# Q15.9

While a guitar string is vibrating, you gently touch the midpoint of the string to ensure that the string does not vibrate at that point.

The lowest-frequency standing wave that could be present on the string

A. vibrates at the fundamental frequency.

B. vibrates at twice the fundamental frequency.

C. vibrates at 3 times the fundamental frequency.

D. vibrates at 4 times the fundamental frequency.

E. not enough information given to decide

# Reminders

- Homework this week is extra credit
- There **IS** lab this week (Lab B)
- Final Exam: Friday, May 13, 10:15am-12:15pm **CR 306**

# Ch 16.1-4
# Sound Waves

PHYS 1210 -- Prof. Jang-Condell

# Normal modes of a string

- For a taut string fixed at both ends, the possible wavelengths are

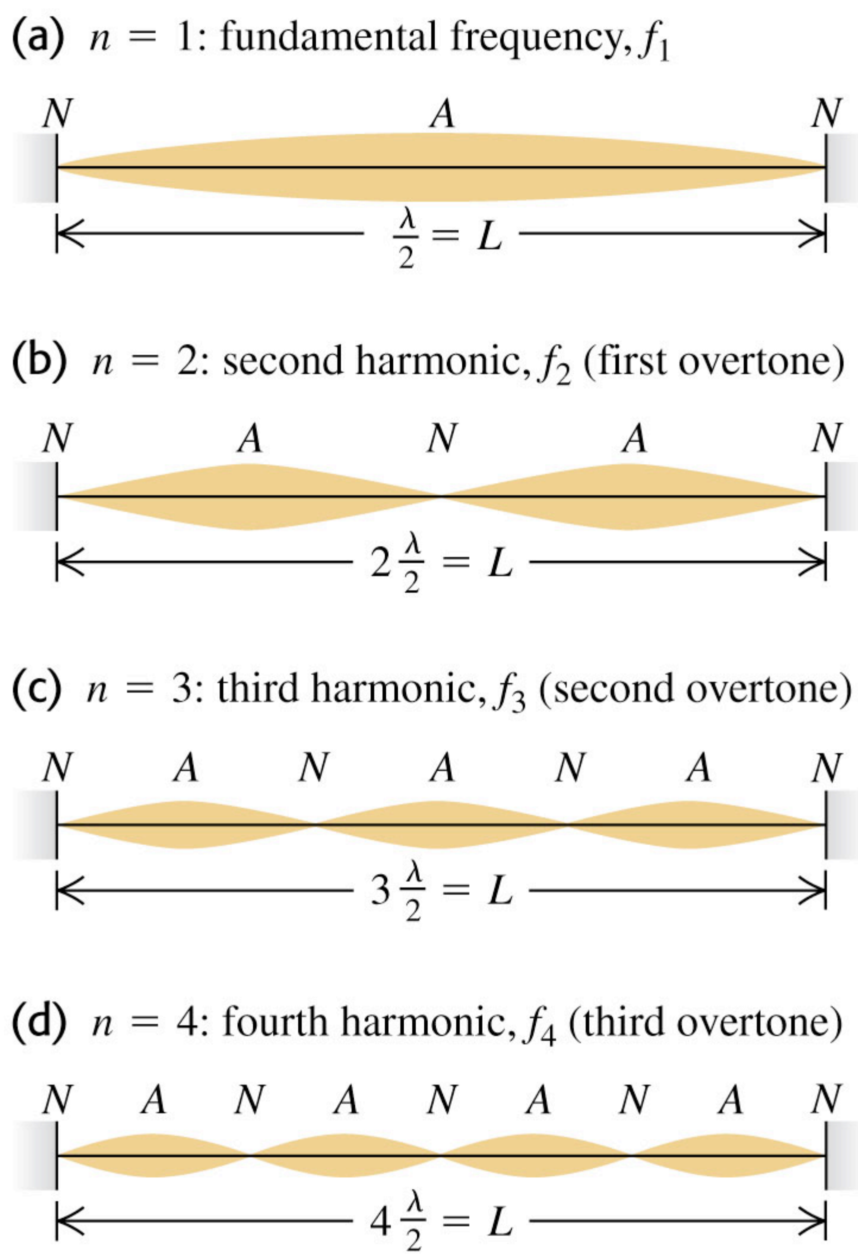
$$\lambda_n = 2L/n$$

and the possible frequencies are

$$f_n = n\, v/2L = nf_1,$$

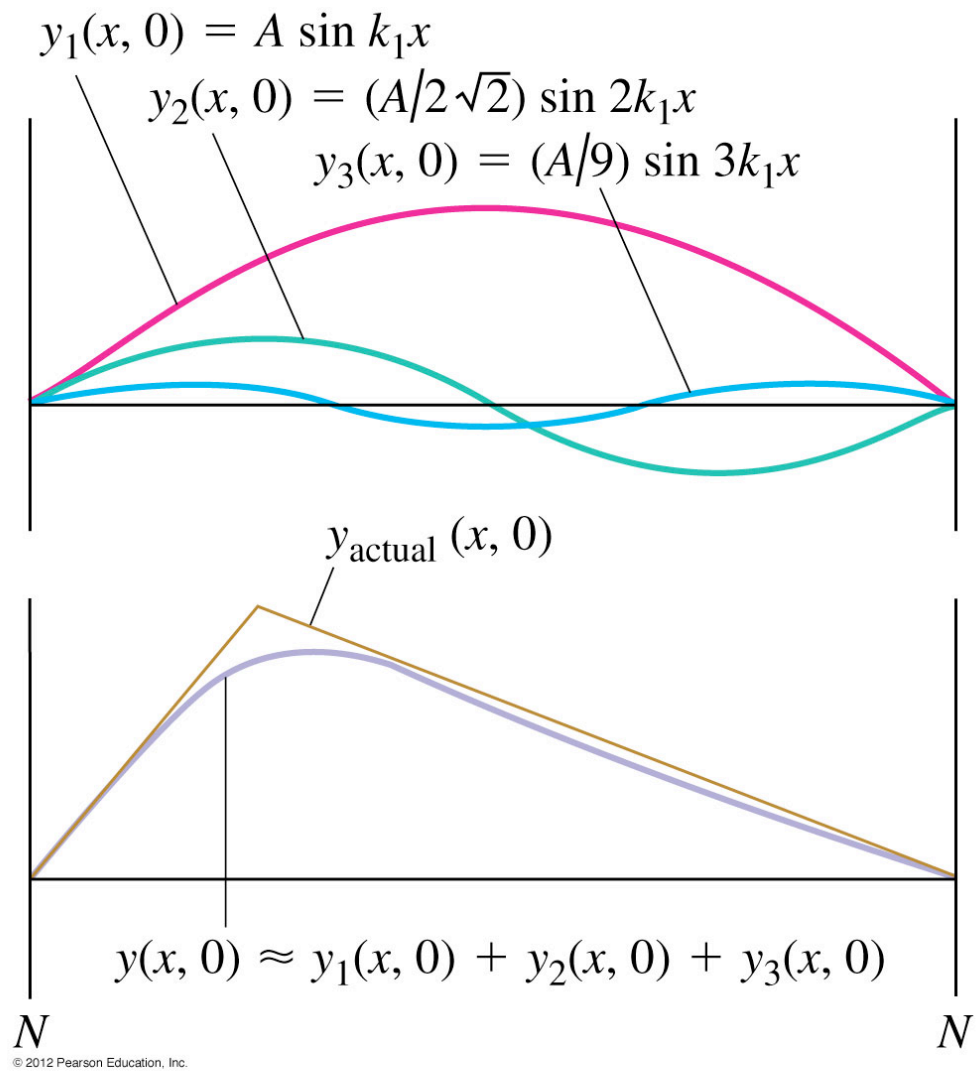
where $n = 1, 2, 3, \ldots$

- $f_1$ is the *fundamental frequency*, $f_2$ is the second harmonic (first overtone), $f_3$ is the third harmonic (second overtone), etc.
- Figure 15.26 illustrates the first four harmonics.



# Plucking a String

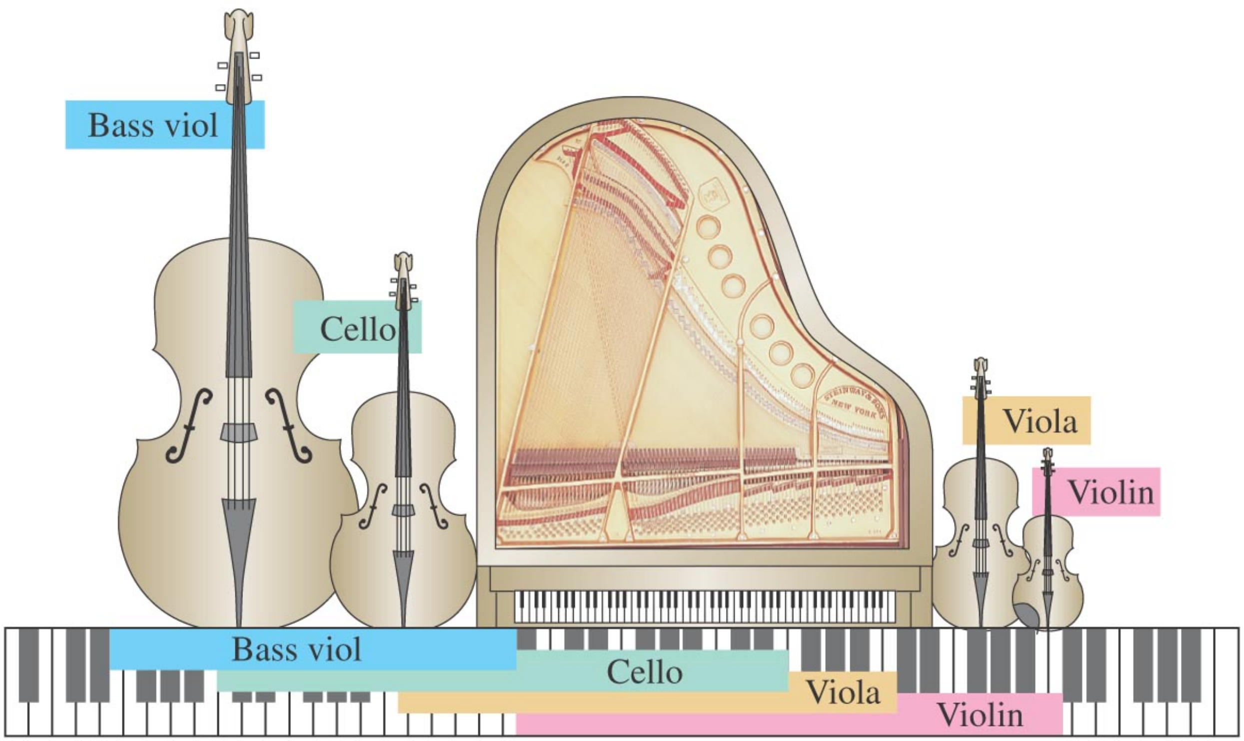
When the string is released, standing waves are formed



