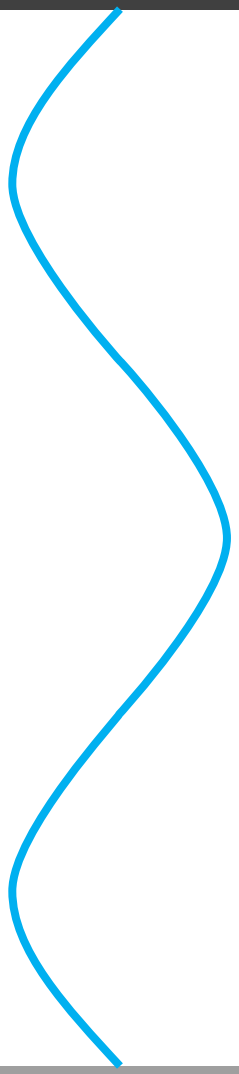
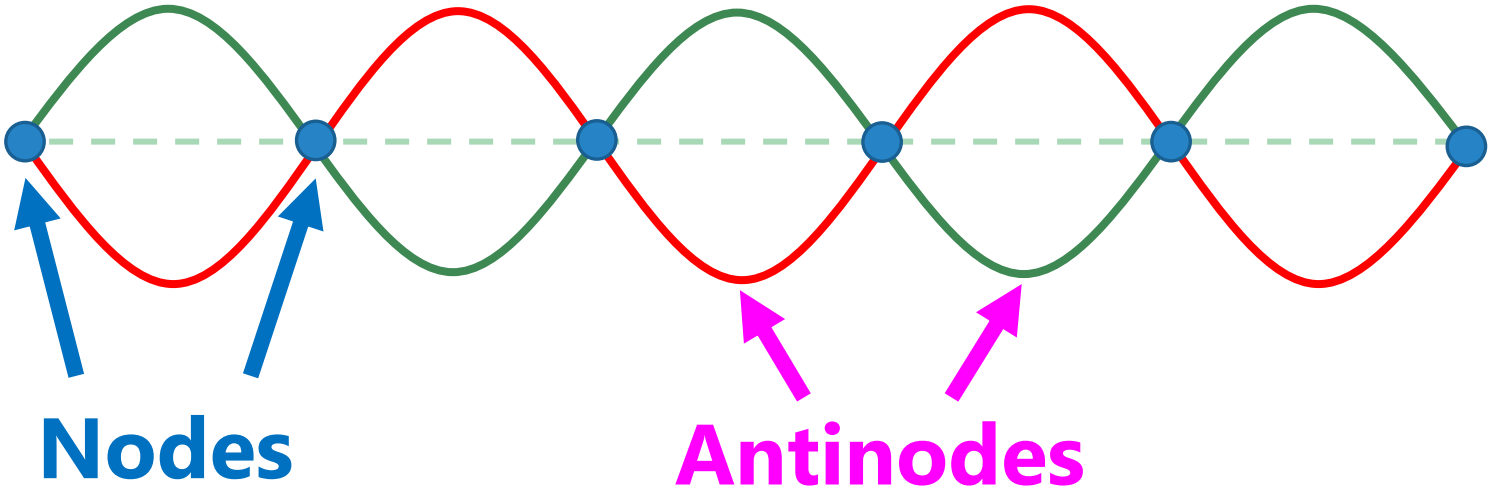
C.4

