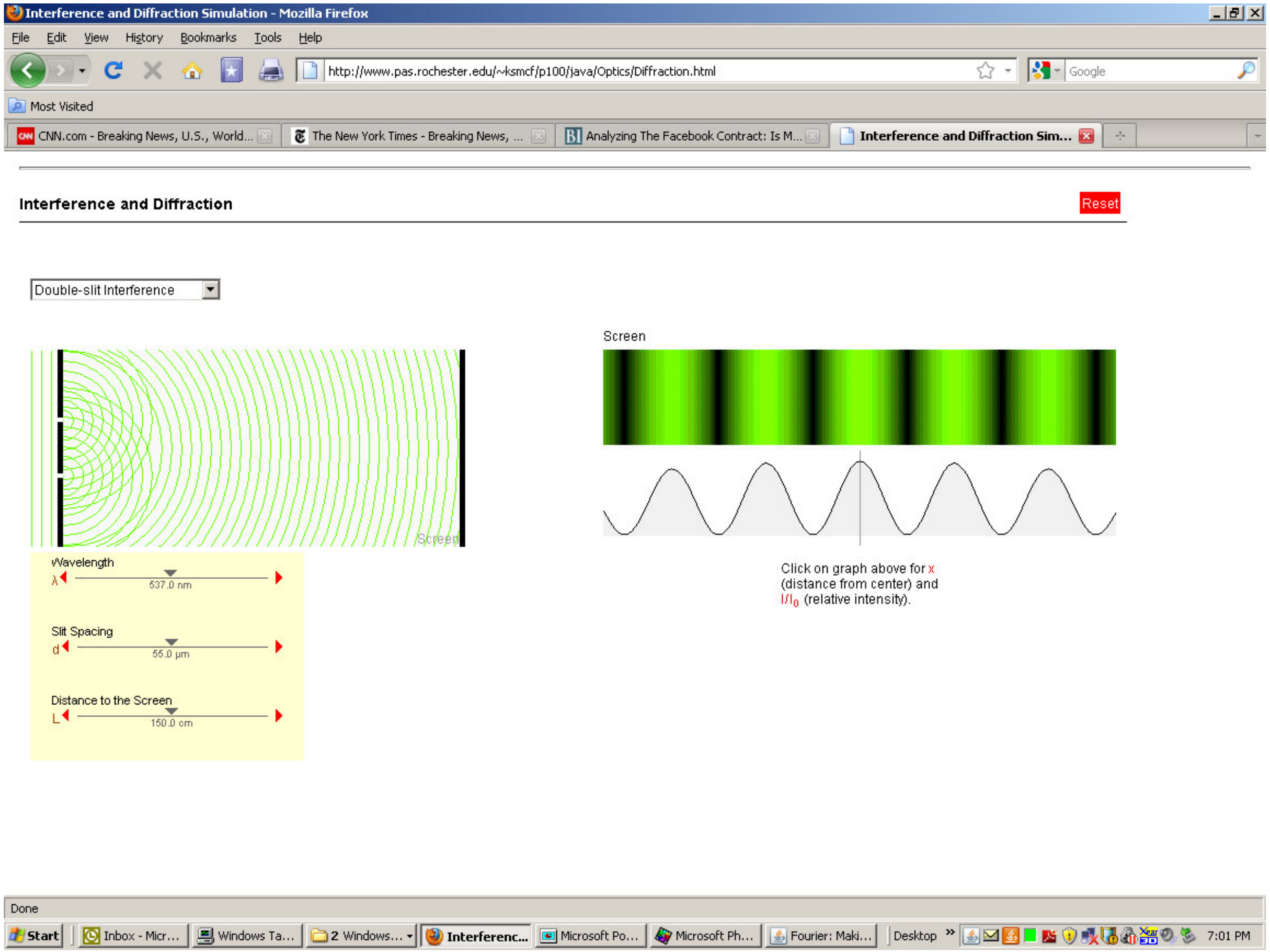
Interference in a Ripple Tank


(a)

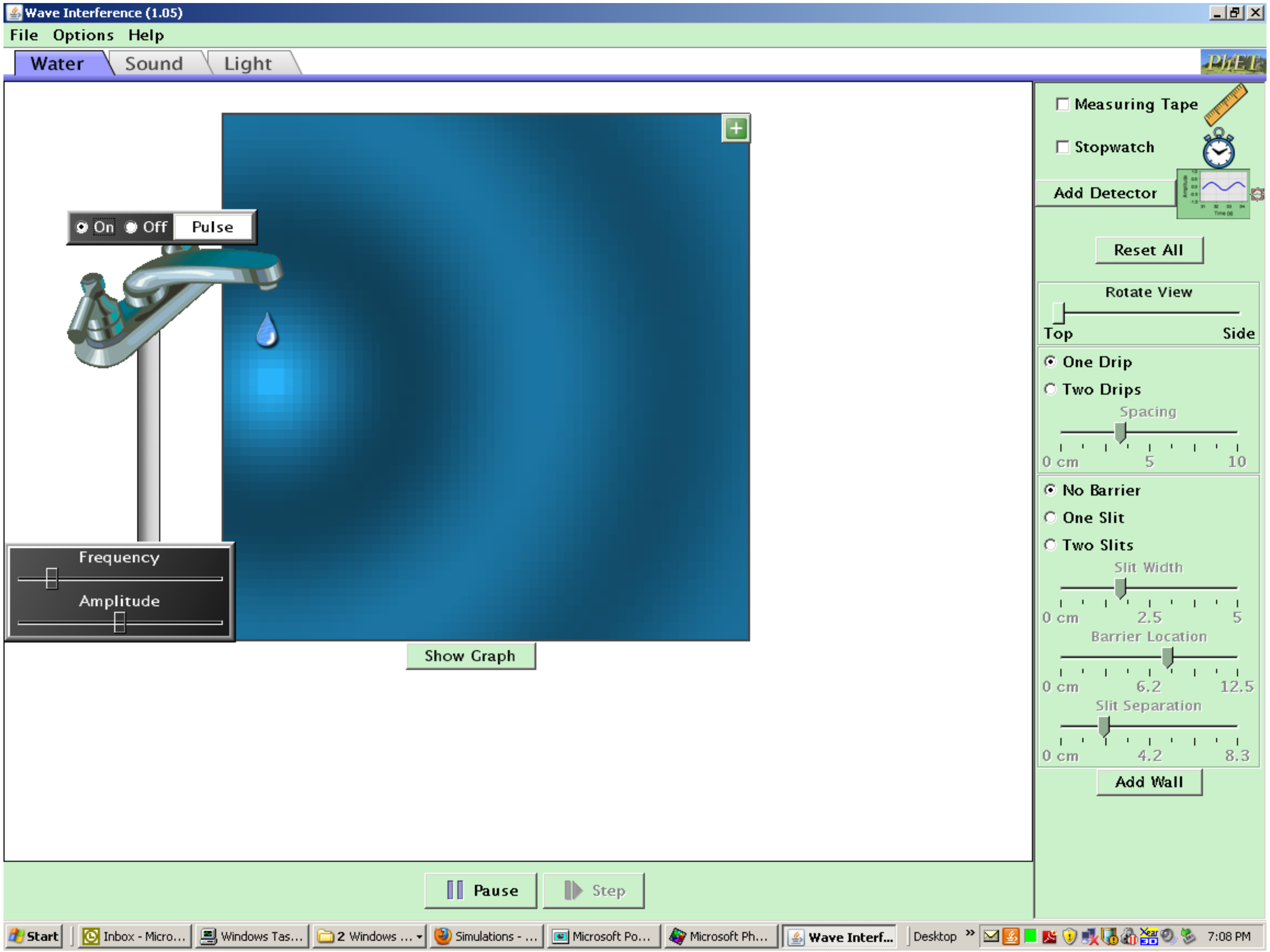


(b)

Interference & Diffraction



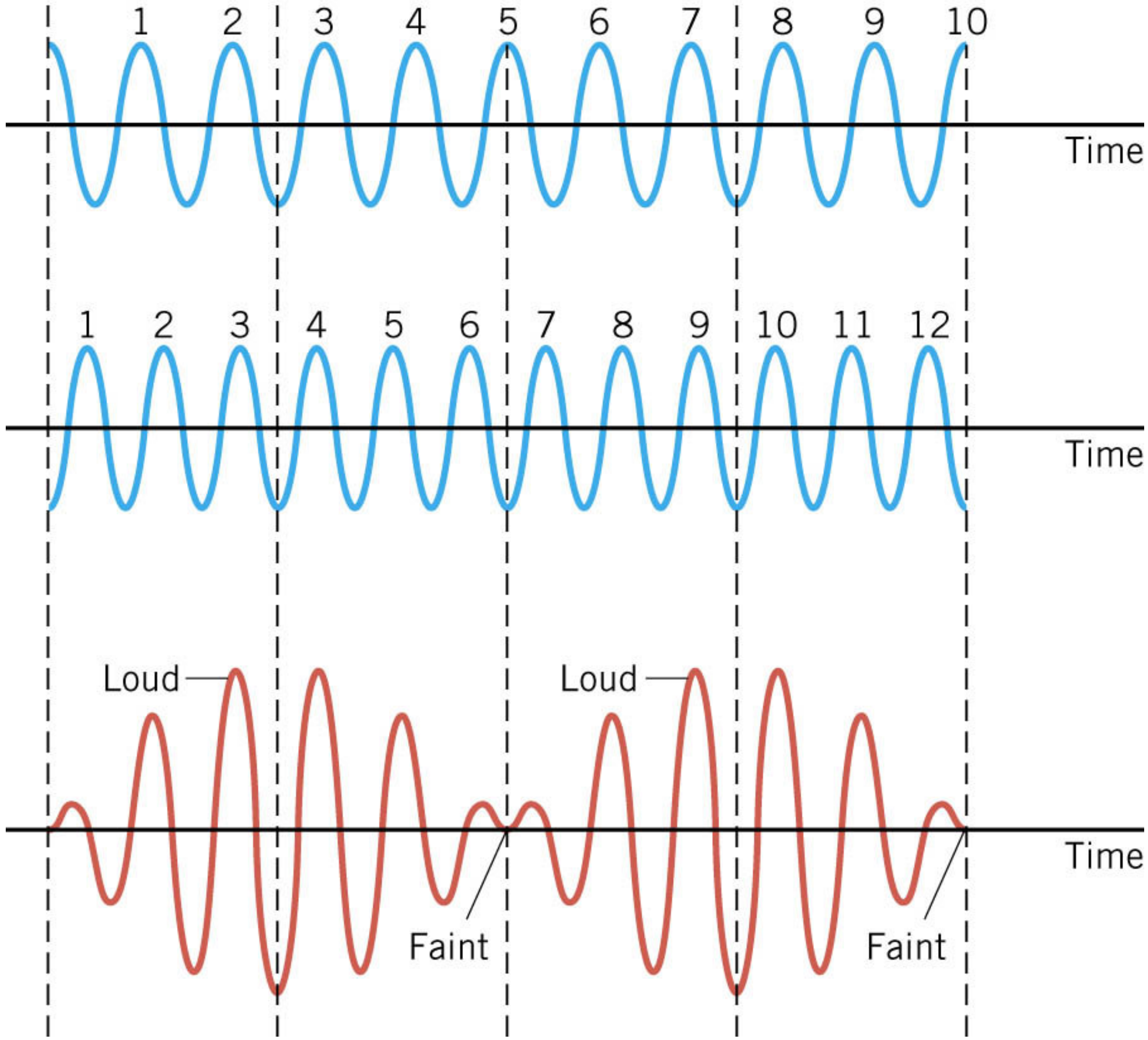
http://www.pas.rochester.edu/~ksmcf/p100/java/Optics/Diffraction.html