# Standing waves and musical instruments

- A stringed instrument is tuned to the correct frequency (pitch) by varying the tension. Longer and thicker strings produce bass notes and shorter and thinner strings produce treble notes.

$$f_1 = \frac{1}{2L}\sqrt{\frac{F}{\mu}} \qquad \text{(string fixed at both ends)}$$



# Chapter 16

# Sound and Hearing

PowerPoint® Lectures for
***University Physics, Thirteenth Edition***
***– Hugh D. Young and Roger A. Freedman***

**Lectures by Wayne Anderson**

# Goals for Chapter 16

- To describe sound waves in terms of particle displacements or pressure variations
- To calculate the speed of sound in different materials
- To calculate sound intensity
- To find what determines the frequencies of sound from a pipe
- To study resonance in musical instruments
- To see what happens when sound waves overlap
- To investigate the interference of sound waves of slightly different frequencies
- To learn why motion affects pitch

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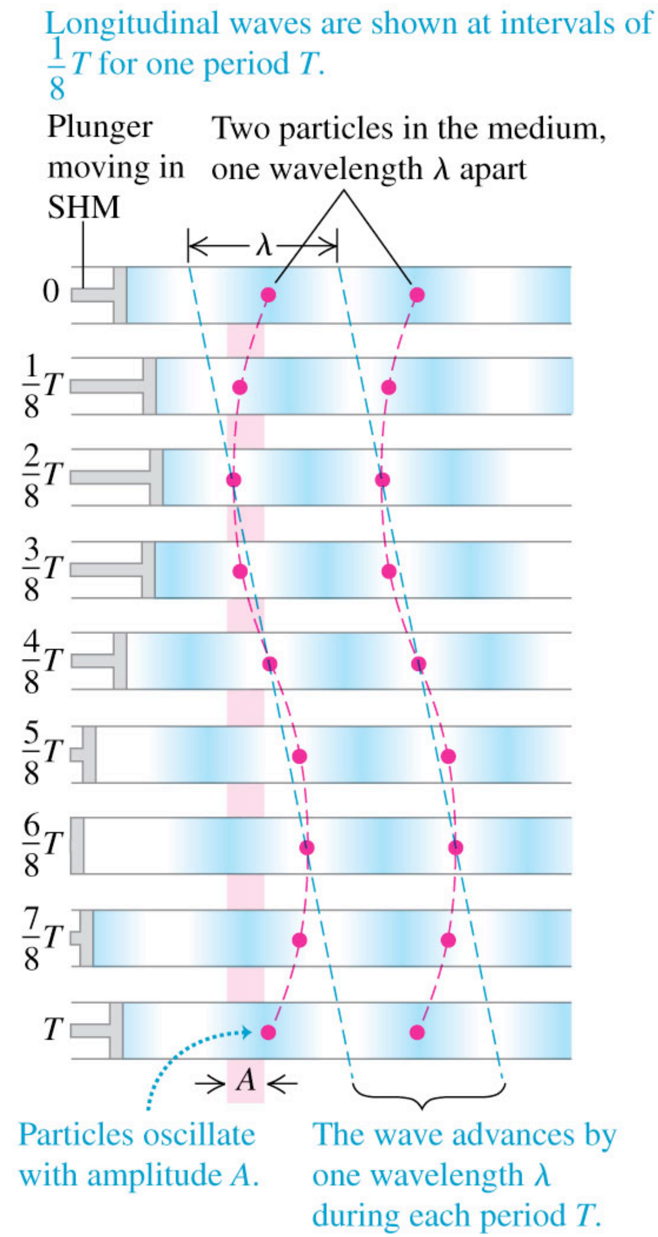
# Sound waves

- *Sound* is simply any longitudinal wave in a medium.
- The *audible range* of frequency for humans is between about 20 Hz and 20,000 Hz.
- *Ultrasonic* sound waves have frequencies above human hearing and *infrasonic* waves are below.
- Figure 16.1 at the right shows sinusoidal longitudinal wave.