Instruments

IB PHYSICS | WAVE RESONANCE

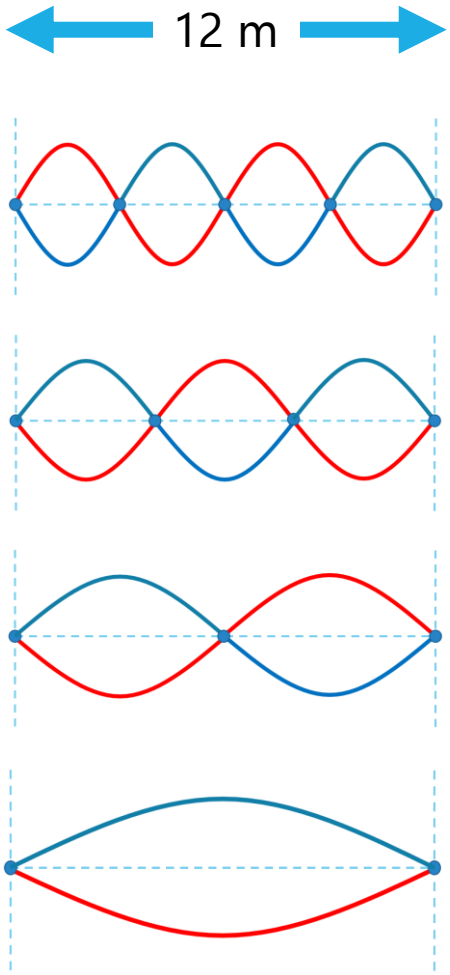
Standing Waves





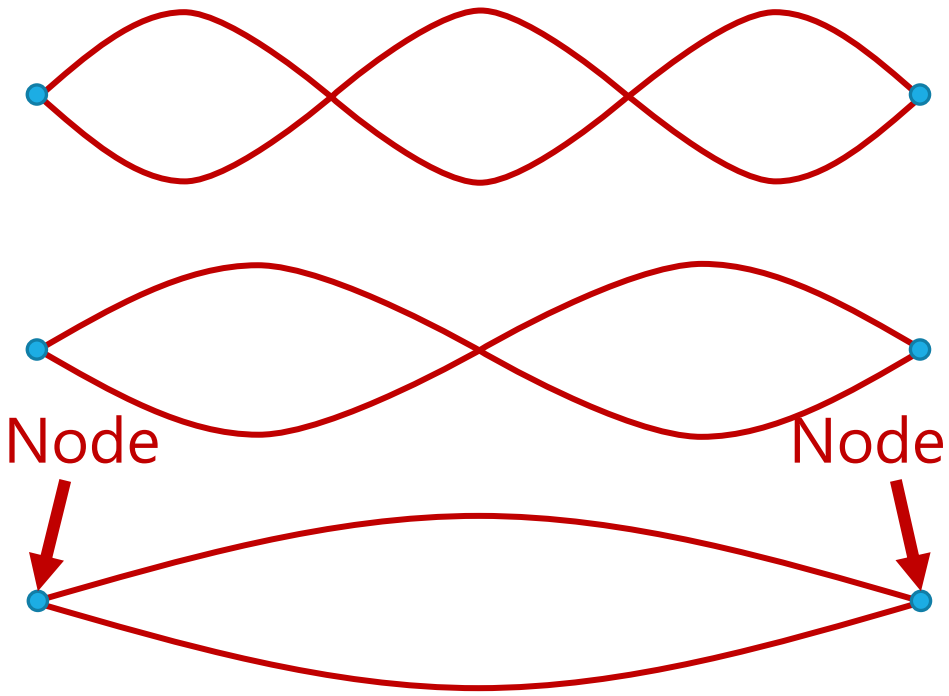
C.4

Standing Waves



# of Standing Waves	# of Wavelengths	Wavelength (m)
4	2	6
3	1.5	8
2	1	12
1	0.5	24

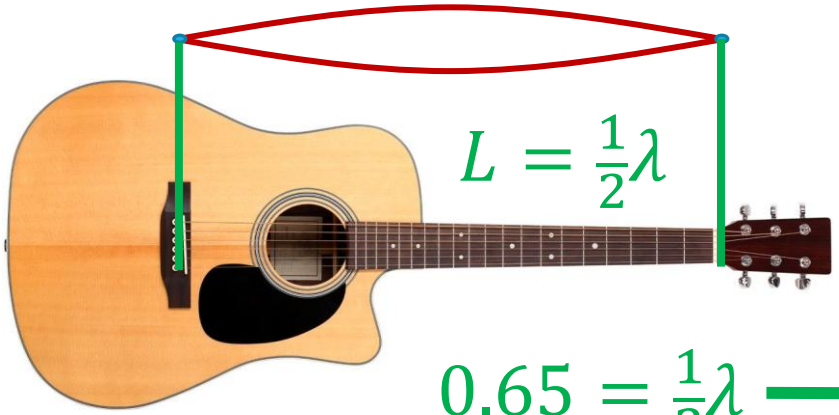
String Resonance



L =	Harmonic
$\frac{3}{2}\lambda$	3
$\frac{2}{2}\lambda$	2
$\frac{1}{2}\lambda$	1

C.4

Looking at a Guitar



What is the first harmonic frequency for a 65 cm string with a speed of 106.6 m s^{-1}?

$$0.65 = \frac{1}{2}\lambda \longrightarrow \lambda = 1.3 \text{ m}$$

$$v = f\lambda \longrightarrow f = \frac{v}{\lambda} = \frac{106.6}{1.3} = \mathbf{82\ Hz}$$

