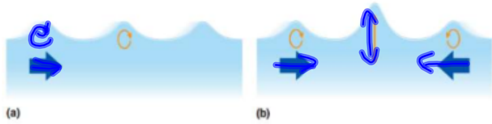
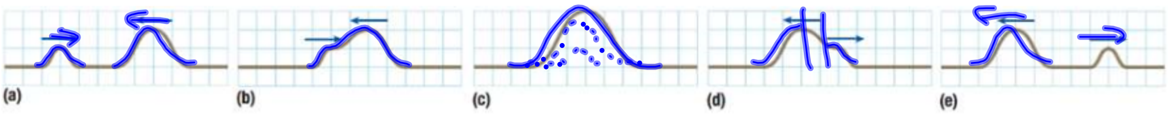
# SPH3U 9.1 Interference of Waves

**1. Wave interference**

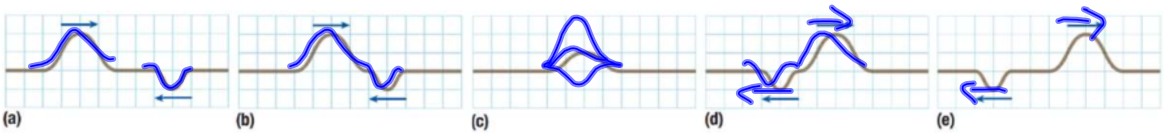
| | |
|---|---|
| Interference: | a new wave is created when two waves meet. |



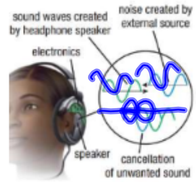
| | |
|---|---|
| Principle of superposition: | when 2 waves meet, the amplitude is the sum of the 2 individual amplitudes. |
| ① Constructive interference: | 2 waves add to make a larger wave. |



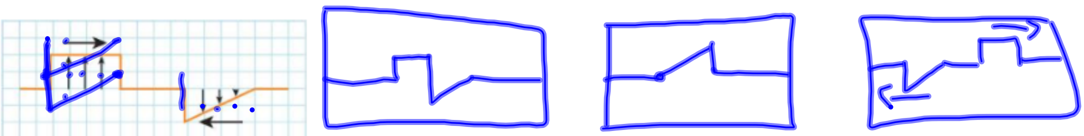
| | |
|---|---|
| ② Destructive interference: | 2 waves add to make a smaller wave. |



| | |
|---|---|
| Noise-cancelling headphones: | cancel outside noise using destructive interference |
| benefit | can listen at lower levels. |




These two waveforms are about to interfere with each other. Draw the resultant waveform.



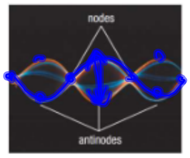
$t_0$   $t_1$ waves meet   $t_2$ fully overlap.   $t_3$ passed each other

**Homework:** page 419: #1-2

## SPH3U 9.2 Waves at Media Boundaries

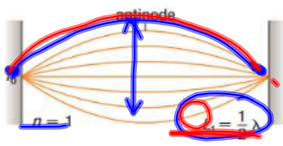
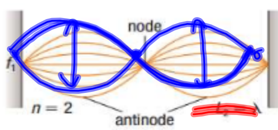
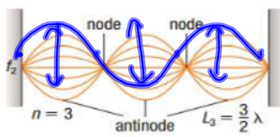
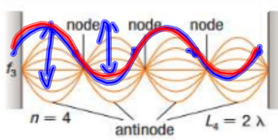
### 1. Standing waves

| | |
|---|---|
| Standing wave: | a wave that looks like it's "standing still" |
| cause | waves interfere with their own reflections as they bounce up and down the medium. |
| nodes | points where particles aren't moving. |
| antinodes | points where particles move the most (up and down). |