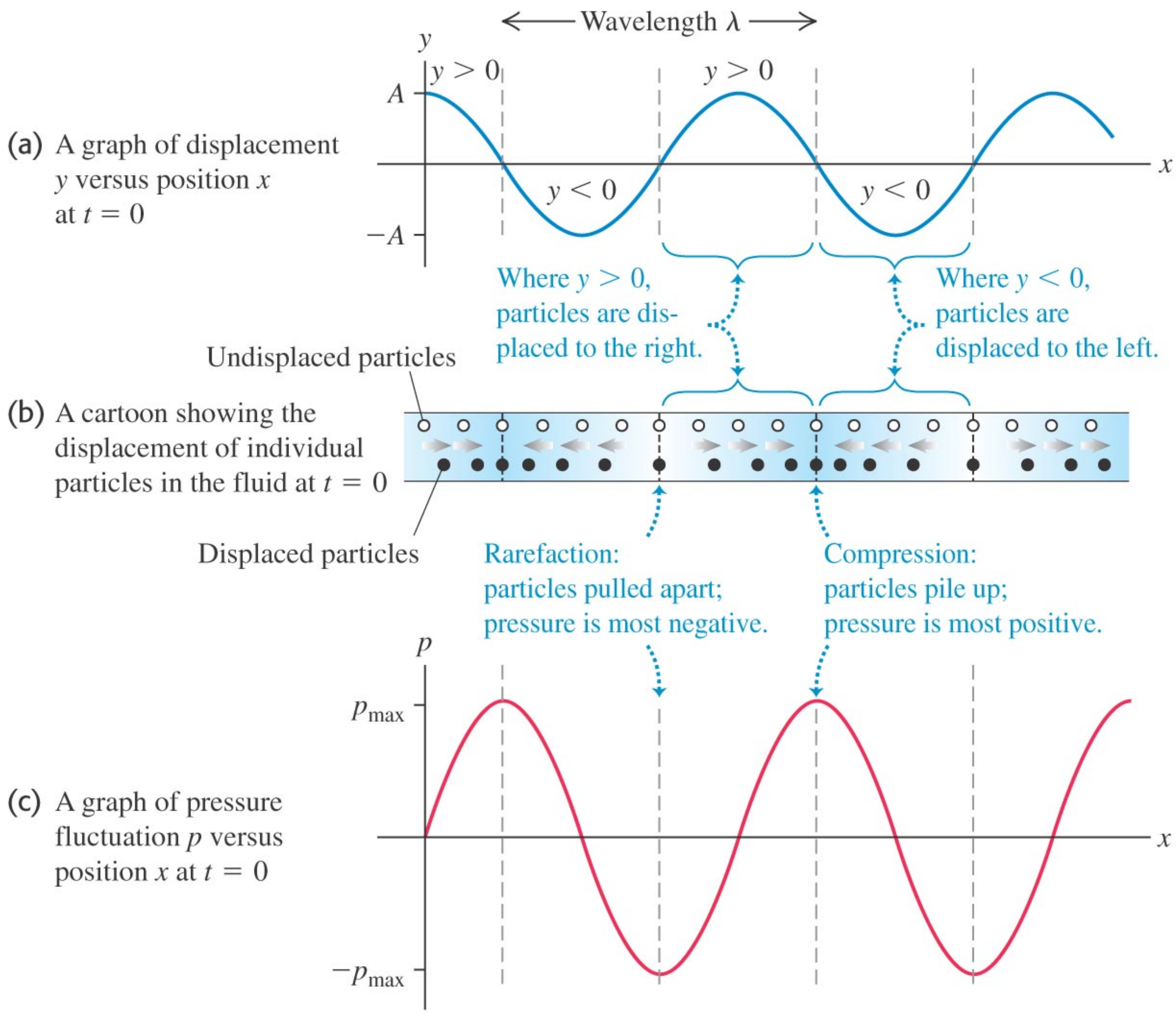
# Frequency of sound

- **Pitch** = frequency of a sound wave
- (demo)

# Different ways to describe a sound wave

- Sound can be described by a graph of displacement versus position, or by a drawing showing the displacements of individual particles, or by a graph of the pressure fluctuation versus position.
- The *pressure amplitude* is

$$p_{max} = BkA.$$



## Q16.1

At a compression in a sound wave,

F. particles are displaced by the maximum distance in the same direction as the wave is moving.

G. particles are displaced by the maximum distance in the direction opposite to the direction the wave is moving.

H. particles are displaced by the maximum distance in the direction perpendicular to the direction the wave is moving.

I. the particle displacement is zero.

# Speed of sound waves

- The speed of sound depends on the characteristics of the medium. Table 16.1 gives some examples.

