Standing Waves - Strings

- Different frequencies are produced by different harmonics

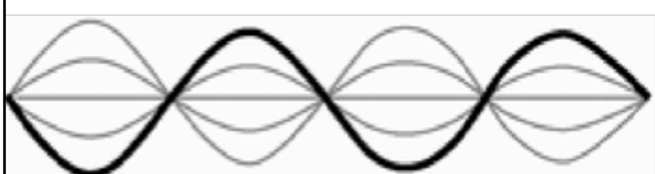
- First Harmonic (f_1)

440 Hz

$$\begin{array}{r} 3 \\ \hline 1320 \end{array}$$

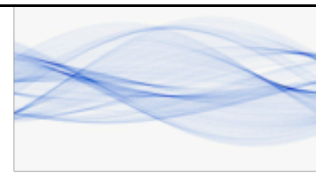
- Second Harmonic (f_2)
- Number of Loops = 2
- $f_2 = 2 \cdot f_1$ 880 Hz

- Third Harmonic (f_3)
- Number of Loops = 3
- $f_3 = 3 \cdot f_1$ 1320 Hz

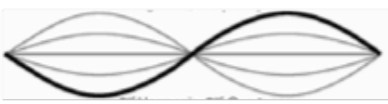


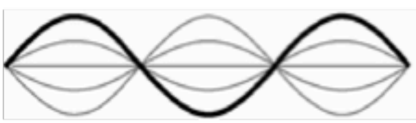
- Fourth Harmonic (f_4)
- Number of Loops = 4
- $f_4 = 4 \cdot f_1$

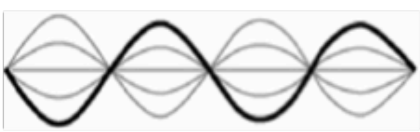
Standing Waves - Strings

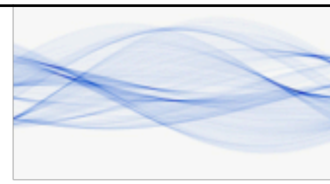


- When thinking about the waves….with the fundamental and the harmonics superimposed on each other, you end up with wave forms that look like….









Example 8

A string is firmly attached at both ends. When a frequency of 60 Hz is applied, the string vibrates in the standing wave pattern shown. Assume the tension in the string and its mass per unit length do not change. Which of the following frequencies could NOT also produce a standing wave pattern in the string?

$f_3 = 3 \cdot f_1$

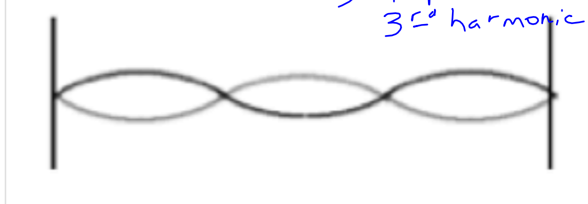
$60 = 3 \cdot f_1 = 20\text{ Hz}$

$f_3 = 60\text{ Hz}$

$f = 60\text{ Hz}$

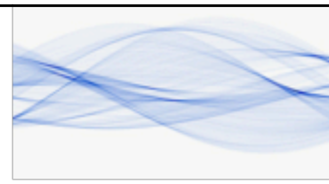
3 loops

3rd harmonic



A. 30 Hz
B. 40 Hz
C. 80 Hz
D. 100 Hz
E. 180 Hz

Example 9



The standing wave pattern diagrammed to the right is produced in a string fixed at both ends. The speed of waves in the string is 2 m/s. What is the frequency of the standing wave pattern?

$v = 2\ m/s$ $f = ?$ 4 loops → 4th harmonic

$v = \lambda \cdot f$

$2 = 0.5 \cdot f$

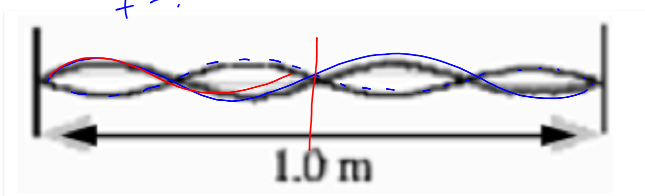
A. 0.25 Hz

B. 1 Hz

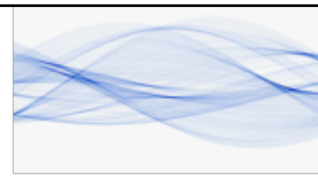
C. 2 Hz

D. 4 Hz

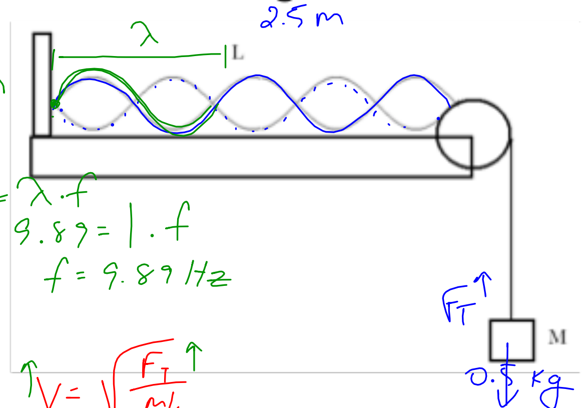
E. 8 Hz



Example 10



A string that is a length of 2.5 m resonates in five loops as shown above. The string linear density is 0.05 kg/m and the suspended mass is 0.5 kg.