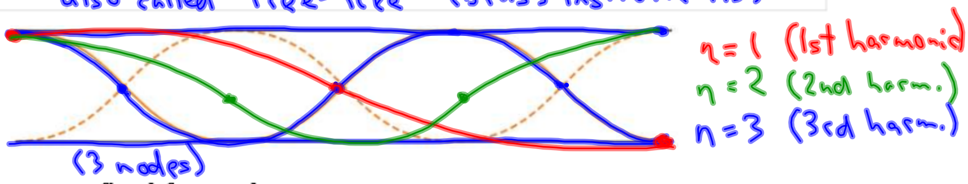

### 2. Standing waves – 2 fixed ends

| | |
|---|---|
| Fixed end: | the end of the medium is held tight in place, so that it must have a node. |
| 2 fixed ends | also called "fixed-fixed" (string instruments) |

| Symbol | Number of nodes between ends | Diagram | Harmonic (n) | Overtone |
|---|---|---|---|---|
| $f_0$ | 0 |  | first | fundamental |
| $f_1$ | 1 |  | second | ~~first~~ |
| $f_2$ | 2 |  | third | second |
| $f_3$ | 3 |  | fourth<br>n = 4<br>n - 1 nodes between ends. | third |

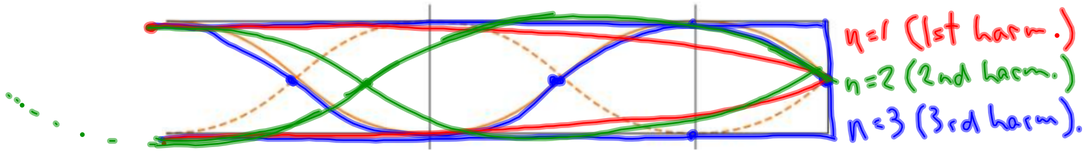
**3. Standing waves – 2 free ends**

| | |
|---|---|
| Free end: | the end of the medium can move freely – it will have an antinode (maximum). |
| 2 free ends | also called "free-free" (brass instruments) |




**4. Standing waves – fixed-free ends**

| | |
|---|---|
| Fixed-free ends: | node on fixed, antinode on free (woodwind) |




**5. Equations**

| | |
|---|---|
| 2 fixed or 2 free: | $L_n = \frac{n\lambda}{2} \Leftrightarrow \lambda_n = \frac{2L}{n}$. |
| Fixed-free: | $L_n = \frac{(2n-1)\lambda}{4}$, $\lambda_n = \frac{4L}{(2n-1)}$ |

The speed of a wave on a string with a fixed end and a free end is 350 m/s. The frequency of the wave is 200.0 Hz. What length of string is necessary to produce a standing wave with the first harmonic?

$n=1$. $f=200\,Hz$, $v=350\,m/s$, $v=f\lambda$.

$\lambda = \frac{v}{f} = \frac{350}{200} = 1.75\,m$.

$L_n = \frac{(2n-1)\lambda}{4}$, $L_1 = \frac{(2-1)(1.75)}{4} = 0.44\,m$.

The sixth harmonic of a 65 cm guitar string is heard. If the speed of sound in the string is 206 m/s, what is the frequency of the standing wave?

$v = 206\,m/s$, $n=6$, $L_6 = 0.65\,m$.

$L_n = \frac{n\lambda}{2}$. $L_6 = \frac{6\lambda}{2} \rightarrow 0.65 = 3\lambda \rightarrow \lambda = \frac{0.65}{3} = 0.2167\,m$.