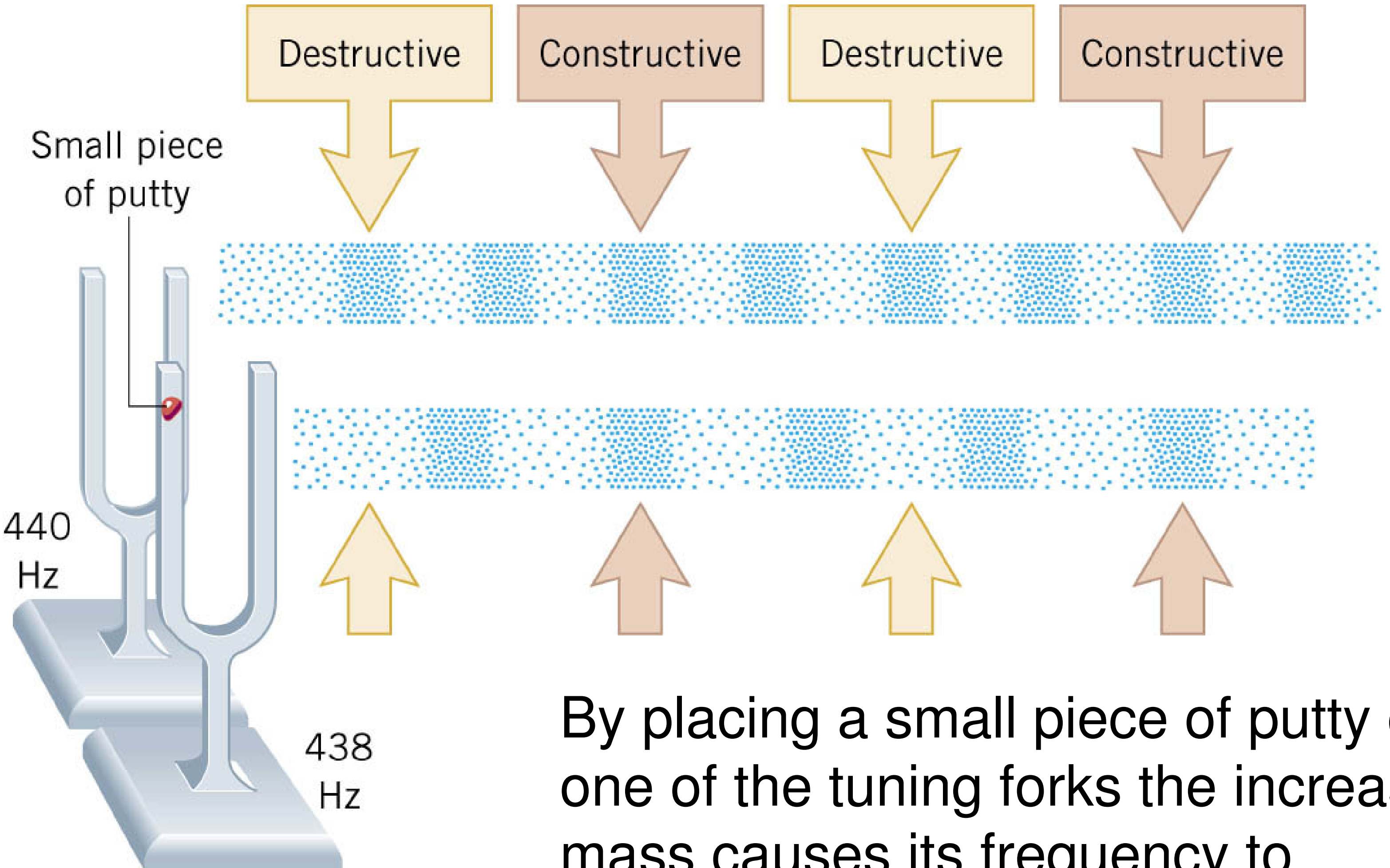
http://www.austincc.edu/mmcgraw/simulations/wave-interference.jar

Beats

Beats

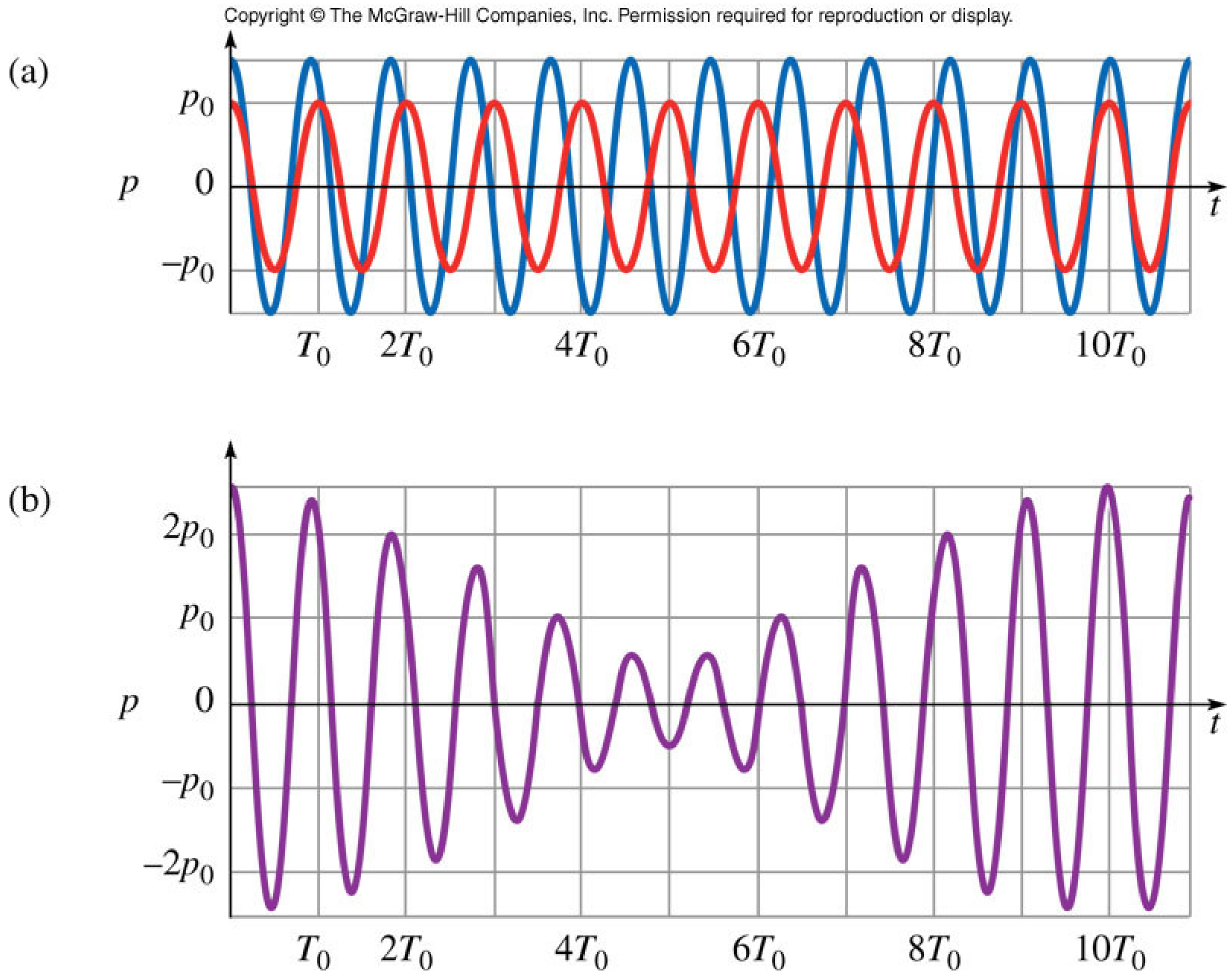

1
2
3
4
5
6
7
8
9
10
Time
1
2
3
4
5
6
7
8
9
10
11
12
Time
Loud
Loud
Time
Faint
Faint

Beat Frequency Example



By placing a small piece of putty on one of the tuning forks the increased mass causes its frequency to decrease slightly.