A. What is the wavelength? 1 m

B. What is the wave speed? 9.89 m/s $*v = \lambda \cdot f$

C. What is the frequency of oscillations?

$v = \lambda \cdot f$

$9.89 = 1 \cdot f$

$f = 9.89\ Hz$

D. What will happen to the number of loops if the suspended mass is increased?

$$v = \sqrt{\frac{F_T}{m/L}} = \sqrt{\frac{M \cdot g}{0.05}} = \sqrt{\frac{(0.5)(9.8)}{0.05}}$$

$m/L \rightarrow$ linear density

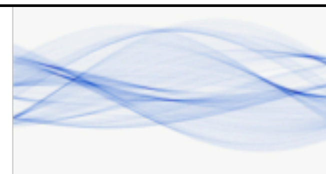
$v = 9.89\ m/s$

$$\uparrow v = \sqrt{\frac{F_T \uparrow}{m/L}}$$

$$\uparrow v = \uparrow \lambda \cdot f$$

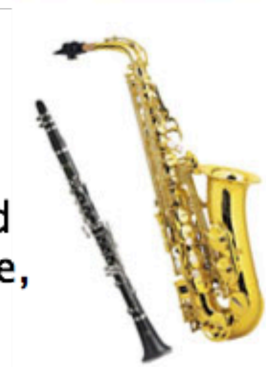
less loops - each needs more space

Standing Waves – Woodwinds and Brass



- These instruments create standing waves using vibrating columns of air

- Two Categories:
  - Instruments (Pipes) Open at Both Ends
    - All brass instruments, flute, organ

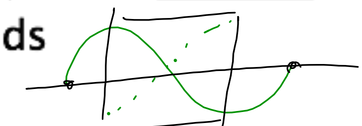


  - Instruments (Pipes) Open at One End
    - Most reed and double-reed instruments: Clarinet, Oboe, Saxophone, Bassoon, etc..

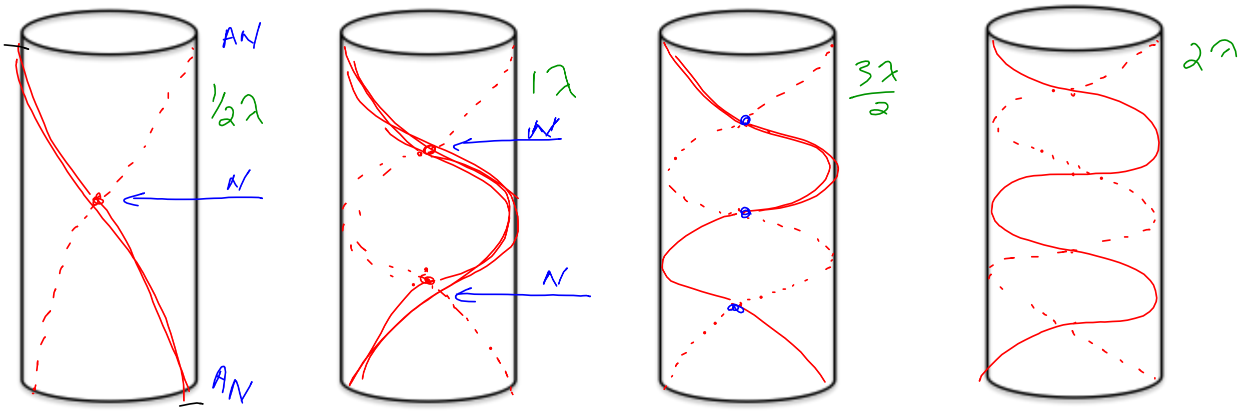
Standing Waves – Pipes Open at Both Ends

*Standing waves have nodes and anti-nodes. The part that can create sounds (vibrations) is the anti-node

*Need an anti-node at both ends



Fundamental
1st Harmonic | 2nd Harmonic | 3rd Harmonic | 4th Harmonic



Pipes Open at One End

*One end is closed – will have a node at the closed end

*Still need an anti-node at the open end

only can hear odd harmonics

$v = \lambda \cdot f$

Fundamental
1st Harmonic | 2nd Harmonic | 3rd Harmonic | 4th Harmonic | 5th Harmonic