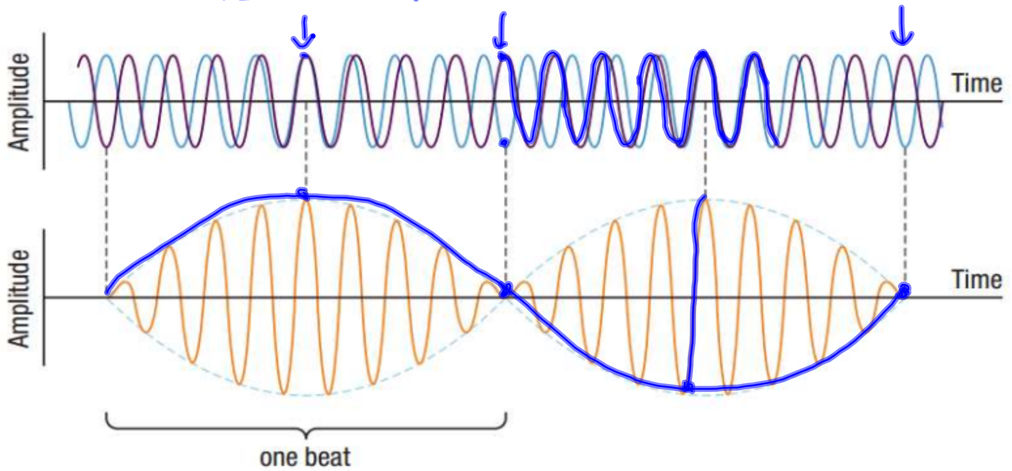
$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{206}{0.2167} = 950\,Hz$.

**Homework:** page 426: #5-7

# SPH3U 9.3 Beats

**1. Beats**

| | |
|---|---|
| Beat: | a periodic change in loudness caused by interference between two similar sound waves. |
| Beat frequency: | frequency of beats produced by this interference. |
| equation | $f_b = \lvert f_2 - f_1 \rvert$ . |




John is tuning his guitar. His string produces a frequency of 442 Hz, and his tuner produces a frequency of 440 Hz. What beat frequency does John hear?

$f_b = \lvert f_2 - f_1 \rvert$

$= \lvert 442 - 440 \rvert$

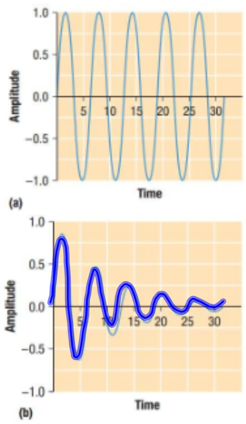
$= 2$ Hz.

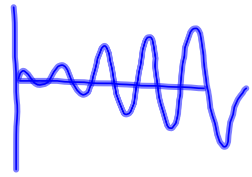
**Homework:** page 429: #2-3

## SPH3U 9.4 Damping and Resonance

**1. Damping and resonance**

| | |
|---|---|
| Damping: | when a wave reduces due to energy absorption/loss. |
| Resonant frequency: | the frequency at which a medium vibrates most easily. |
| resonance | when an incoming wave has the same frequency as the medium's resonant freq. |
| standing waves | wavelength must be a multiple of one of the harmonics (the resonant frequencies). |
| Vibrating structures: | we often want damping so that buildings, bridges, etc don't get damaged. |



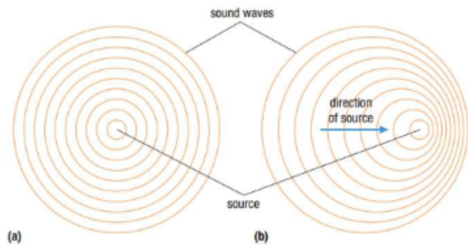



**Homework:** page 432: #1-2

# SPH3U 9.5 The Doppler Effect

## 1. The Doppler Effect

| | |
|---|---|
| The Doppler Effect: | when an observed frequency changes because the source is moving. |
| equation | $f_{obs} = \left(\frac{v_s + v_{detector}}{v_s + v_{source}}\right) f_o$ |
| $v_{source}$ | + is away from observer, − is towards the observer. |


Suppose a fire truck is moving toward a stationary observer at 25.0 m/s. The frequency of the siren on the fire truck is 800.0 Hz. Calculate (a) the frequency detected by the observer as the fire truck approaches and (b) the frequency detected by the observer after the truck passes by. The speed of sound in this case is 342 m/s.

(a) $f_{obs} = \left(\frac{v_s + v_{obs}}{v_s + v_{source}}\right) f_o = \left(\frac{342 + 0}{342 - 25}\right)$

$= 863\ \text{Hz}.$

(b) $f_{obs} = \left(\frac{342 + 0}{342 + 25}\right)$

$= 746\ \text{Hz}.$

**Homework:** page 435: #4-5