- The speed of sound:

$$v = \sqrt{\frac{B}{\rho}} \qquad \text{(fluid)}$$

$$v = \sqrt{\frac{Y}{\rho}} \qquad \text{(solid rod)}$$

$$v = \sqrt{\frac{\gamma RT}{M}} \qquad \text{(ideal gas)}$$

**Table 16.1** Speed of Sound in Various Bulk Materials

| Material | Speed of Sound (m/s) |
|---|---|
| *Gases* | |
| Air (20°C) | 344 |
| Helium (20°C) | 999 |
| Hydrogen (20°C) | 1330 |
| *Liquids* | |
| Liquid helium (4 K) | 211 |
| Mercury (20°C) | 1451 |
| Water (0°C) | 1402 |
| Water (20°C) | 1482 |
| Water (100°C) | 1543 |
| *Solids* | |
| Aluminum | 6420 |
| Lead | 1960 |
| Steel | 5941 |

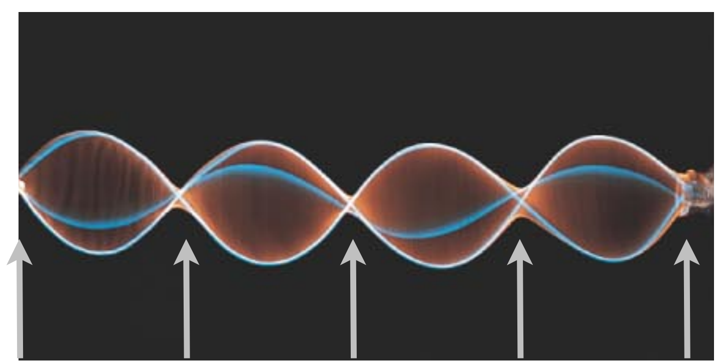
# Thunder and lightning
## (very, very frightening)

A bolt of lightning strikes the ground 1.00 mile away. You see the flash of lightning almost instantaneously. How much time passes before you hear the thunder? Recall that the speed of sound in air is 344 m/s, and a mile is about 1600 m.

# Standing Wave: Transverse

$$y(x, t) = (A_{SW} \sin kx) \sin \omega t$$ (standing wave on a string, fixed end at $x = 0$)

Nodes:



$x$=0 $\lambda/2$ $\lambda$ $3\lambda/2$ $2\lambda$

# Normal modes of a string

- For a taut string fixed at both ends, the possible wavelengths are

$$\lambda_n = 2L/n$$

  and the possible frequencies are

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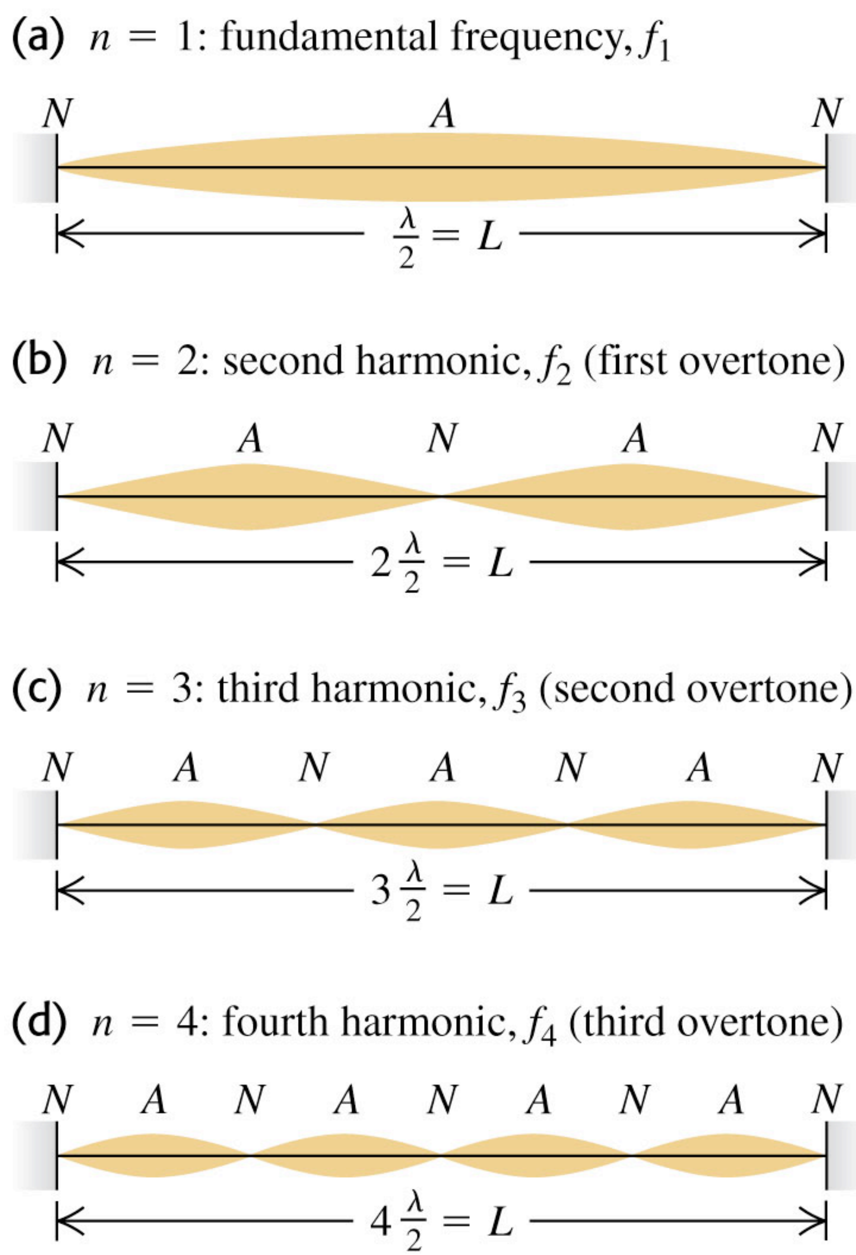
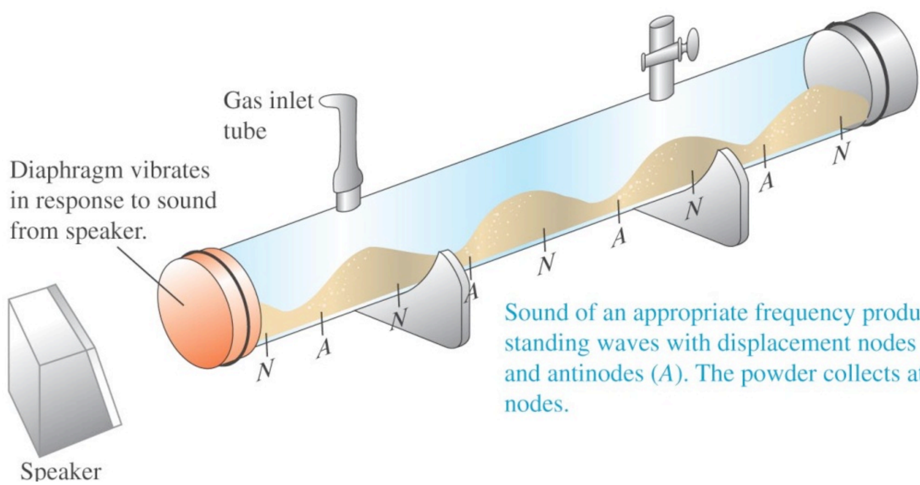