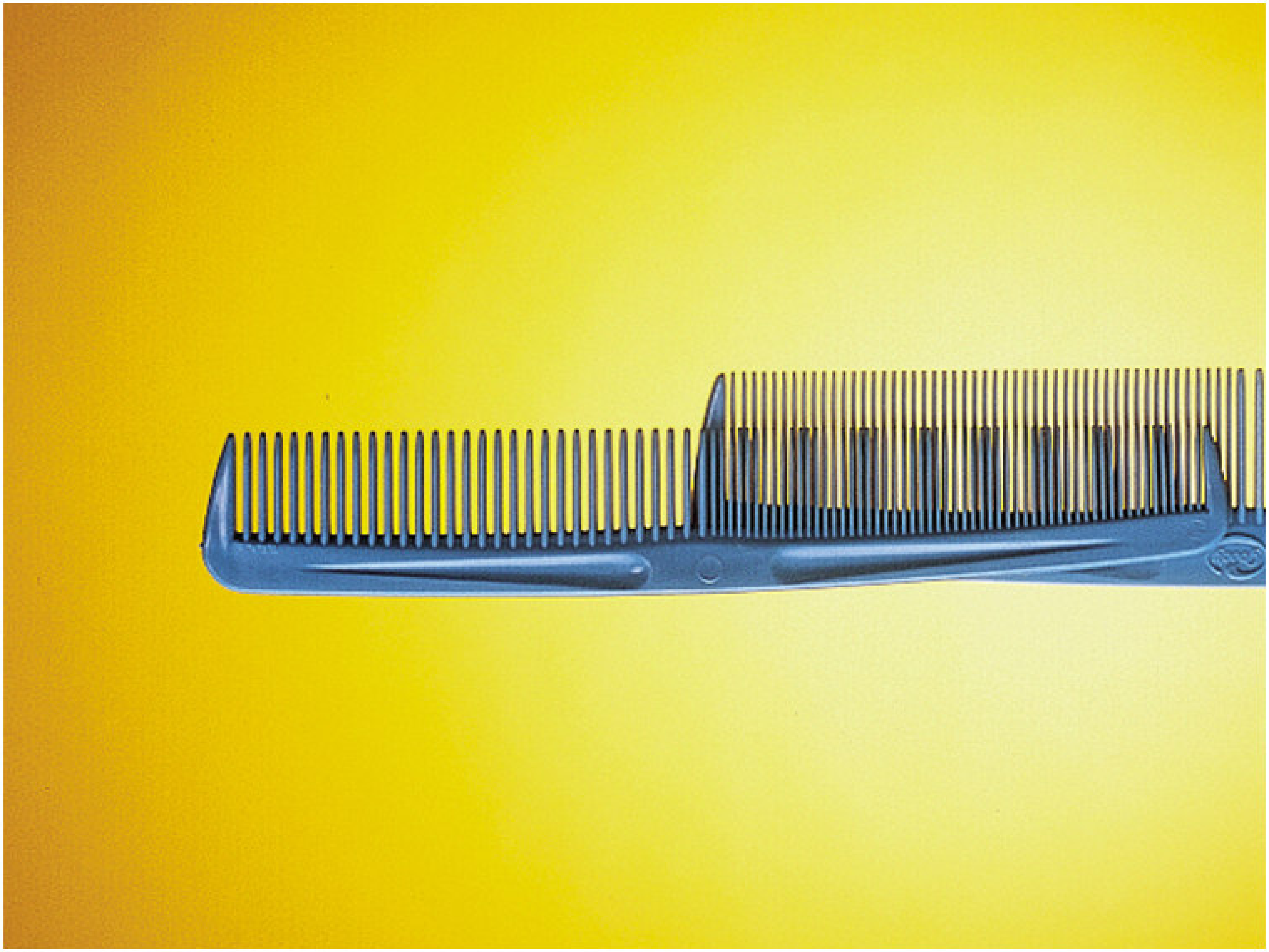
Beat Frequency



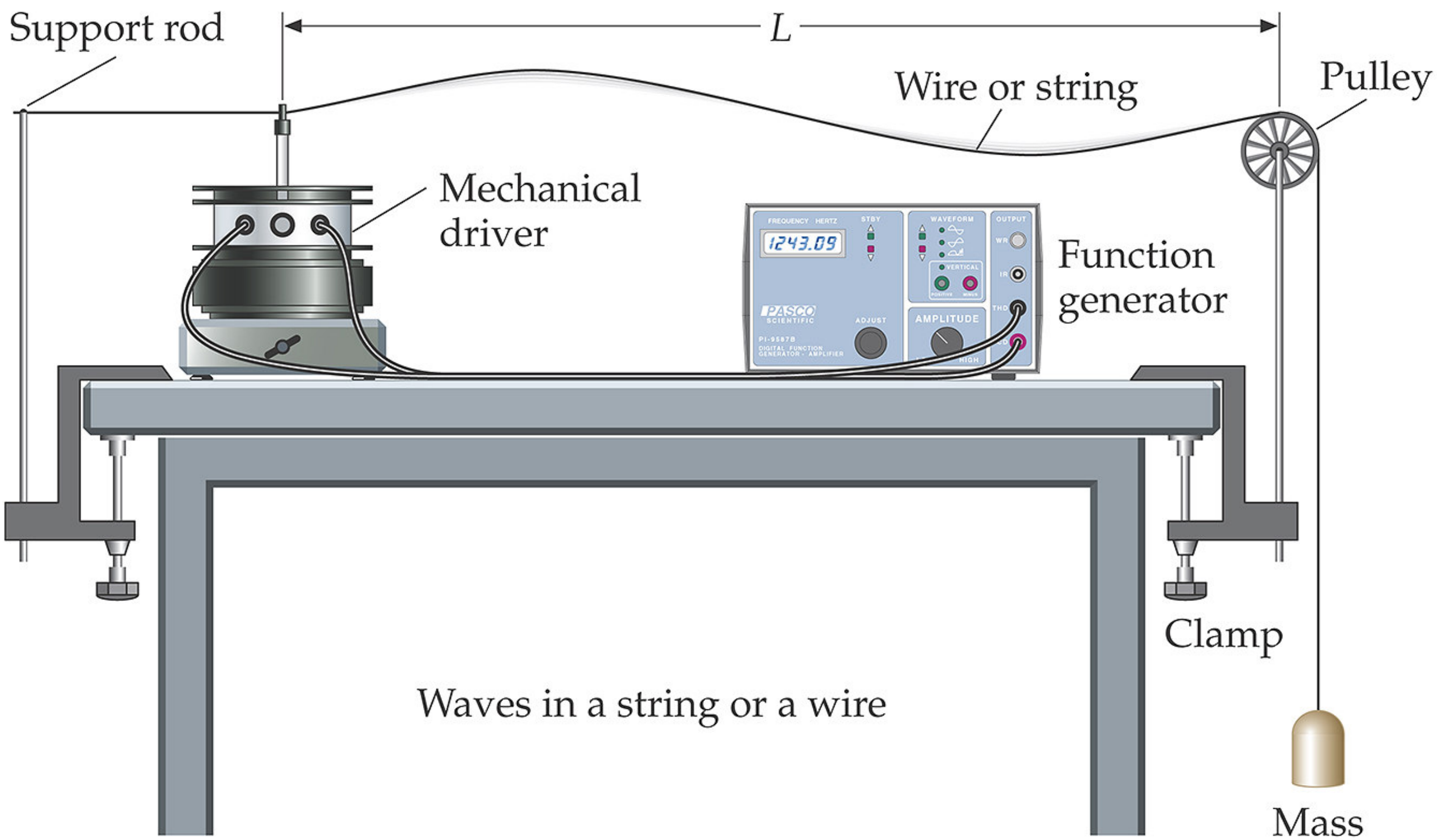
Two waves of different frequency

Superposition of the above waves

The beat frequency is $\Delta f = f_1 - f_2$

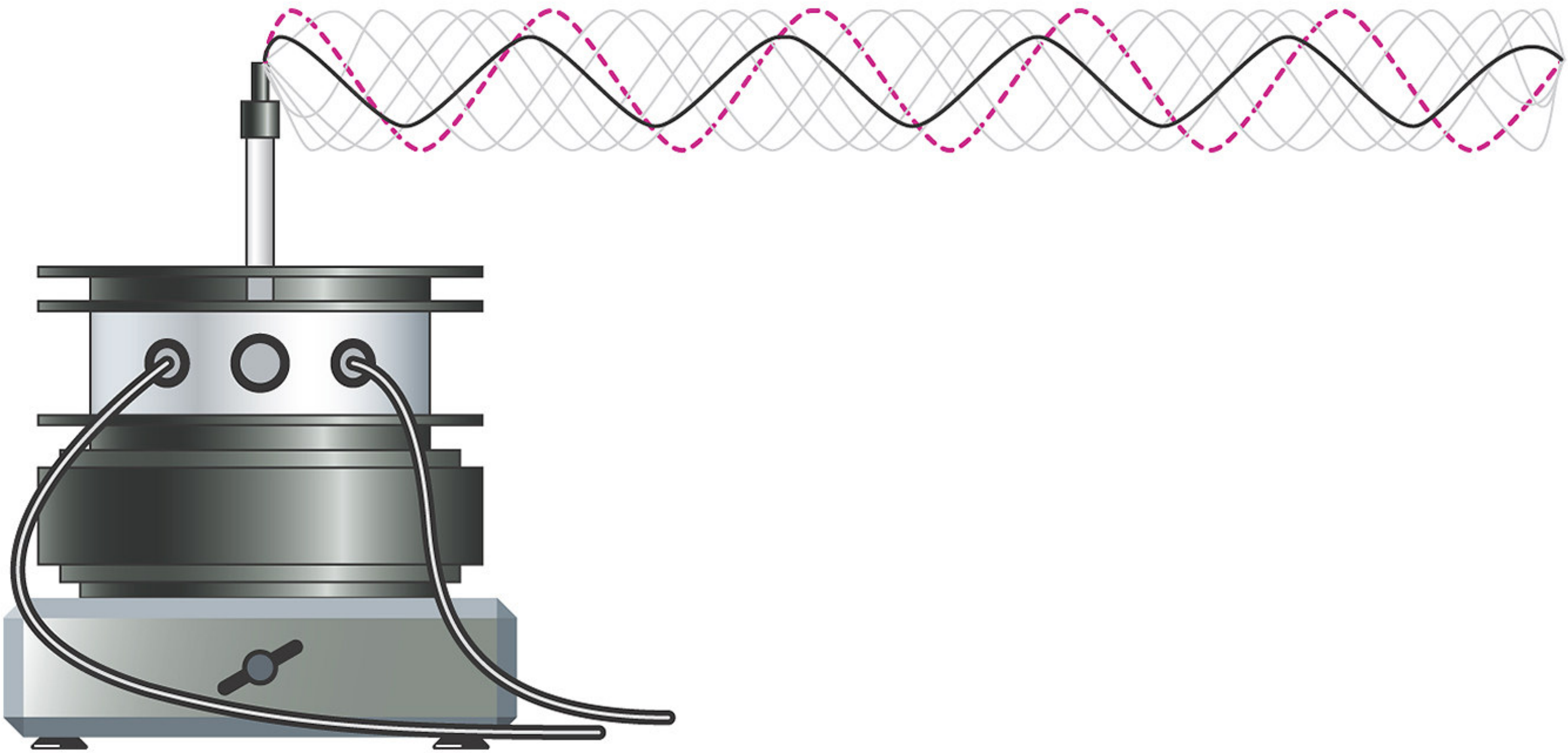


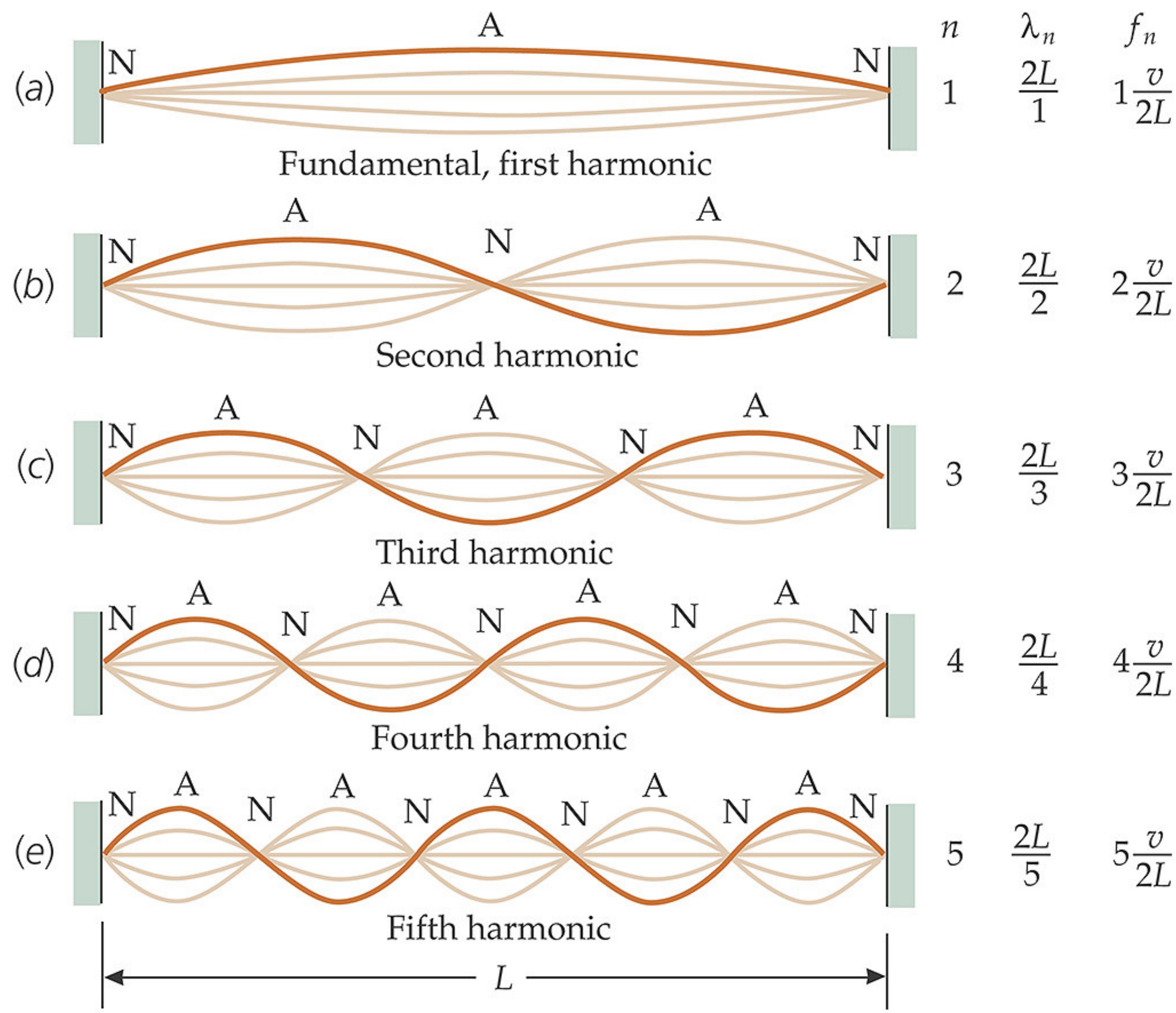
Standing Wave on a String



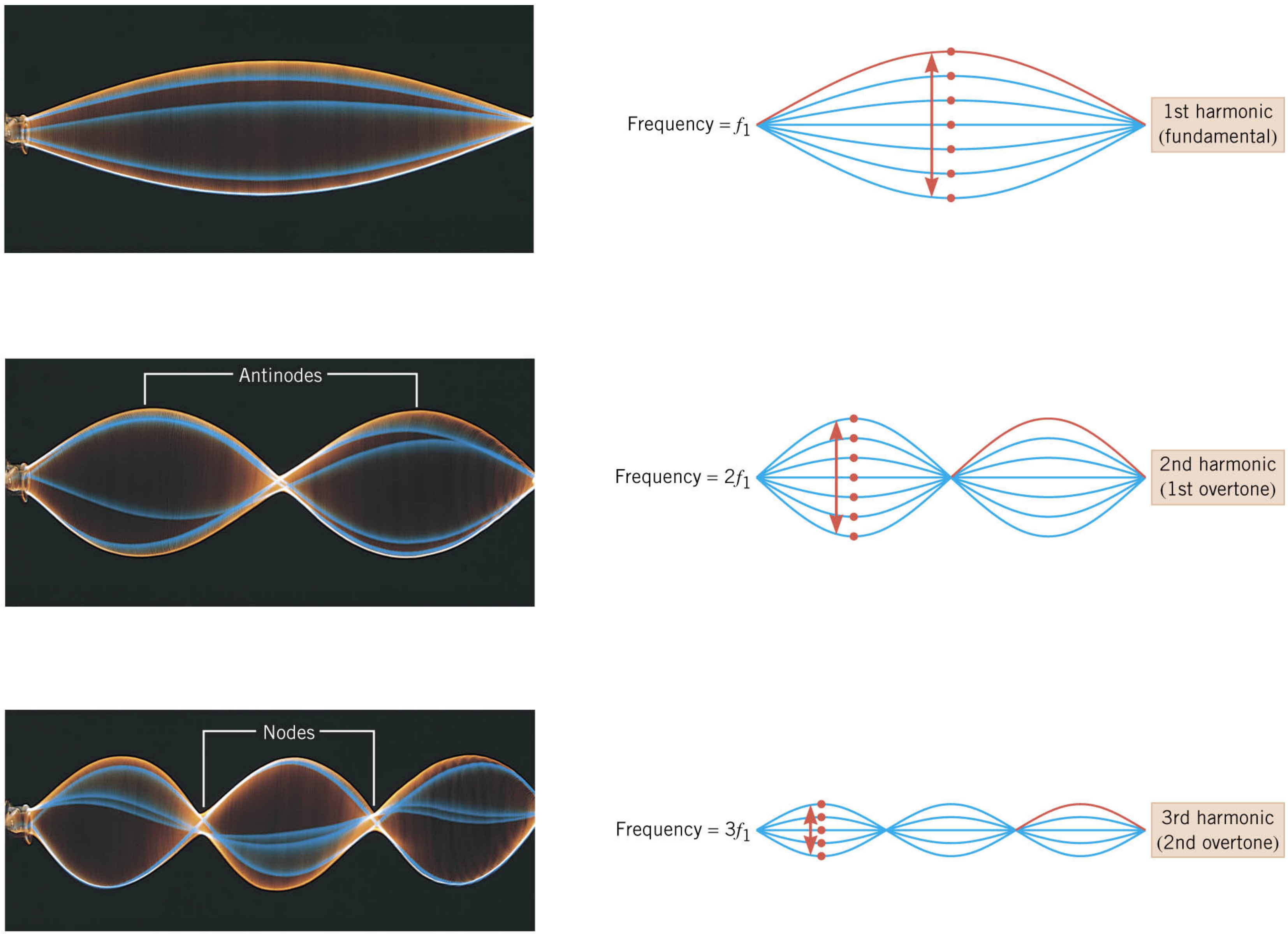
Waves in a string or a wire

Tunable Standing Wave Generator



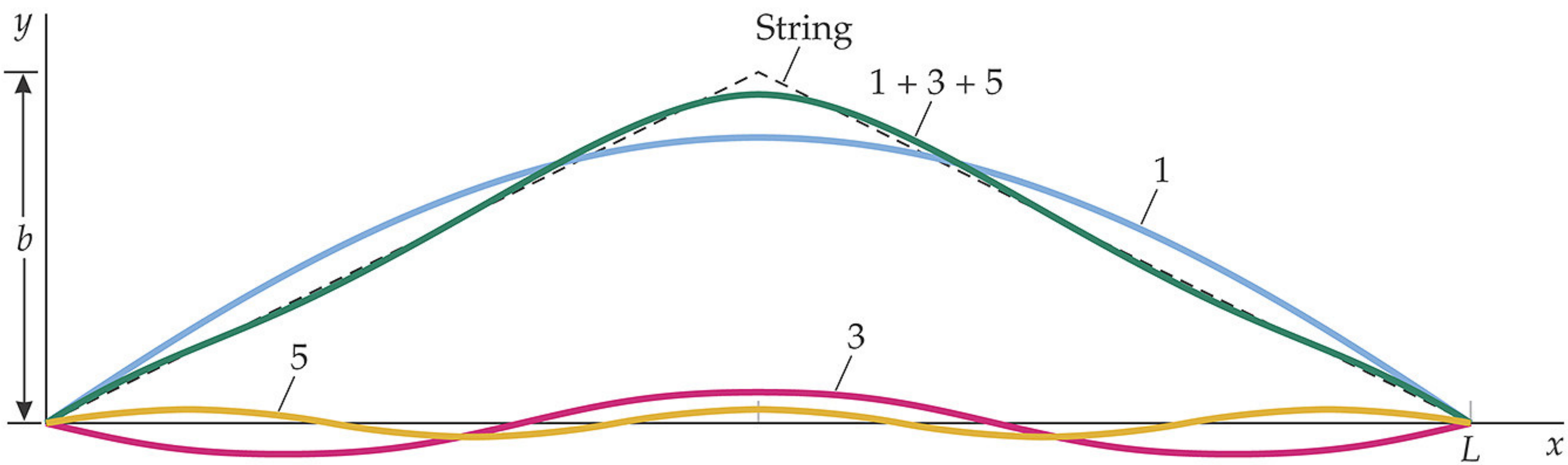


n
λn
fn
(a)
N
A
N
1
2L/1
1 v/2L
Fundamental, first harmonic
(b)
N
A
N
A
N
2
2L/2
2 v/2L
Second harmonic
(c)
N
A
N
A
N
A
N
3
2L/3
3 v/2L