Changing the Length

Finger position on fret changes length to 45 cm

$$0.45 = \frac{1}{2}\lambda \longrightarrow \lambda = 0.9 \text{ m}$$

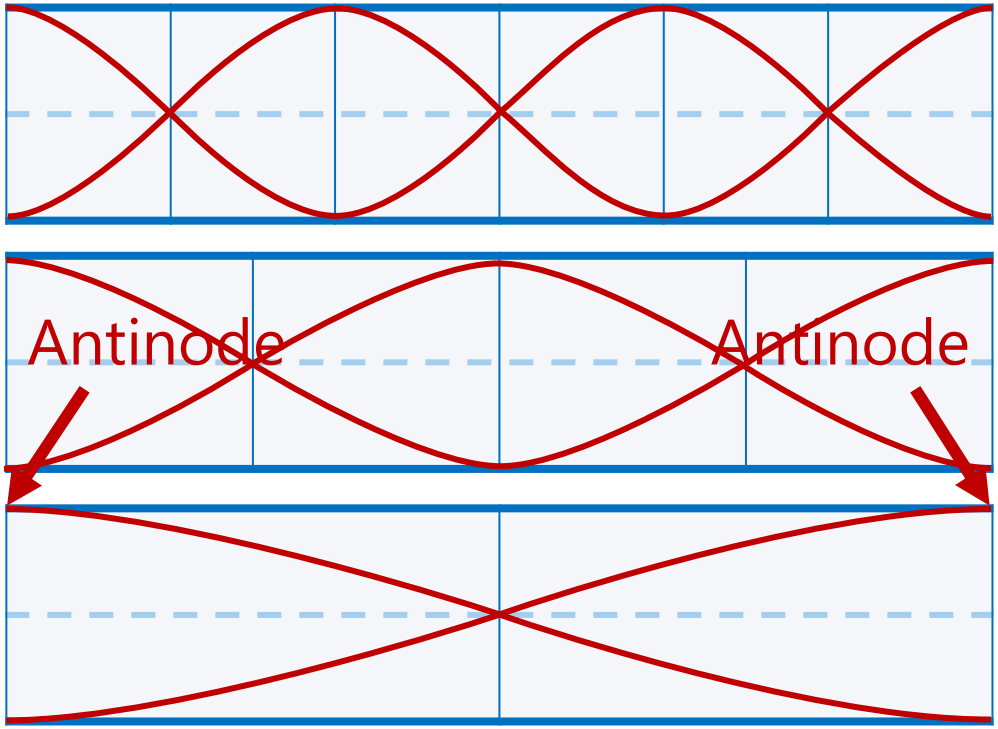
$$f = \frac{v}{\lambda} = \frac{106.6}{0.9} = \mathbf{118.4\ Hz}$$

Changing the Tension

Tightening the string increases speed to 120 m s^{-1}

$$f = \frac{v}{\lambda} = \frac{120}{1.3} = \mathbf{92.3\ Hz}$$

Open Pipe Resonance

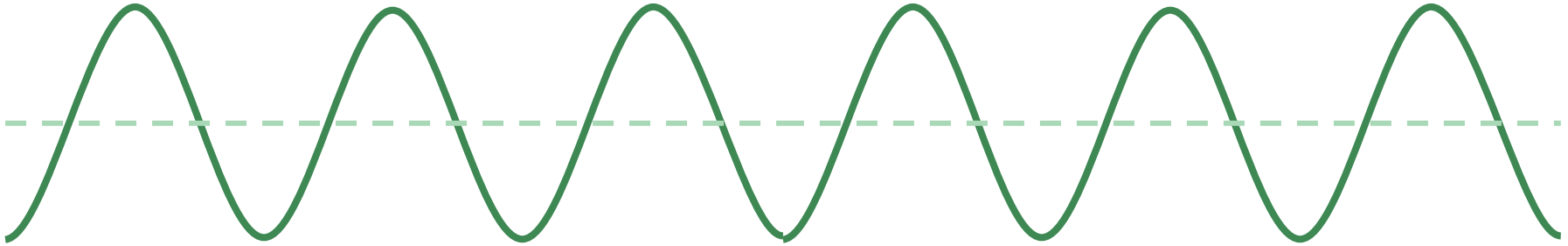


$L =$	Harmonic
$\frac{3}{2}\lambda$	3
$\frac{2}{2}\lambda$	2
$\frac{1}{2}\lambda$	1