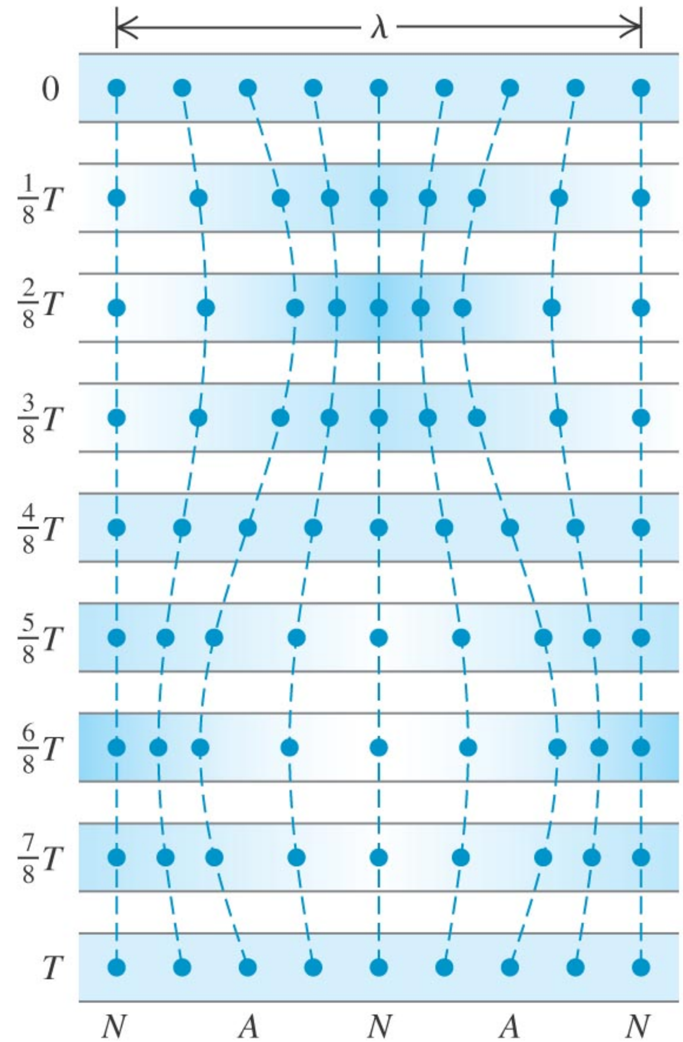
# Standing sound waves and normal modes

- The bottom figure shows displacement nodes and antinodes.
- A pressure node is always a displacement antinode, and a pressure antinode is always a displacement node, as shown in the figure at the right.




Sound of an appropriate frequency produces standing waves with displacement nodes (*N*) and antinodes (*A*). The powder collects at the nodes.

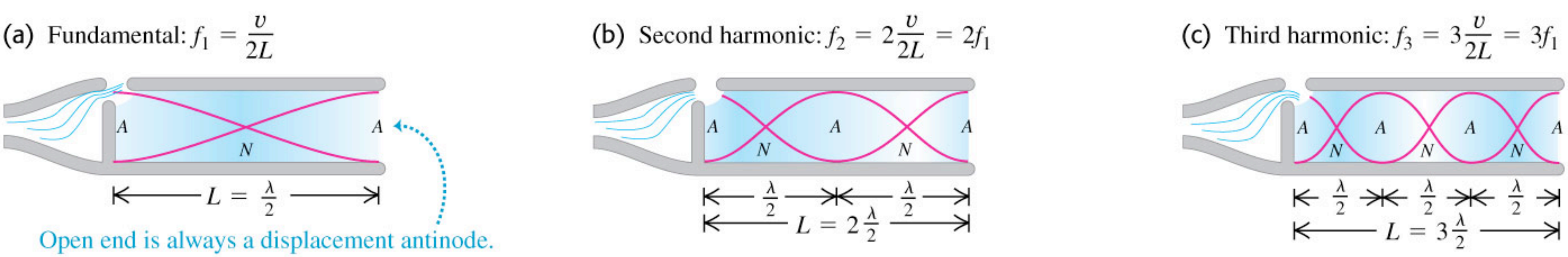
A standing wave shown at intervals of $\frac{1}{8}T$ for one period $T$




*N* = a displacement node = a pressure antinode
*A* = a displacement antinode = a pressure node

