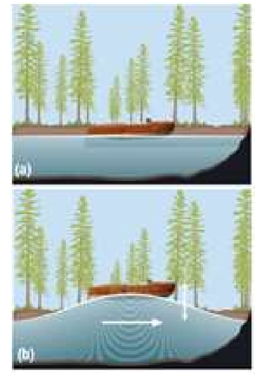
# SPH3U 8.1 Vibrations

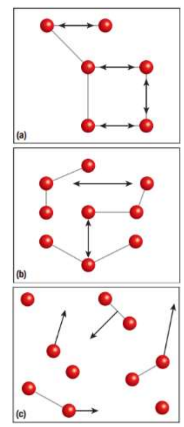
## 1. Vibrations and mechanical waves

| | |
|---|---|
| Vibration: | |
| equilibrium | |
| Mechanical wave: | |
| medium | |
| net motion | |



## 2. Particle behaviour in different media

| | |
|---|---|
| Waves in solids: | |
| elastic material | |
| Waves in fluids: | |

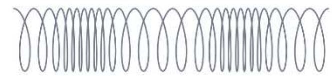


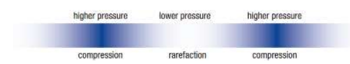
**Homework:** page 380: #1-4

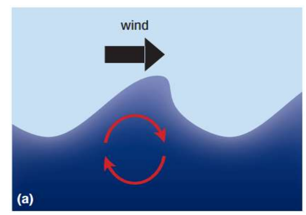
# SPH3U 8.2 Types of Mechanical Waves

### 3. Types of waves

| | |
|---|---|
| Transverse wave: | |
| Longitudinal wave: | |
| waves in gases | |
| sound | |
| complex wave motion | |



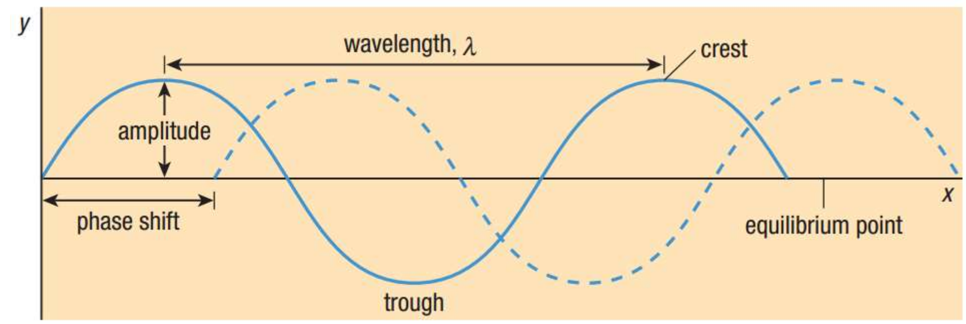



**Homework:** page 384: #2-4

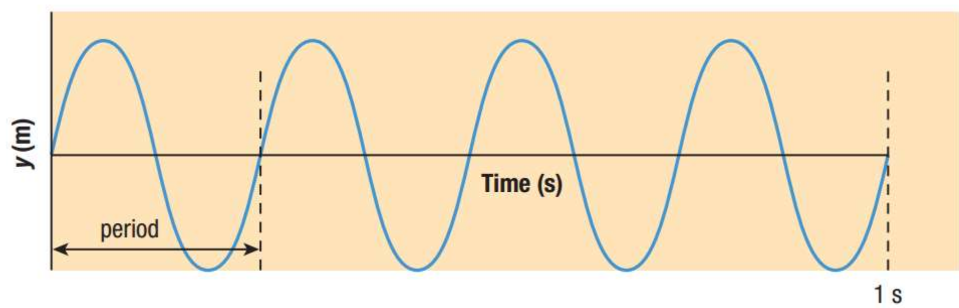
# SPH3U 8.3 Wave Characteristics

**4. Geometric wave characteristics**




| | |
|---|---|
| Amplitude: | |
| Wavelength: | |
| Phase: | |
| Phase shift: | |

**5. Geometric wave characteristics**




| | | |
|---|---|---|
| Period: | | |
| Frequency: | | |
| equation | | |
| Wave speed: | | |
| equation | | |

| | |
|---|---|
| Simple harmonic motion (SHM): | |

**Homework:** page 387: #1, 3-4

# SPH3U 8.4 Determining Wave Speed

**6. The universal wave equation**

| | |
|---|---|
| Universal wave equation: | |

A harp string supports a wave with a wavelength of 2.3 m and a frequency of 220.0 Hz. Calculate its wave speed.

