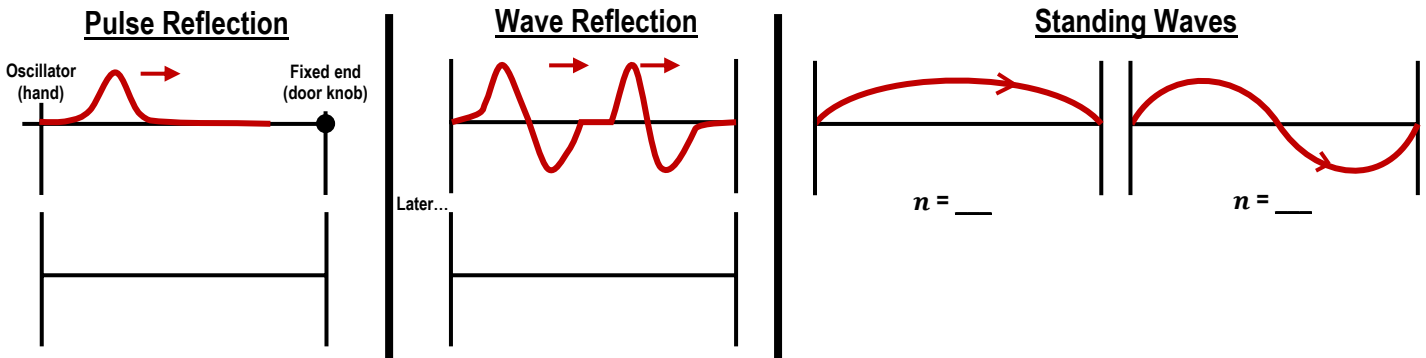


CONCEPT: INTRO TO TRANSVERSE STANDING WAVES

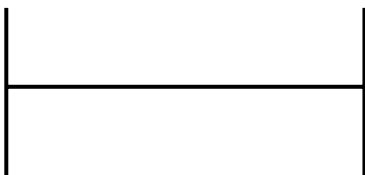
- When a traveling wave reaches a fixed endpoint, it creates a *reflected* wave that travels backwards, upside-down.
 - For most frequencies, these waves interfere randomly.
 - For very special frequencies, these waves interfere & make a wave that “looks” _____ → **Standing Wave**



[You change the wave width by changing your frequency (wiggle faster/slower)]

- There are infinite special frequencies which create standing waves, where $n = \# \text{ of loops}$.
 - "**Fundamental**" Frequency (f_1) $\Rightarrow$ always when $n = \underline{\quad}$
 - Harmonic Frequencies:** All other frequencies for $n > 1$ standing waves are multiples of f_1 : $f_n = \underline{\quad}$ (For $n=1,2,3,\dots$)

EXAMPLE: A string between two supports vibrates in a standing-wave pattern of 3 loops with a frequency of 15Hz. **a)** Draw a sketch of the wave. **b)** What is the fundamental frequency? **c)** What is the frequency for standing wave with 5 loops?



PROBLEM: By whipping a string up and down, you determine the fundamental frequency to be 4 Hz. If you attached the string to a motorized oscillator and increased the frequency to 28Hz, how many loops would this standing wave have?

- A) 14
- B) 4
- C) 28
- D) 7

STANDING WAVES

$f_n = nf_1$

PROBLEM: One of the harmonic frequencies for a particular string under tension is 325 Hz. The next higher harmonic frequency is 390 Hz. What harmonic frequency is next higher after the harmonic frequency 195 Hz?