Third harmonic
(d)
N
A
N
A
N
A
N
A
N
4
2L/4
4 v/2L
Fourth harmonic
(e)
N
A
N
A
N
A
N
A
N
A
N
5
2L/5
5 v/2L
Fifth harmonic
L


Frequency = f_1
1st harmonic (fundamental)
Antinodes
Frequency = $2f_1$
2nd harmonic (1st overtone)
Nodes
Frequency = $3f_1$
3rd harmonic (2nd overtone)
(*a*)
(*b*)
(*c*)

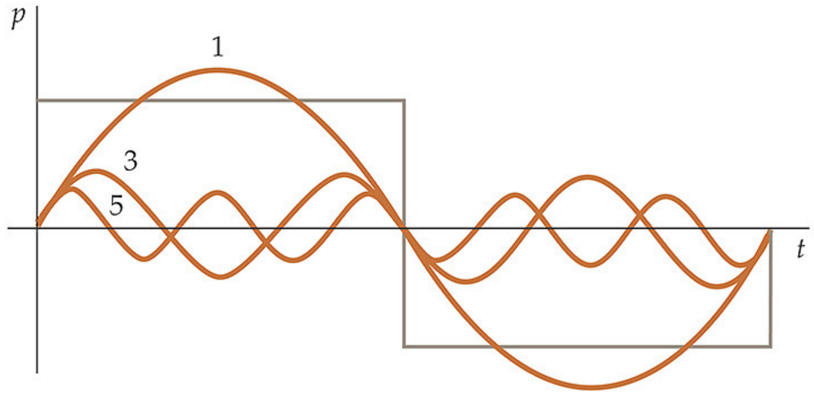
Fourier Analysis

Fourier Analysis

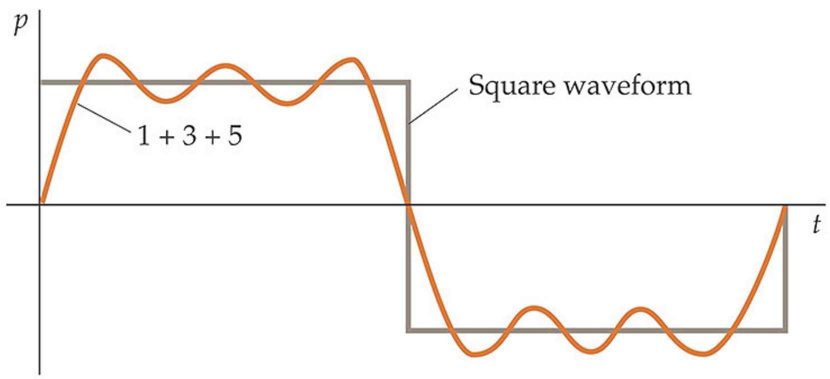


Every waveform can be broken down into its frequency components.

Fourier Analysis - Square Wave

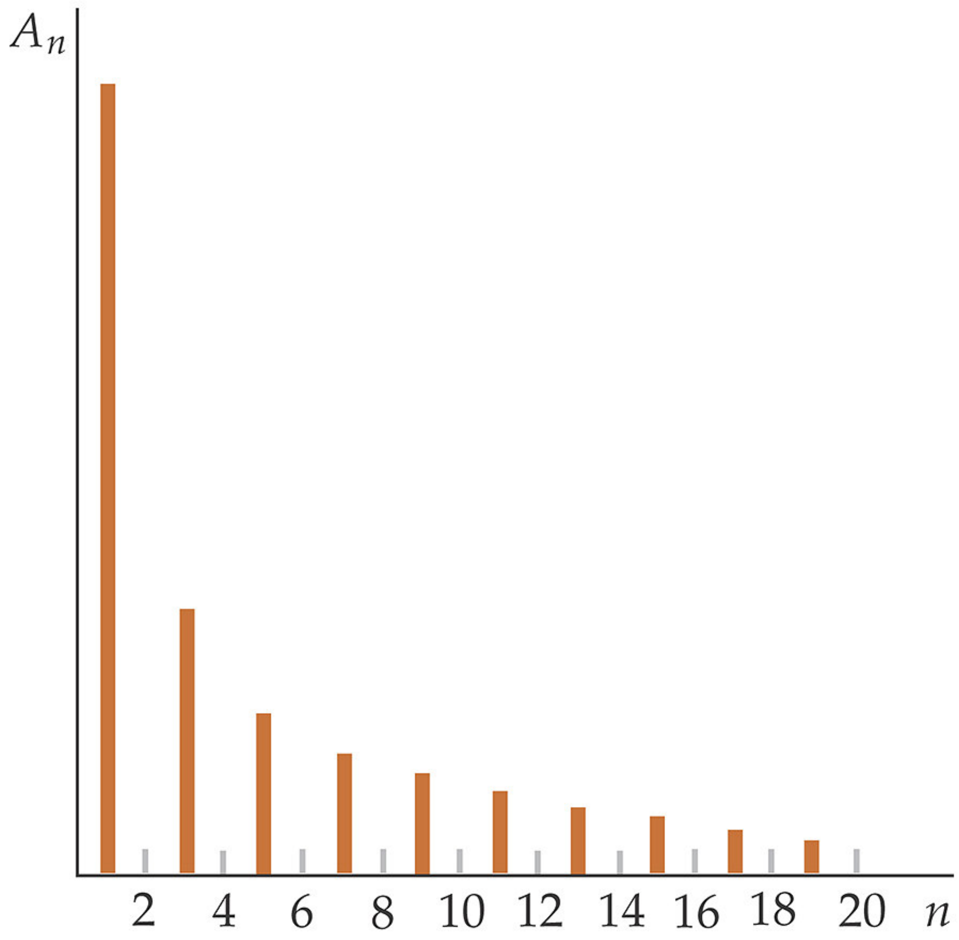


(a)



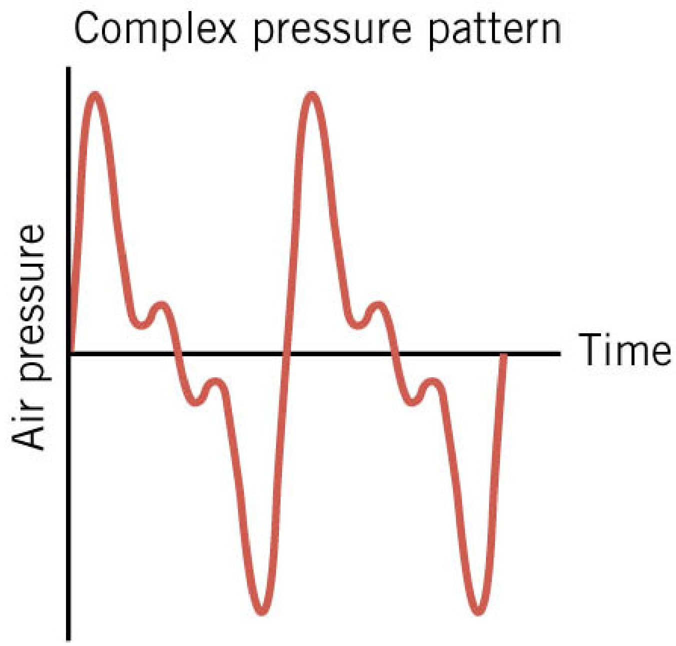
(b)