A trumpet produces a sound wave that is observed travelling at 350 m/s with a frequency of 1046.50 Hz. Calculate the wavelength of the sound wave.

**7. Factors that affect wave speed**

| | |
|---|---|
| Rigidity: | |
| Temperature: | |
| Linear density: | |
| equation | |
| Speed of a wave on a string: | |

On your class wave machine, you have a string of mass 350 g and length 2.3 m. You would like to send a wave along this string at a speed of 50.0 m/s. What must the tension of the string be?

**Homework:** page 391: #1-3, 7

# SPH3U 8.5 Properties of Sound Waves

## 1. Categories of sound waves

| | |
|---|---|
| Audible sound waves: | |
| infrasonic | |
| ultrasonic | |

## 2. The speed of sound through air

| | |
|---|---|
| Equation: | |

The temperature outside is 23 °C. What is the speed of sound in air at this temperature?

If the speed of sound is measured to be 318 m/s, what is the current air temperature?

## 3. Mach number

| | |
|---|---|
| Mach number: | |
| equation | |

An aircraft is flying at 905 km/h in air at the temperature −50.0 °C. Calculate the Mach number associated with this speed.

## 4. Sound intensity

| | |
|---|---|
| Sound intensity: | |
| sound level | |

| Type of sound | Typical sound intensity (W/m²) | Sound level (dB) | Type of sound | Typical sound intensity (W/m²) | Sound level (dB) |
|---|---|---|---|---|---|
| threshold of human hearing | $1 \times 10^{-12}$ | 0 | jet flyover (at 300 m) | $1 \times 10^{-2}$ | 100 |
| normal breathing (at 1 m) | $1 \times 10^{-11}$ | 10 | rock band | 0.1 | 110 |
| typical whisper (at 1 m) | $1 \times 10^{-10}$ | 20 | jet aircraft engine (at 80 m), power saw | 1.0 | 120 |
| empty classroom | $1 \times 10^{-9}$ | 30 | threshold of pain | 10 | 130 |
| computer (at 1 m) | $1 \times 10^{-8}$ | 40 | military jet taking off | 100 | 140 |
| library | $1 \times 10^{-7}$ | 50 | space shuttle (at 180 m) | 316 | 145 |
| alarm clock (at 1 m) | $1 \times 10^{-6}$ | 60 | sound cannon (at 1 m) | 1 000 | 150 |
| vacuum cleaner (at 2 m) | $1 \times 10^{-5}$ | 70 | 1 tonne TNT (at 30 m) (buildings 50 % destroyed) | 380 000 | 175.8 |
| diesel locomotive (at 30 m) | $1 \times 10^{-4}$ | 80 | tornado | $1 \times 10^{12}$ | 240 |
| motorcycle (at 10 m) | $1 \times 10^{-3}$ | 90 | atomic bomb | $1 \times 10^{13}$ | 250 |

Loudness and distance:

| Distance (m) | Sound level (dB) |
|---|---|
| 1 | 120 |
| 10 | 100 |
| 50 | 86 |
| 100 | 80 |
| 200 | 74 |
| 500 | 66 |
| 1 000 | 60 |
| 2 000 | 54 |
| 5 000 | 46 |
| 10 000 | 40 |

Sound safety:

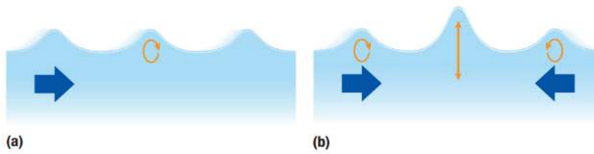
| Continuous dB | Permissible exposure time |
|---|---|
| 85 | 8 h |
| 88 | 4 h |
| 91 | 2 h |
| 94 | 1 h |
| 97 | 30 min |
| 100 | 15 min |
| 103 | 7.5 min |
| 106 | 3.75 min (<4 min) |
| 109 | 1.88 min (<2 min) |
| 112 | 0.94 min (~1 min) |
| 115 | 0.47 min (~30 s) |