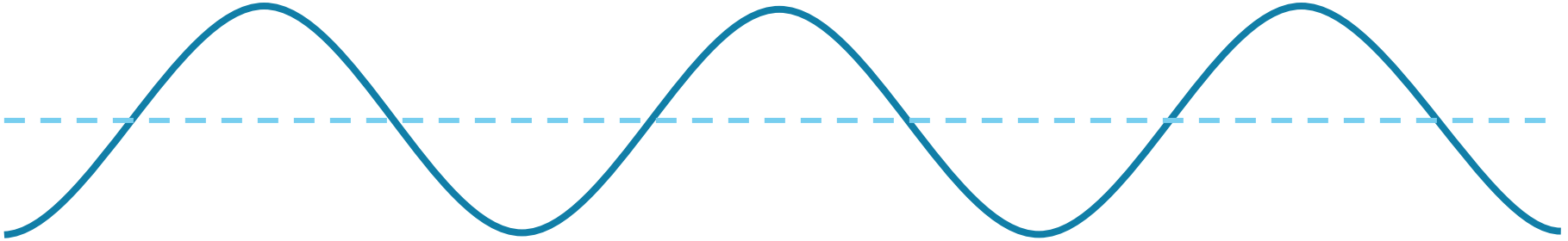
Remember Pitch and Frequency

C.4

High pitched sounds have high frequencies

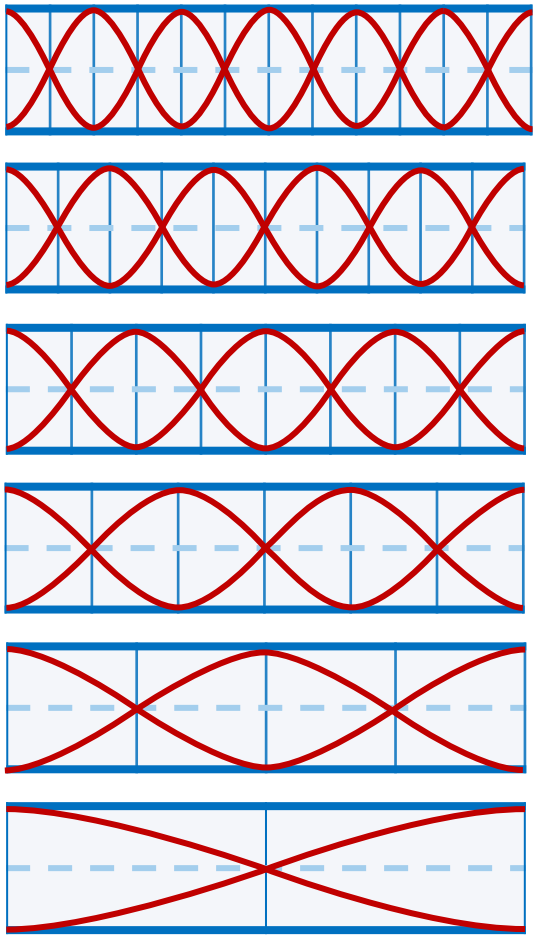


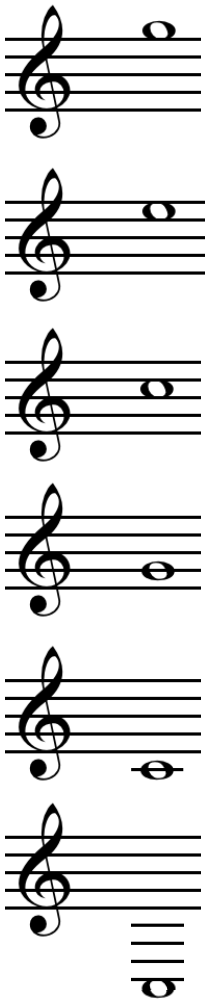
Low pitched sounds have low frequencies

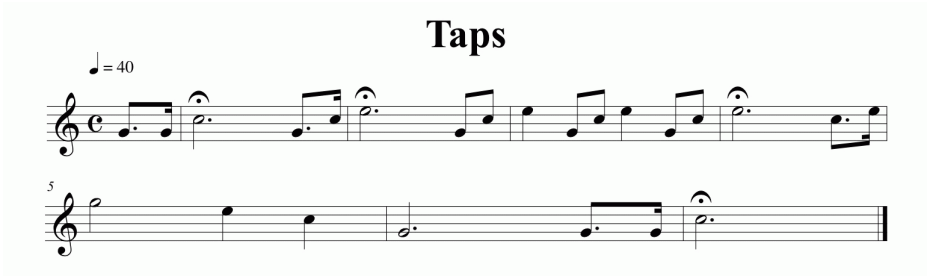


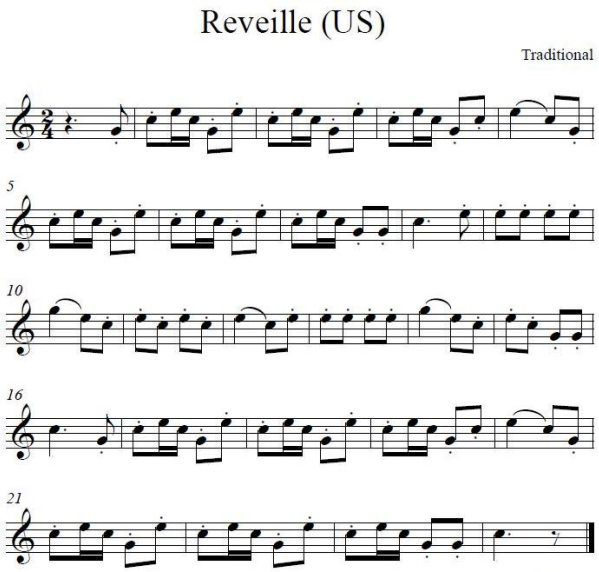
Harmonics

C.4