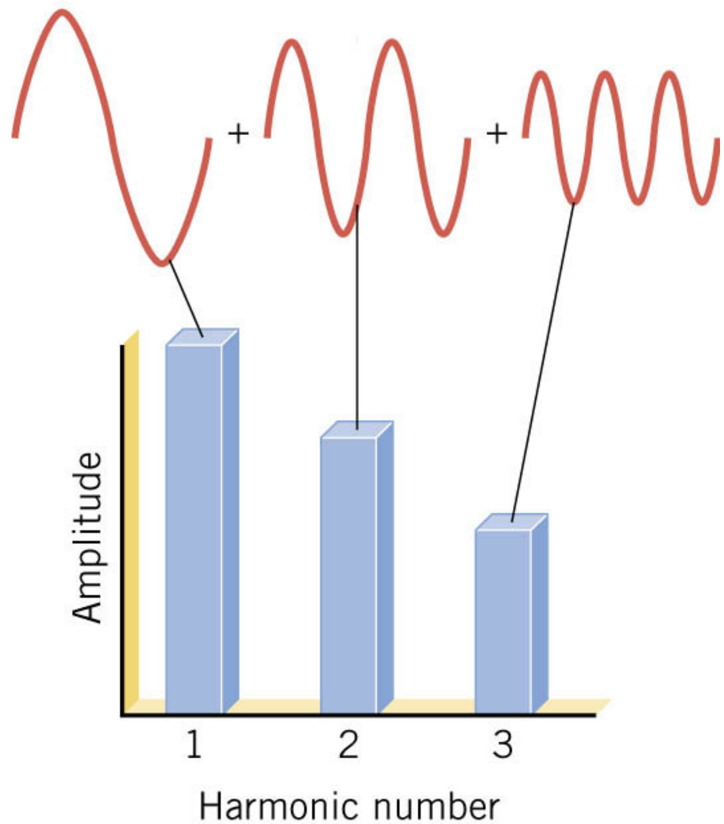
Frequency Component Amplitude



Wave Components in Frequency Space

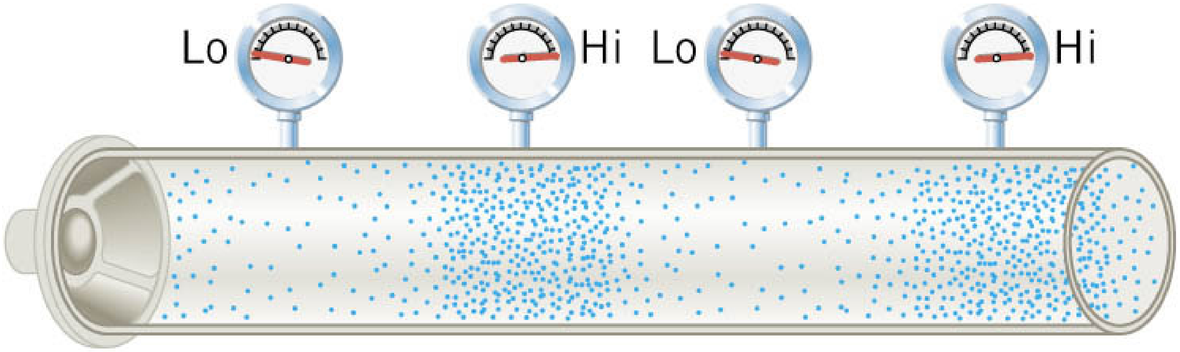
Fourier Analysis

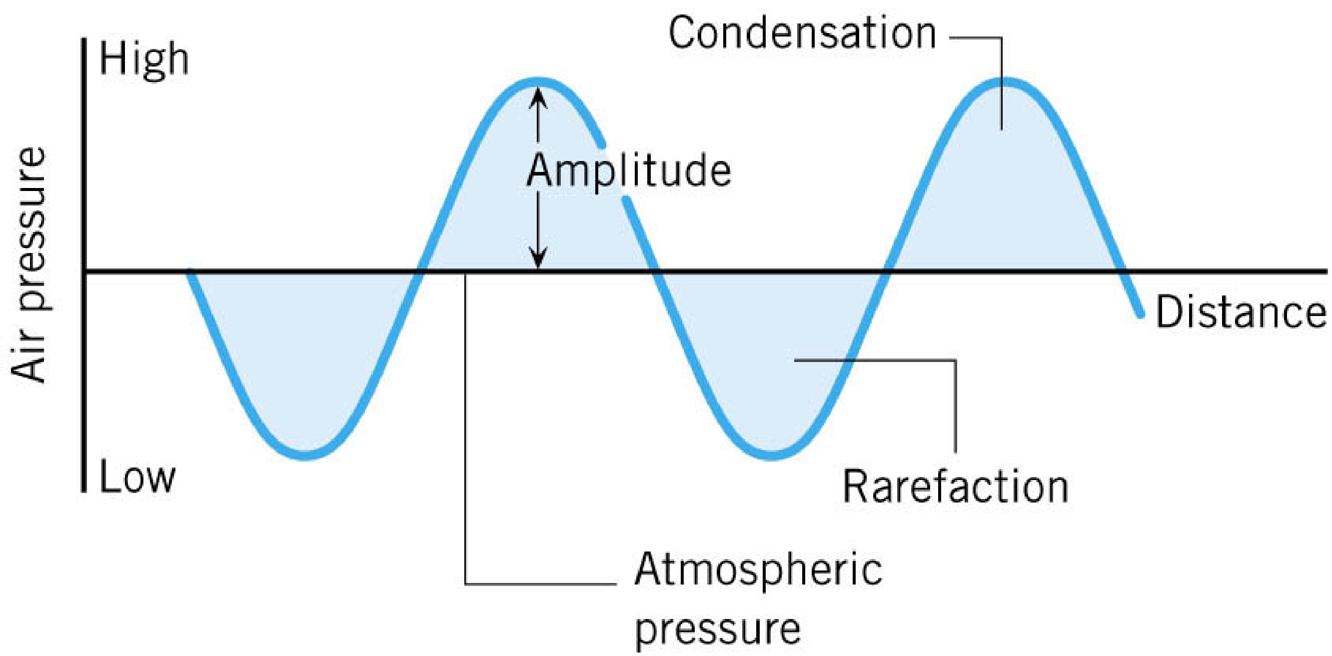




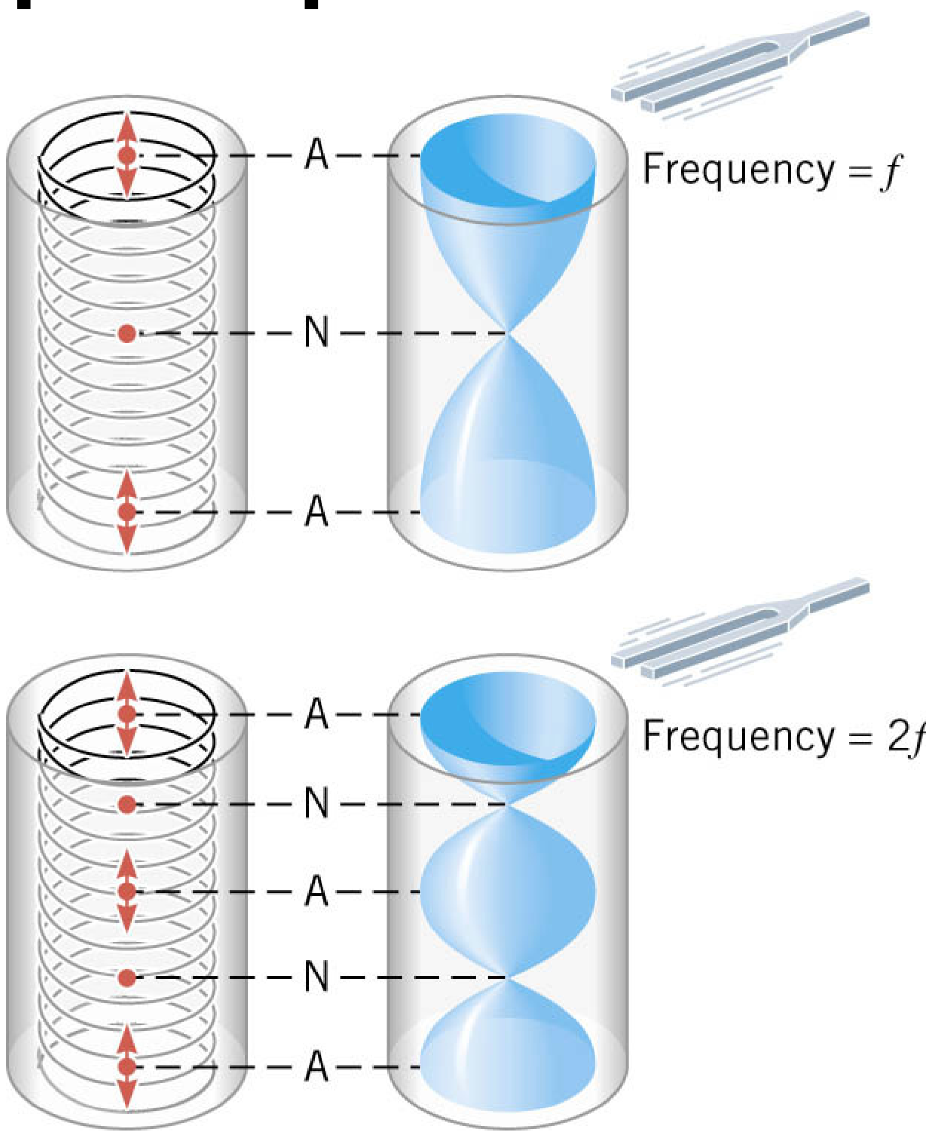
Musical Instruments

Pressure Variations in a Pipe

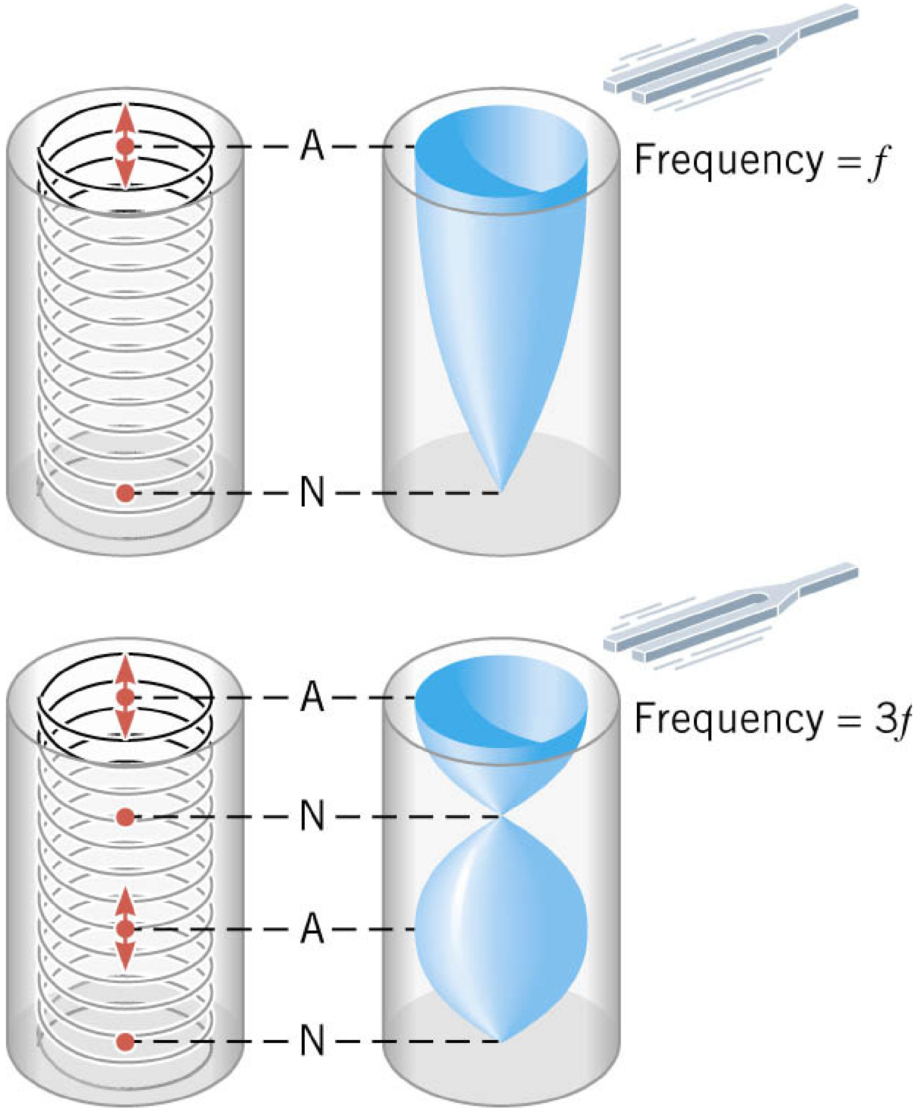




Open Pipe Resonator

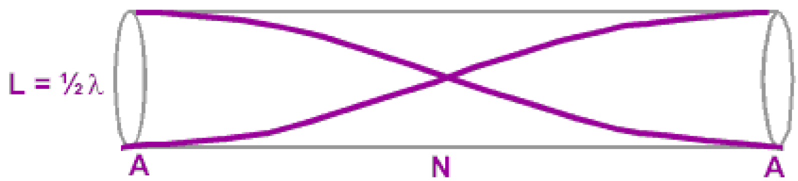


Closed Pipe Resonator



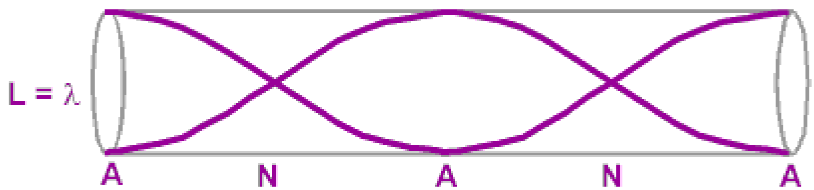
Open and Closed Pipes

Resonance States

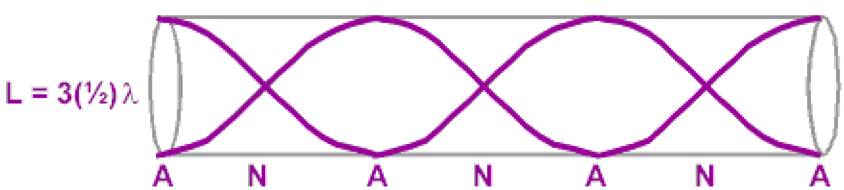


fundamental frequency f_o

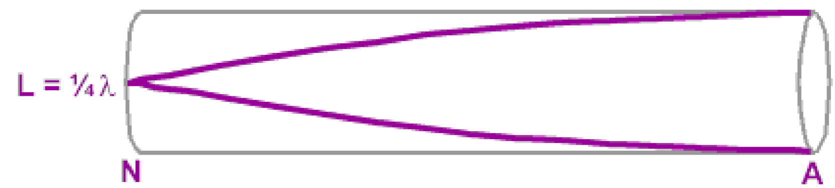
1st harmonic



2nd harmonic f_1 = **2**f_o