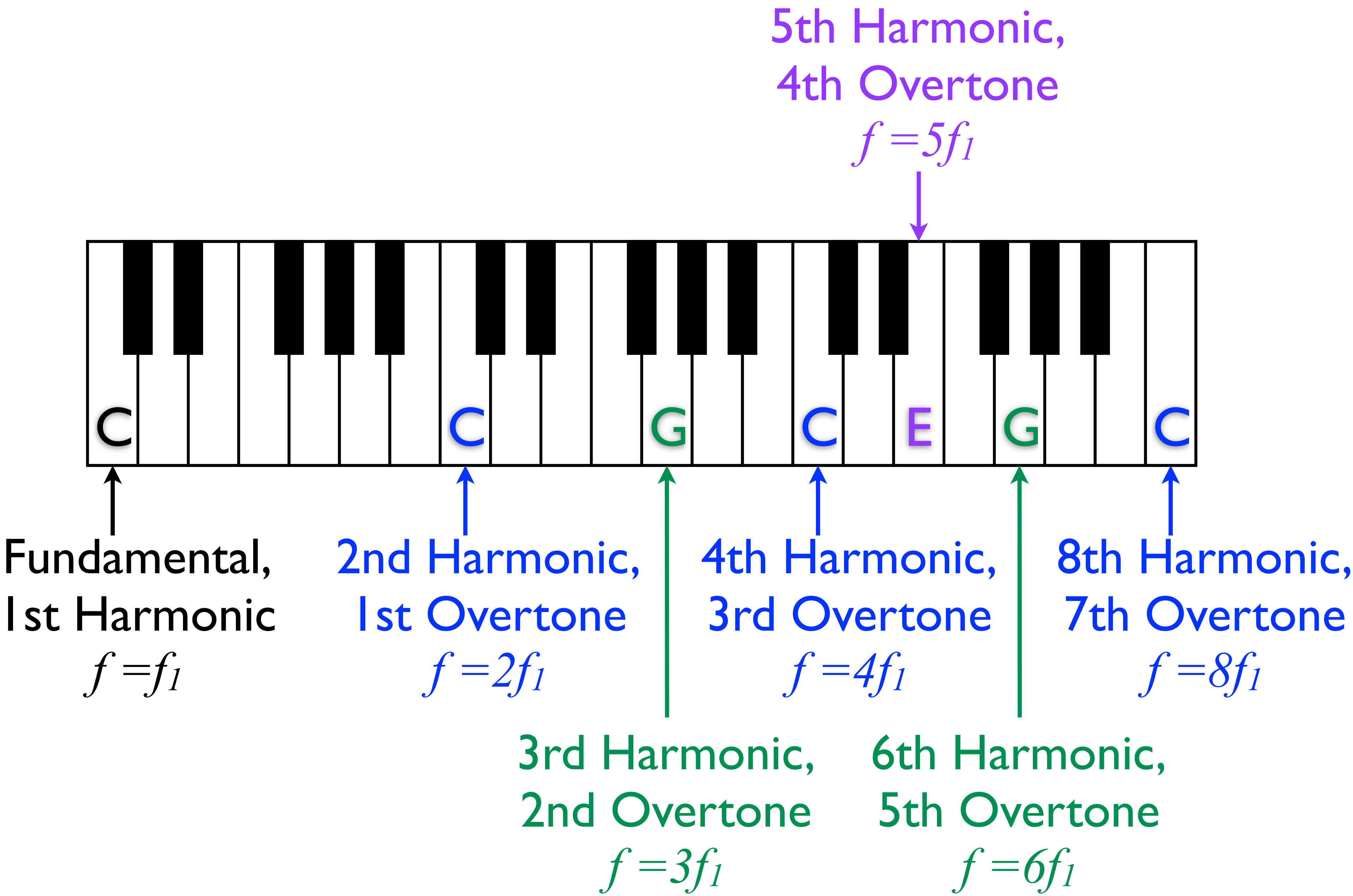
# Harmonics in an open pipe

- An *open pipe* is open at both ends.
  - Examples: flute, recorder, organ pipe
- For an open pipe $\lambda_n = 2L/n$ and $f_n = nv/2L$ $(n = 1, 2, 3, \ldots)$.
- Figure 16.17 below shows some harmonics in an open pipe.



# Pitch and Harmonics

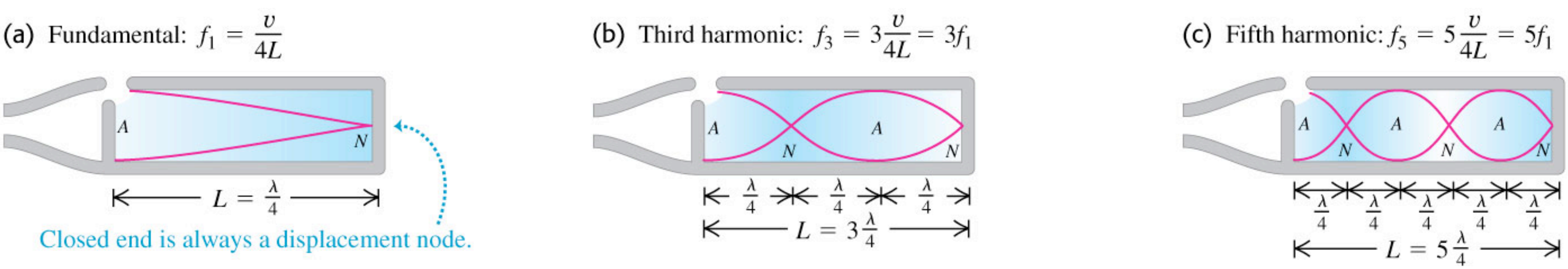
- 1st harmonic = fundamental = root
- 2nd harmonic = 1 octave up
- 3rd harmonic = 1 octave up + 5th
- 4th harmonic = 2 octaves up
- 5th harmonic = 2 octaves up + major 3rd
- 6th harmonic = 2 octaves up + major 5th
- 7th harmonic
- 8th harmonic = 3 octaves up


5th Harmonic,
4th Overtone
$f = 5f_1$
C
C
G
C
E
G
C
Fundamental,
1st Harmonic
$f = f_1$
2nd Harmonic,
1st Overtone
$f = 2f_1$
4th Harmonic,
3rd Overtone
$f = 4f_1$
8th Harmonic,
7th Overtone
$f = 8f_1$
3rd Harmonic,
2nd Overtone
$f = 3f_1$
6th Harmonic,
5th Overtone
$f = 6f_1$

# Normal Modes Demo

# Harmonics in a closed pipe

- A *closed pipe* is open at one end and closed at the other end.
  - Examples: clarinet, reed instruments
- For a closed pipe $\lambda_n = 4L/n$ and $f_n = nv/4L$ $(n = 1, 3, 5, \ldots)$.
- Figure 16.18 below shows some harmonics in a closed pipe.



Q16.6

When you blow air into an open organ pipe, it produces a sound with a fundamental frequency of 440 Hz.

If you close one end of this pipe, the new fundamental frequency of the sound that emerges from the pipe is

Q. 110 Hz.

R. 220 Hz.

S. 440 Hz.

T. 660 Hz.

U. 880 Hz.