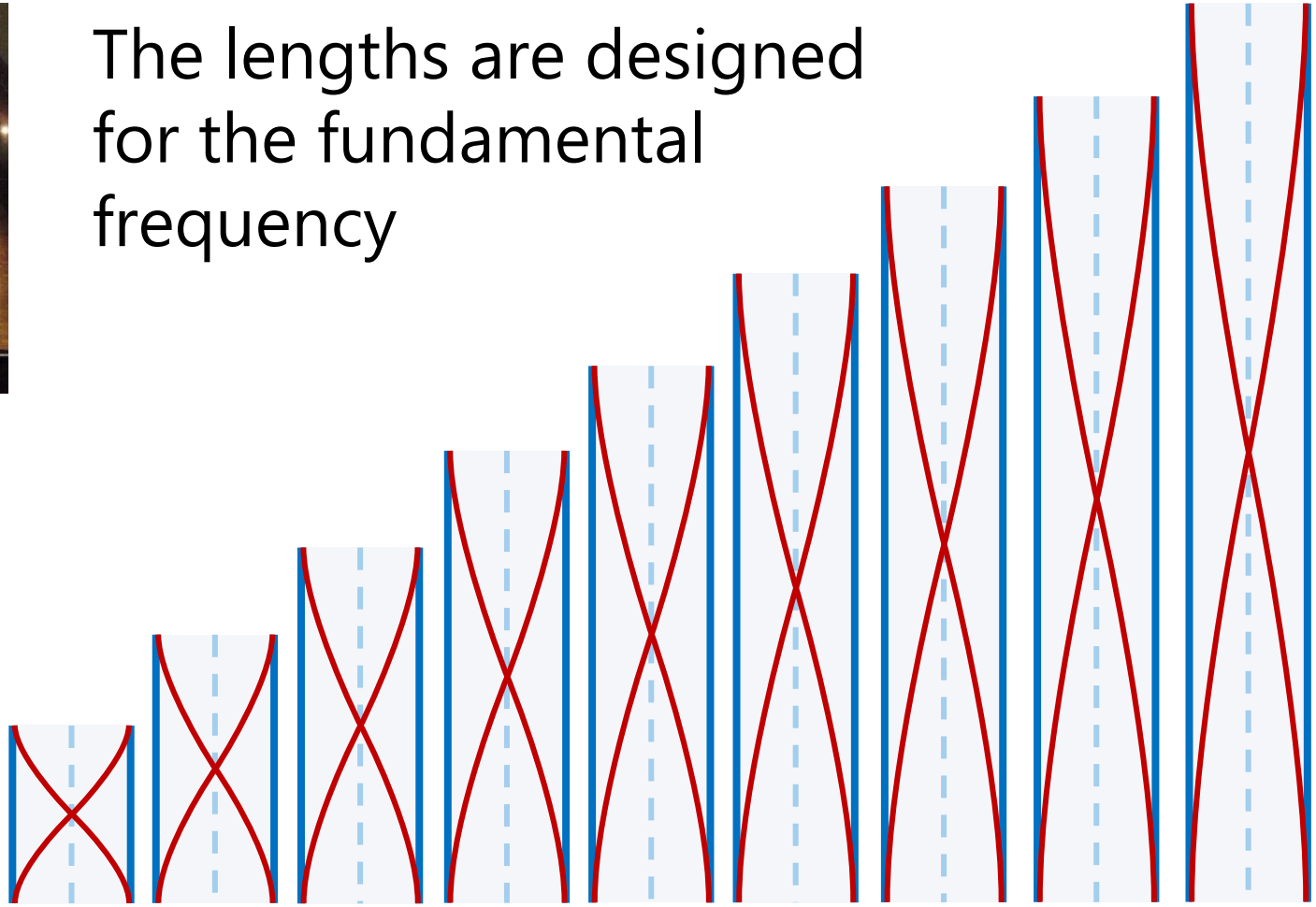






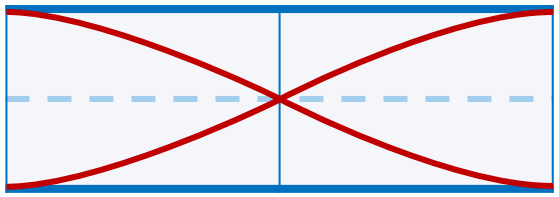
Changing the Length

The lengths are designed for the fundamental frequency



Calculating Frequency | Open Pipes

C.4



An open organ pipe is 2.1 m (L) long and the speed of sound in the pipe is 341 m/s. What is the fundamental frequency of the pipe?