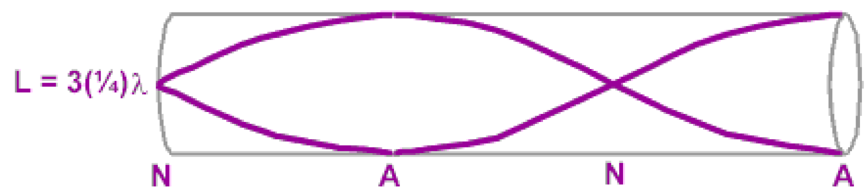


3th harmonic f_2 = **3**f_o

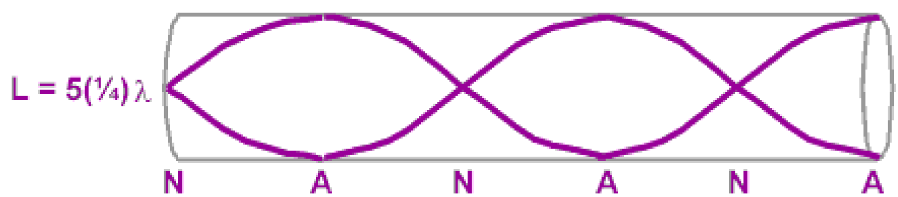


fundamental frequency f_o

1st harmonic



3rd harmonic f_1 = **3**f_o



5th harmonic f_2 = **5**f_o

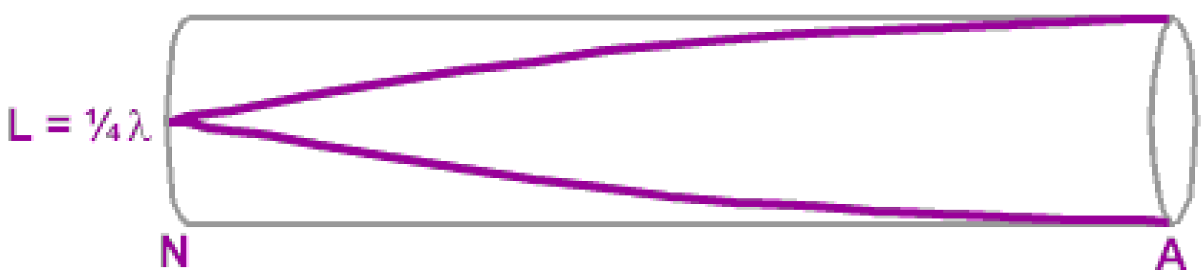
Pipe Resonator Calculations

Natural frequency dependent on length of pipe

For closed pipe - no "even harmonics”

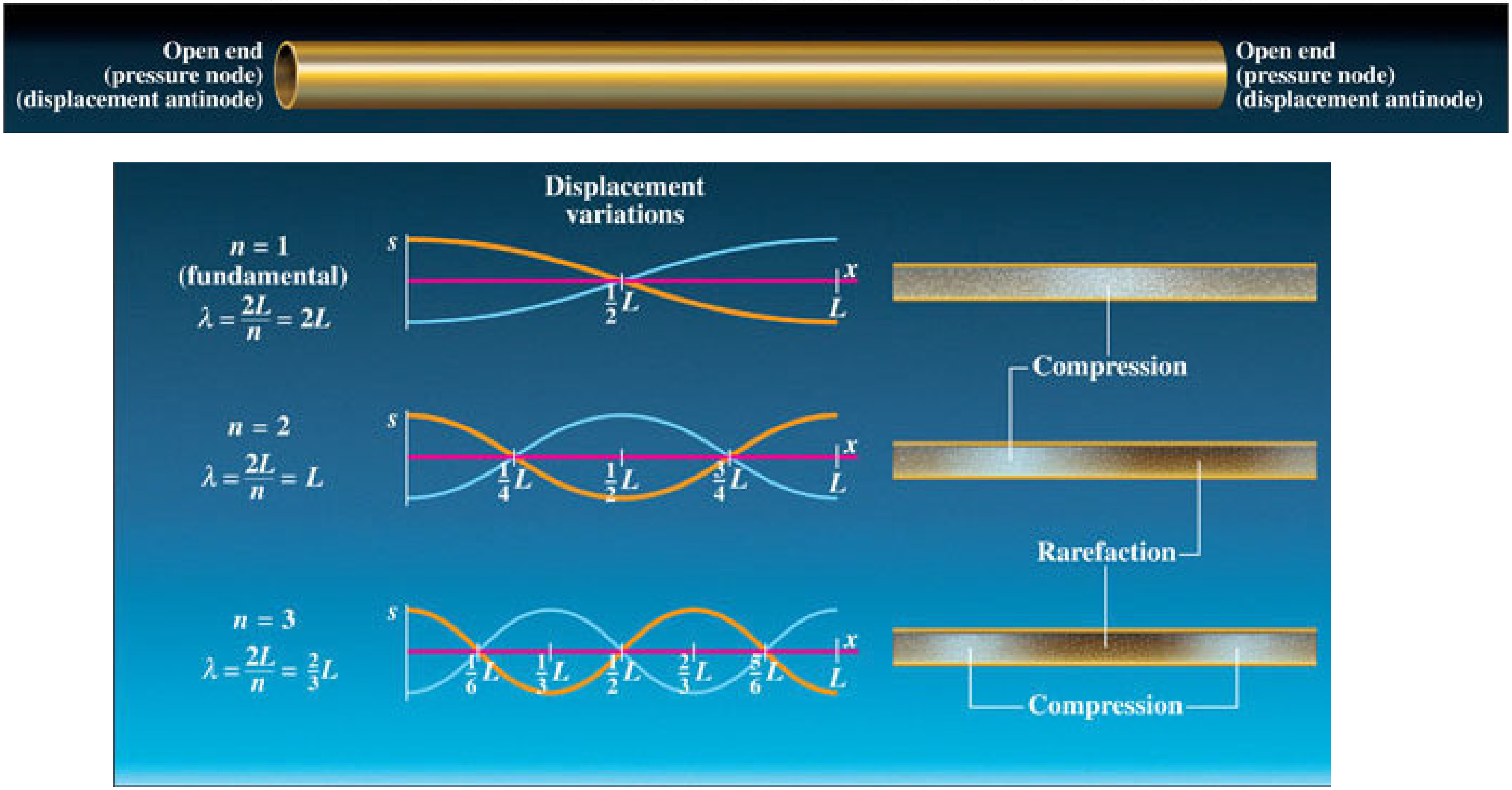
Fundamental frequency is a half-loop or ¼ L.
Since every harmonic represents the addition of a complete loop, which contains two half-loops, we can never add just one more half-loop.

Thus, we cannot generate even harmonics in closed pipes.