- A) 130 Hz
- B) 260 Hz
- C) 196 Hz
- D) 4 Hz

STANDING WAVES

$f_n = nf_1$

CONCEPT: EQUATIONS FOR TRANSVERSE STANDING WAVES

- **Standing Waves** can *ONLY* exist for special “Harmonic” frequencies, and have special values for wavelength:

- “Fundamental” (**n=1**) Frequency:

$$f_1 = \text{---}$$

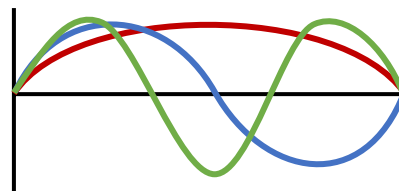
- Harmonic frequencies:

$$f_n = n f_1 = \text{---}$$

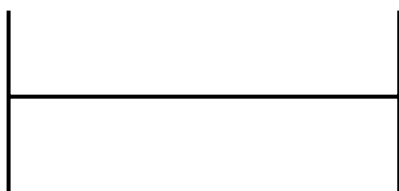
- Wavelength:

$$\lambda_n = \text{---}$$

For $n = 1, 2, 3 \dots$



EXAMPLE: A 1.5m long string stretched between two supports with a Tension that makes the speed of transverse waves 48 m/s. What are the wavelength and frequency of the **a)** fundamental tone; **b)** first overtone?



- “Harmonic” and “Overtone” are 2 words that *tell* you the value of ***n***.

1st harmonic: $n = 1$;
(fundamental)

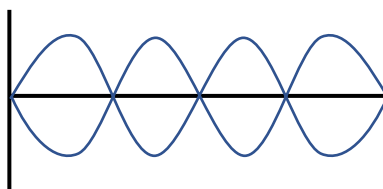
2nd harmonic: $n = 2$;
1st overtone: $n = 2$;

3rd harmonic: $n = 3$;
2nd overtone: $n = 3$;

- In general, n^{th} Overtone = n tones over fundamental frequency

PROBLEM: The figure below shows a standing wave on a 2.0-m-long string that has been fixed at both ends and tightened until the wave speed is 40 m/s. What is the frequency of this wave?

- A) 20 Hz
- B) 160 Hz
- C) 40 Hz
- D) 10 Hz



STANDING WAVES

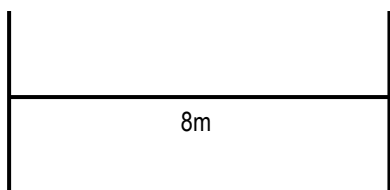
$$f_1 = \frac{v}{2L}$$

$$f_n = n f_1 = \frac{nv}{2L}$$

$$\lambda_n = \frac{2L}{n}$$

$$n^{\text{th}} \text{ Overtone} = (n+1)^{\text{th}} \text{ Harmonic}$$

PROBLEM: A string fixed at both ends is 8 m long and has a mass of 0.20 kg. It is subjected to a tension of 100.0 N and set oscillating. **a)** What is the speed of waves on the string? **b)** What is the longest possible wavelength for a standing wave? **c)** Calculate the frequency of that wave.



STANDING WAVES

$$v = \sqrt{\frac{F_T}{\mu}} \text{ (for strings only)}$$

$$f_1 = \frac{v}{2L}$$

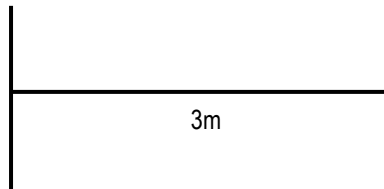
$$f_n = n f_1 = \frac{nv}{2L}$$

$$\lambda_n = \frac{2L}{n}$$

$$n^{\text{th}} \text{ Overtone} = (n+1)^{\text{th}} \text{ Harmonic}$$

PROBLEM: A 3m-long rope is stretched between two supports with a tension that makes the speed of transverse waves 60 m/s. What are the wavelength and frequency of the second overtone?

- A) $\lambda = 2 \text{ m}$; $f = 30 \text{ Hz}$
- B) $\lambda = 1 \text{ m}$; $f = 60 \text{ Hz}$
- C) $\lambda = 3 \text{ m}$; $f = 20 \text{ Hz}$
- D) $\lambda = 6 \text{ m}$; $f = 10 \text{ Hz}$



STANDING WAVES

$$v = \sqrt{\frac{F_T}{\mu}} \text{ (for strings only)}$$

$$f_1 = \frac{v}{2L}$$

$$f_n = n f_1 = \frac{nv}{2L}$$

$$\lambda_n = \frac{2L}{n}$$

$$n^{\text{th}} \text{ Overtone} = (n+1)^{\text{th}} \text{ Harmonic}$$