$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{341}{4.2}$

$f = ?$

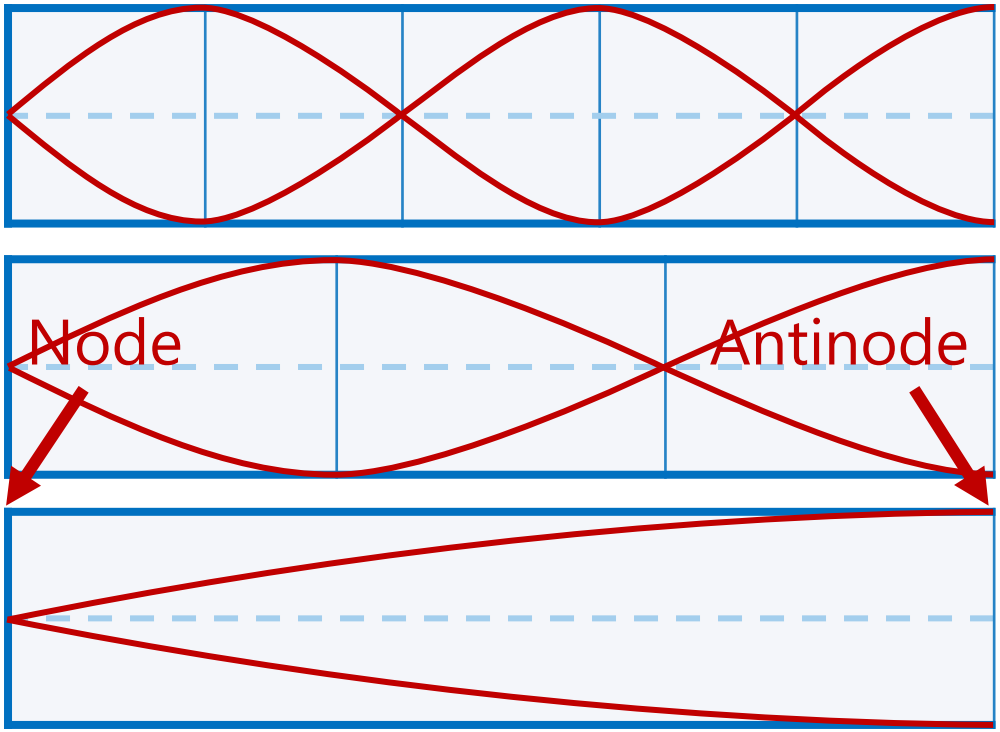
$v = 341\ m\ s^{-1}$

$\lambda = 4.2\ m$

$= \mathbf{81.2\ Hz}$

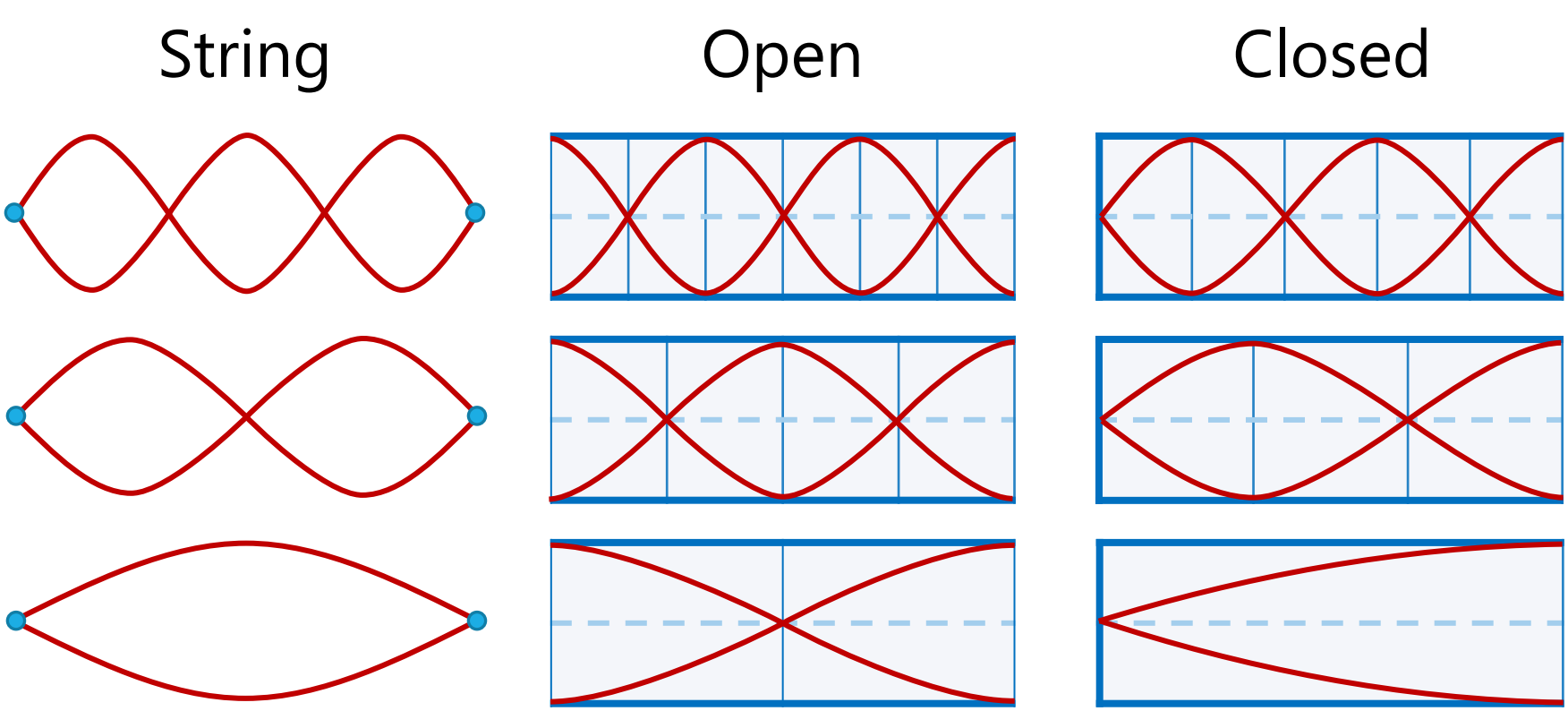
$L = \frac{1}{2}\lambda \rightarrow \lambda = 2L = 2(2.1) = 4.2\ m$