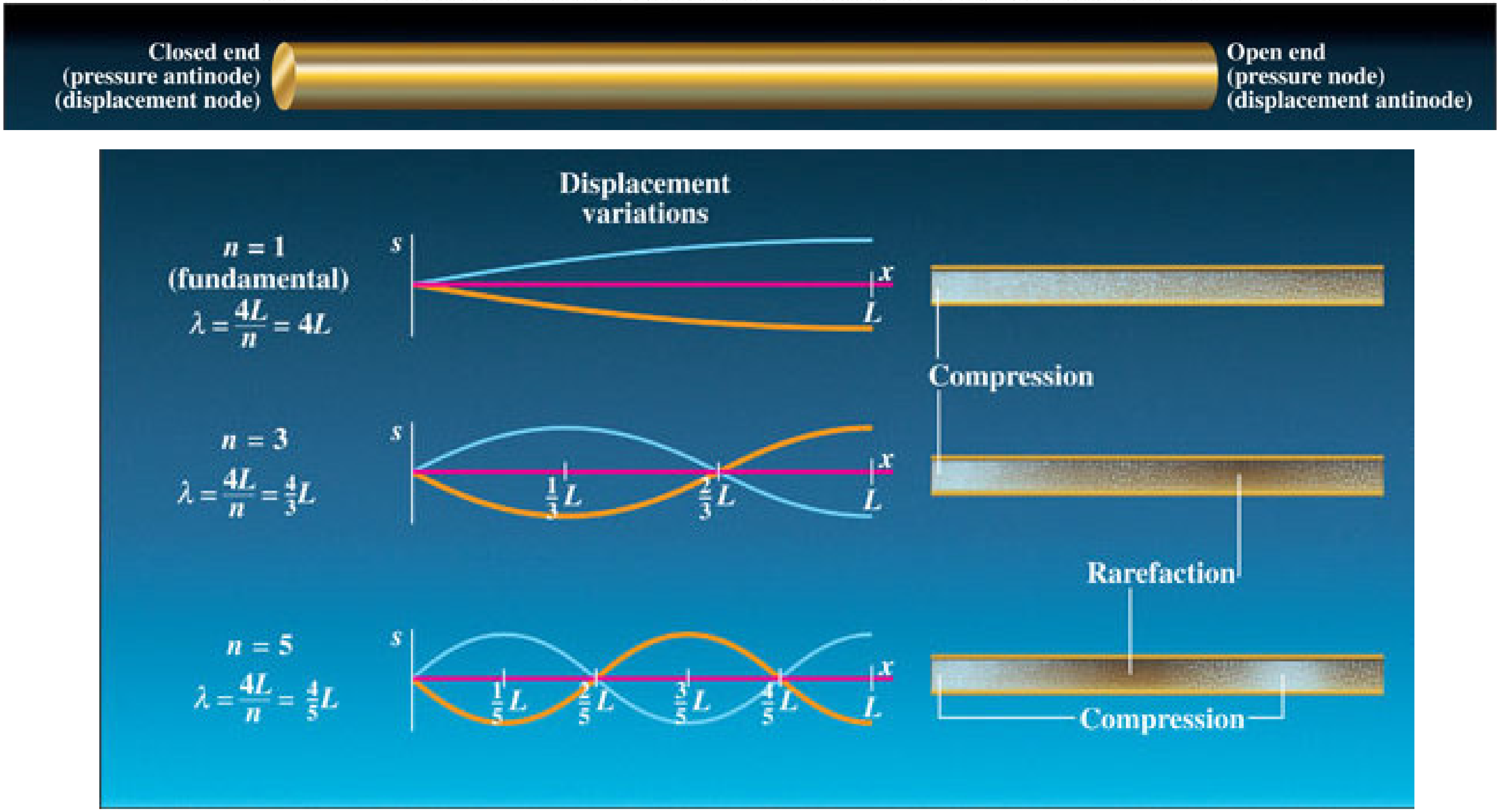


Pipe Resonator Calculations

Open Pipe Resonator



Closed Pipe Resonator



Musical Instruments

Frequency Components

Fundamental Wave and the 4th Harmonic

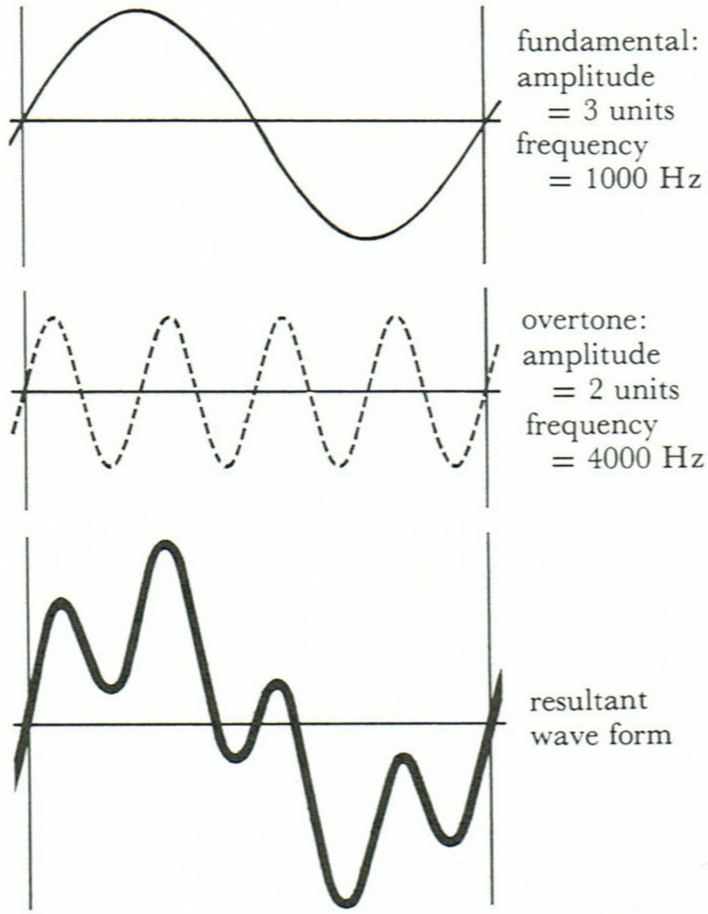
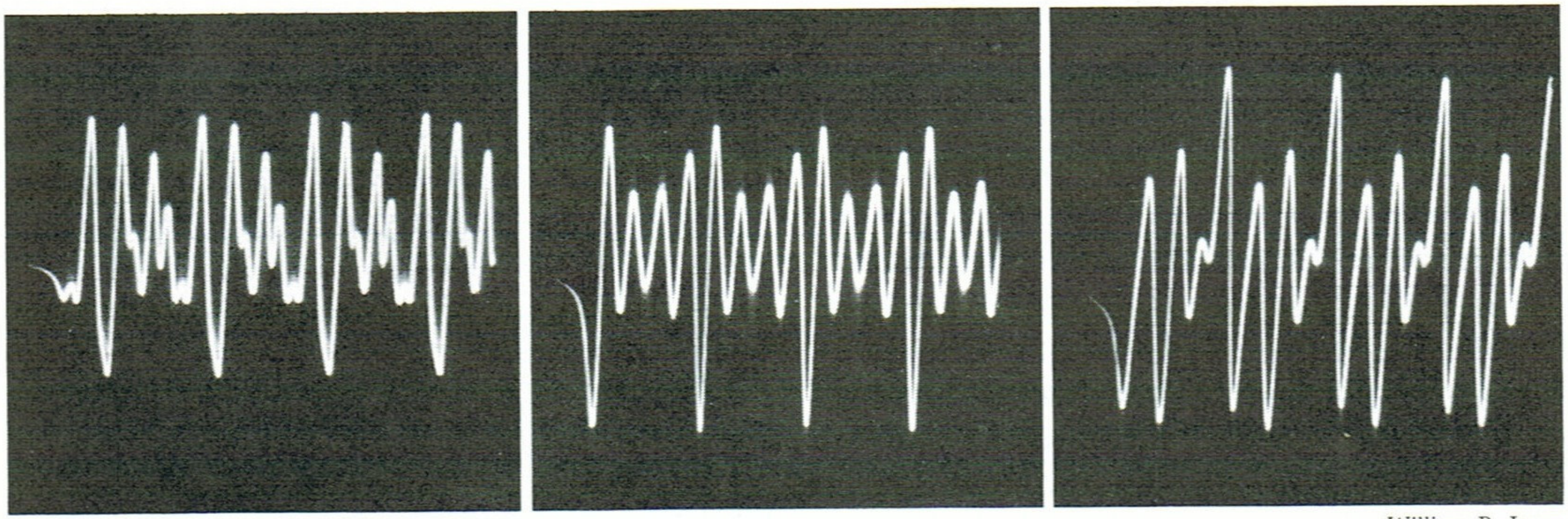


Figure 11-14

Musical Instrument Waveforms

Violin **Trumpet** **Clarinet**

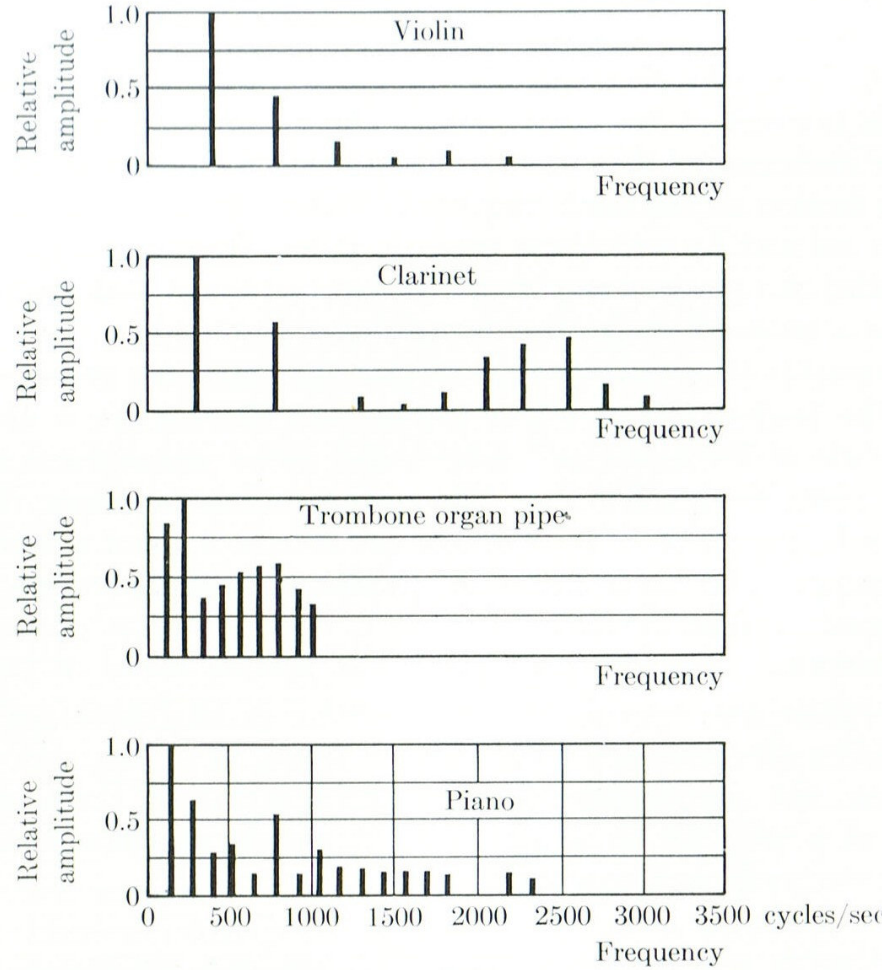


William B. Joyce

(a) (b) (c)

Figure 11-13 Wave forms of musical sounds. (a) Violin; (b) trumpet; (c) clarinet.

Frequency Component Structure



Violin

Clarinet

Organ Pipes

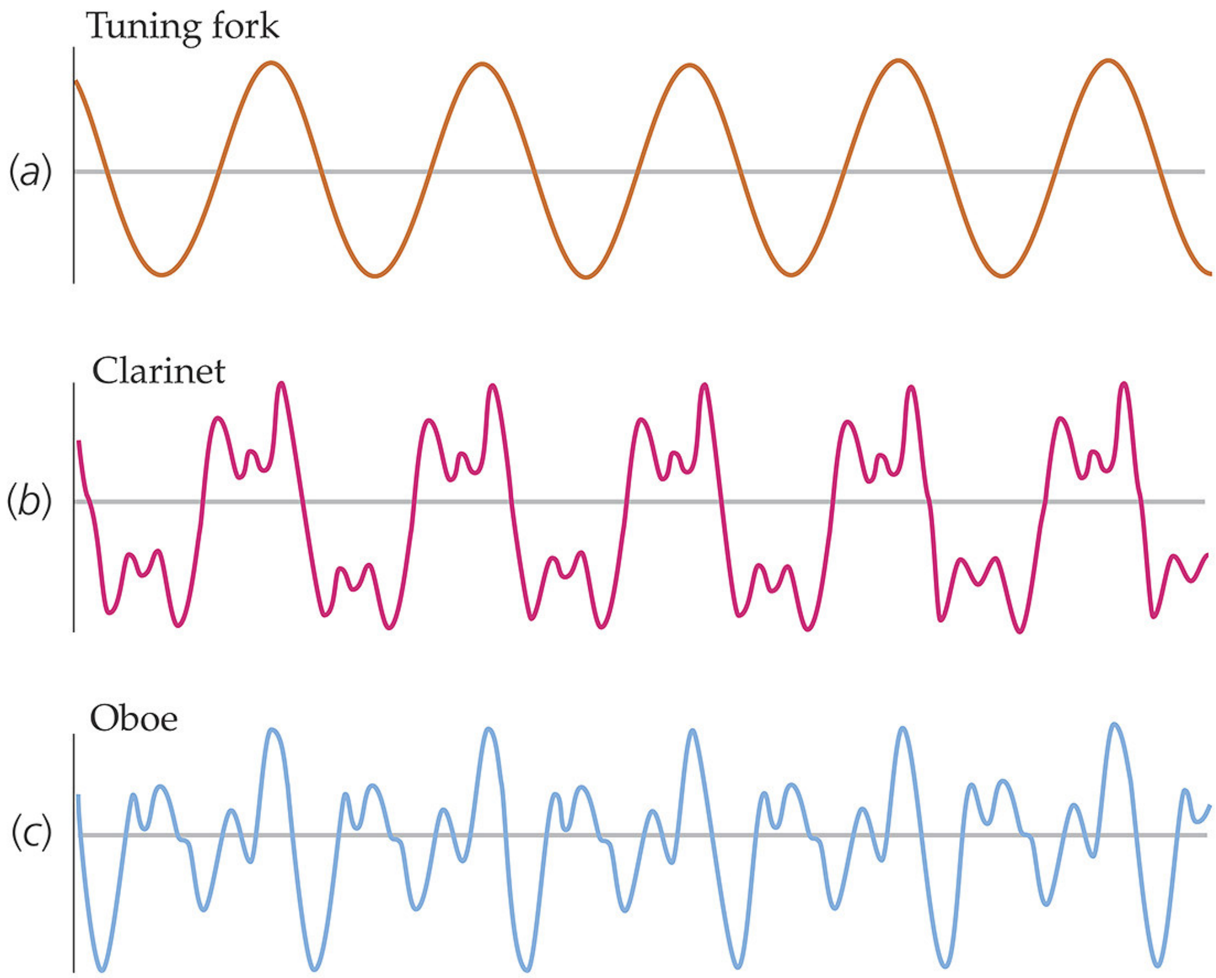
Piano

FIG. 13–14. Sound spectra of some musical instruments. (Courtesy of Dr. Harvey Fletcher.)