Closed Pipe Resonance



L =	Harmonic
$\frac{5}{4}\lambda$	5
$\frac{3}{4}\lambda$	3
$\frac{1}{4}\lambda$	1

All the Harmonics!



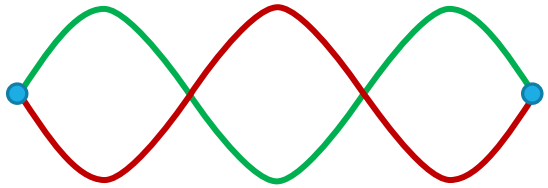
Review of End Conditions

C.4

Closed Pipe	Node	Antinode
Open Pipe	Antinode	Antinode
String	Node	Node

Try This…

The note produced on a violin string of length 42 cm produces a wave speed of 250 m/s. What is the 3rd harmonic of this note?



$v = f\lambda$

$f = ?$

$v = 250\ m\ s^{-1}$

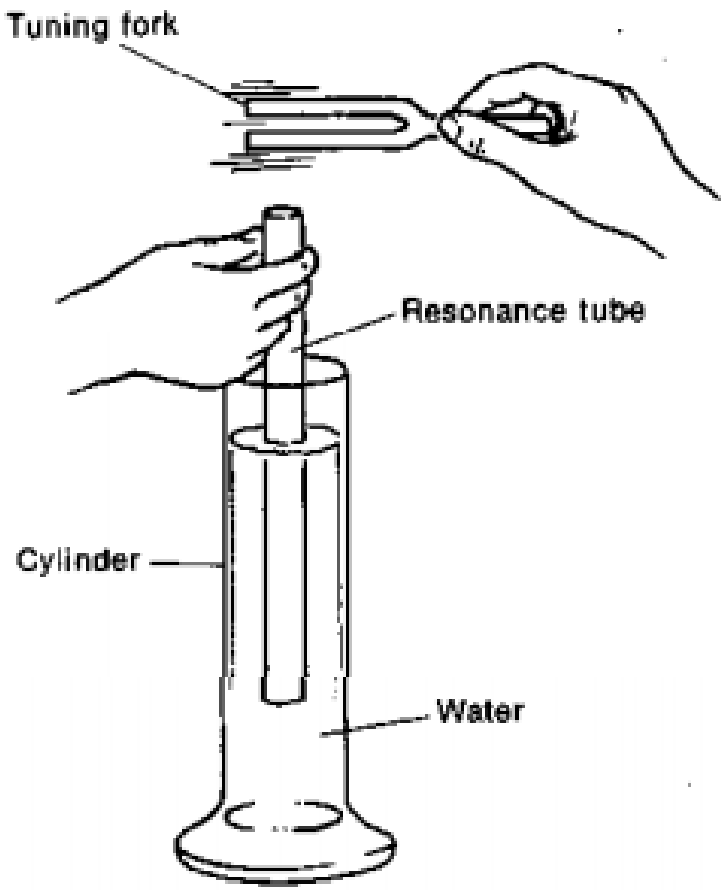
$\lambda = 0.28\ m$

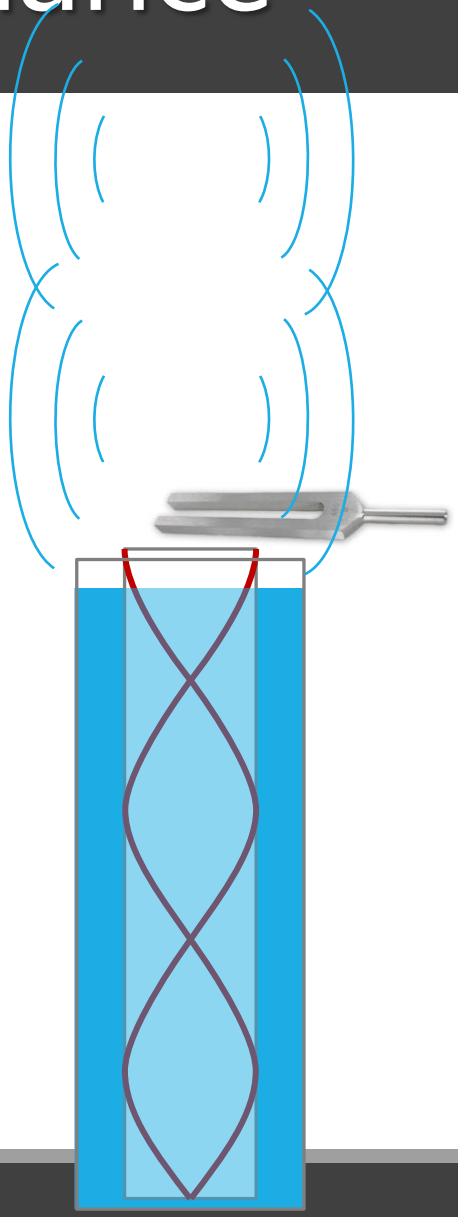
$f = \frac{v}{\lambda} = \frac{250}{0.28}$

$= \mathbf{893.9\ Hz}$

$L = \frac{3}{2}\lambda \rightarrow \lambda = \frac{2}{3}L = \frac{2}{3}(0.42) = 0.28\ m$

Finding Resonance

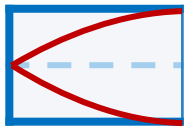




Calculating Frequency | Closed Pipes

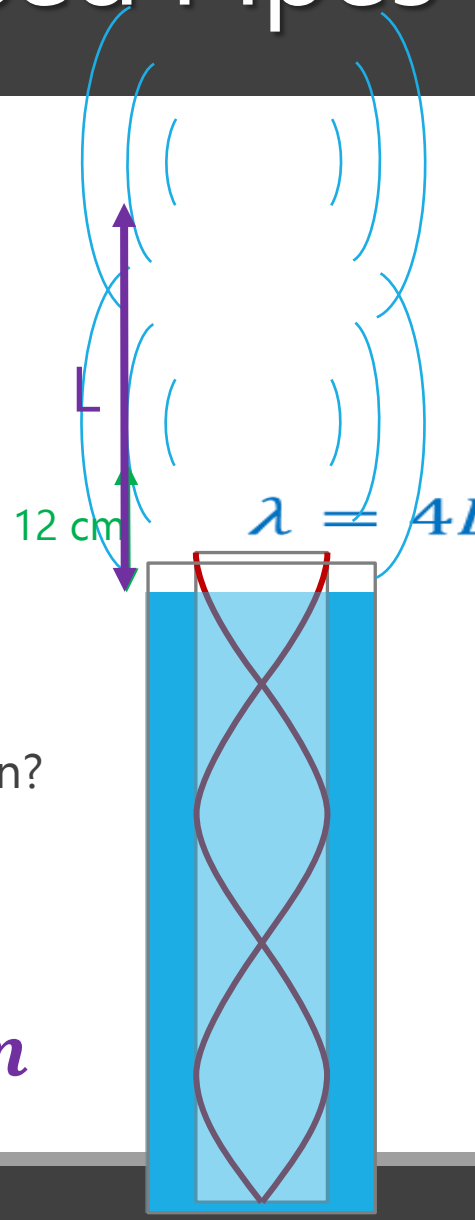
C.4

You found an unmarked tuning fork in your collection. You notice that the smallest length for closed pipe resonance is **12 cm**. If the speed of sound is **345 m/s**, what is the tuning fork frequency?



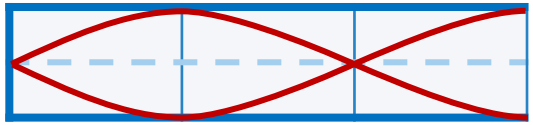
$$L = \frac{1}{4}\lambda \longrightarrow \lambda = 4L = 4(0.12) = \boxed{0.48\ m}$$

$$f = \frac{v}{\lambda} = \frac{345}{0.48} = \mathbf{718.75\ Hz}$$



What should the length of the tube be for the 2nd resonant position?

3rd Harmonic



$$L = \frac{3}{4}\lambda = \frac{3}{4}(0.48) = \mathbf{0.36\ m}$$

C.4

Lesson Takeaways

- ❑ I can identify and label the node and antinodes on a standing wave diagram
- ❑ I can describe the end conditions and nodes/antinodes for open/closed pipes and vibrating strings
- ❑ I can relate length and wavelength for open/closed pipes and vibrating strings
- ❑ I can calculate the length of a pipe/string required to resonate a specific frequency