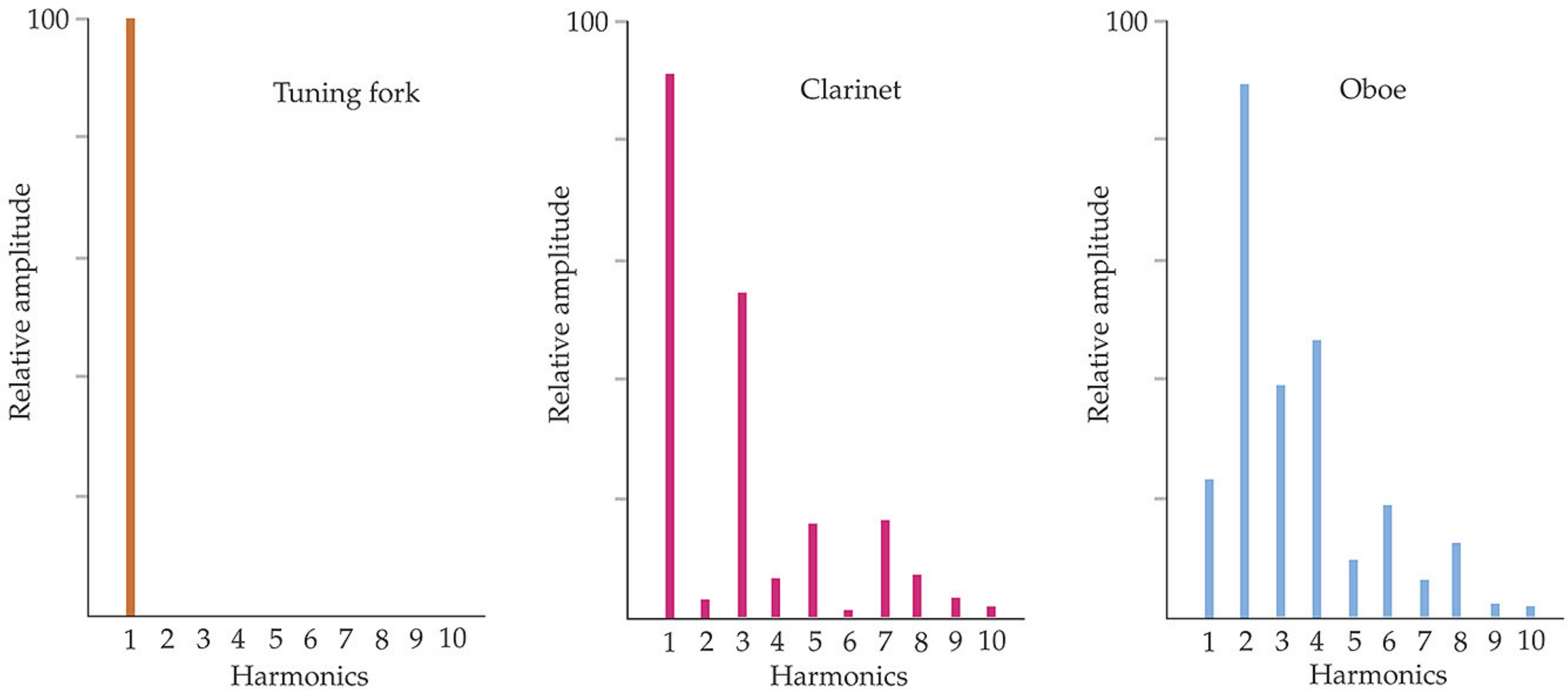
Typical Musical Overtone Structures

CLARINET		FRENCH HORN	
Frequency, Hz	Relative intensity, %	Frequency, Hz	Relative intensity, %
400	36	100	3
800	0	200	22
1200	34	300	24
1600	9	400	44
2000	17	500	3
.	.	600	2
.	.	700	1
.	.		
4000	3		

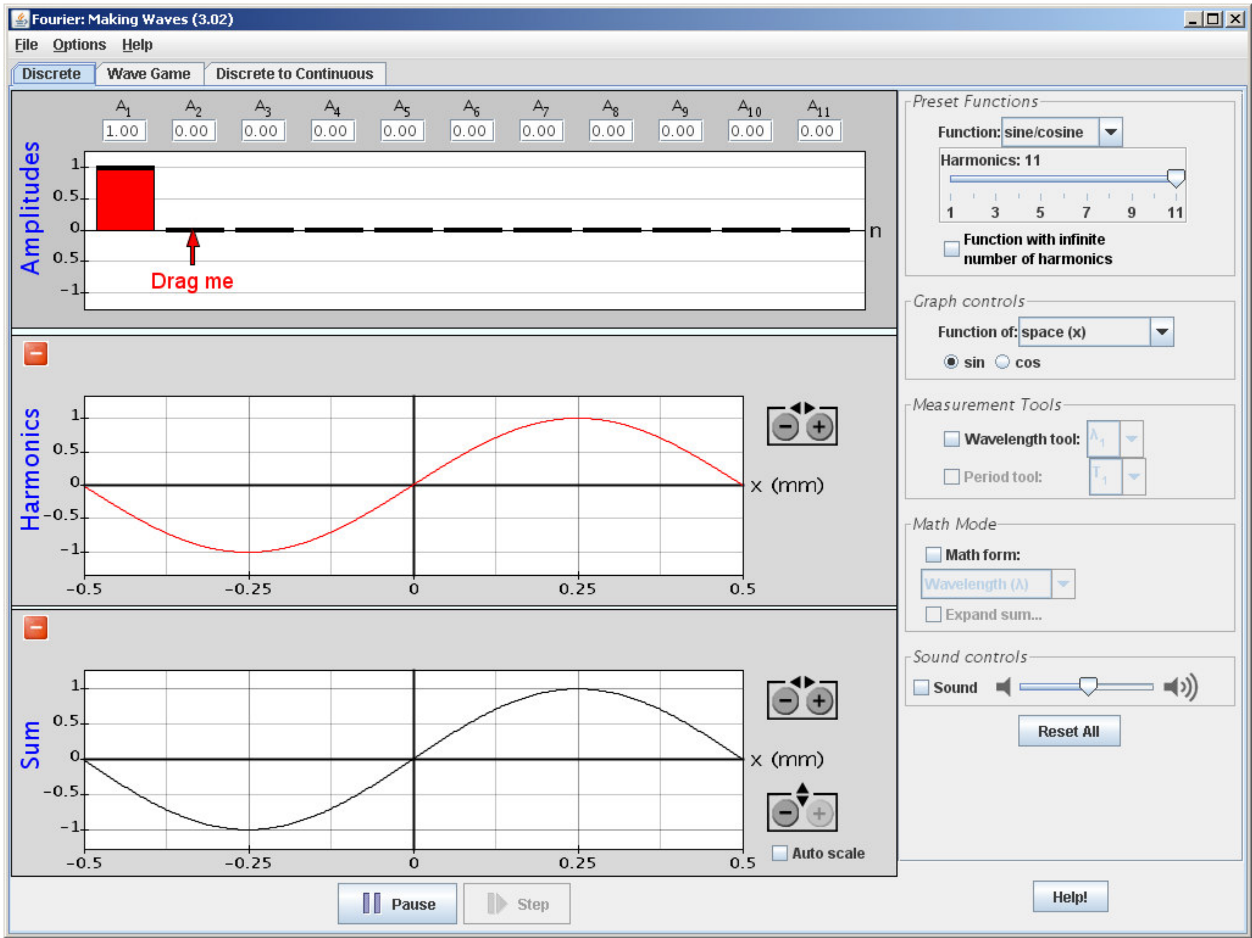
Musical Sound Waveforms



Musical Sound Frequency Spectrum



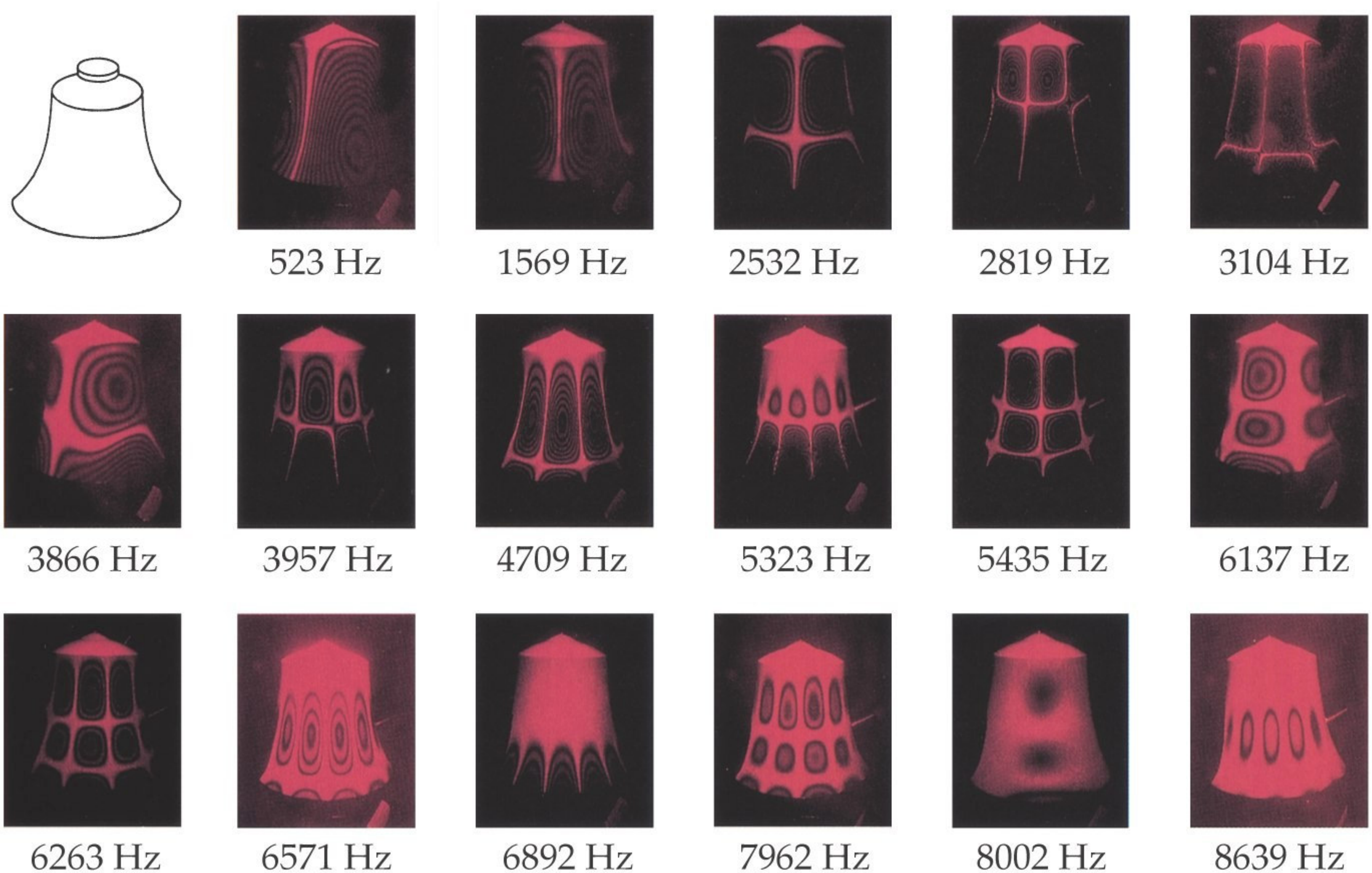
Fourier Analysis



http://www.austincc.edu/mmcgraw/simulations/fourier.jar

Standing Wave Patterns

Ringing Bell - Resonant Modes



Guitar - Resonant Modes