**Homework:** page 397 #2-3, 9-10

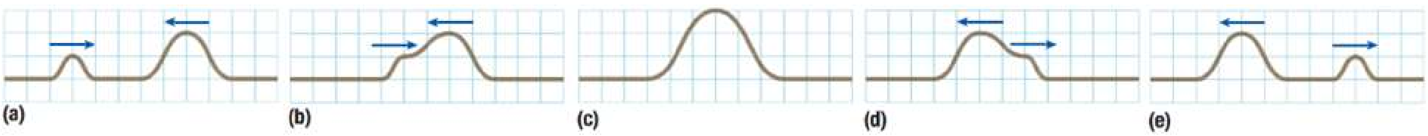
# SPH3U 9.1 Interference of Waves

## 8. Wave interference

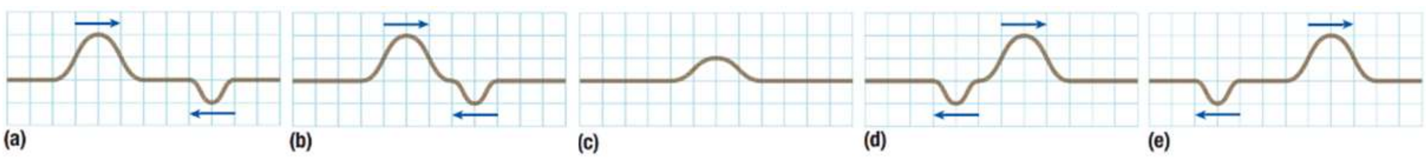
| | |
|---|---|
| Interference: | |



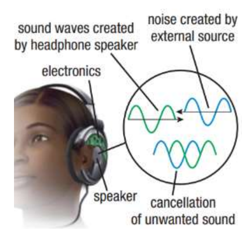
| | |
|---|---|
| Principle of superposition: | |
| Constructive interference: | |



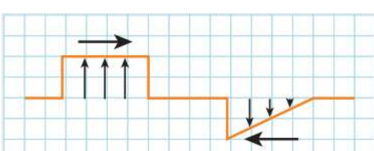
| | |
|---|---|
| Destructive interference: | |



| | |
|---|---|
| Noise-cancelling headphones: | |
| benefit | |




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

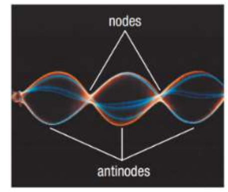


**Homework:** page 419: #1-2

# SPH3U 9.2 Waves at Media Boundaries

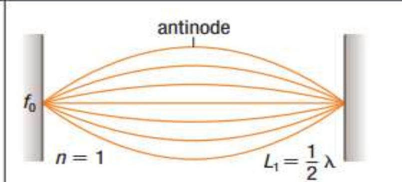
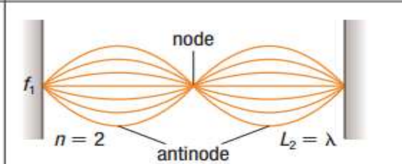
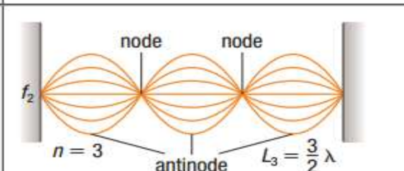
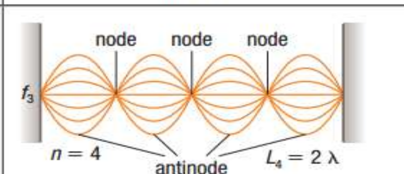
## 9. Standing waves

| | |
|---|---|
| Standing wave: | |
| cause | |
| nodes | |
| antinodes | |



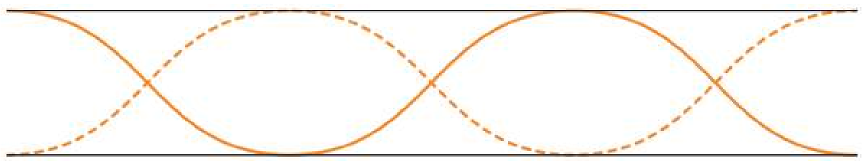

## 10. Standing waves – 2 fixed ends

| | |
|---|---|
| Fixed end: | |
| 2 fixed ends | |

| 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 | third |

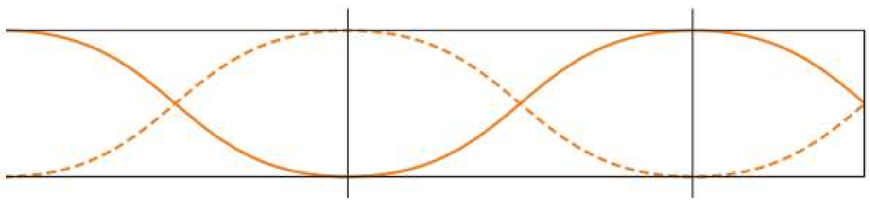
**11. Standing waves – 2 free ends**

| | |
|---|---|
| Free end: | |
| 2 free ends | |



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

| | |
|---|---|
| Fixed-free ends: | |



**13. Equations**

| | |
|---|---|
| 2 fixed or 2 free: | |
| Fixed-free: | |

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?

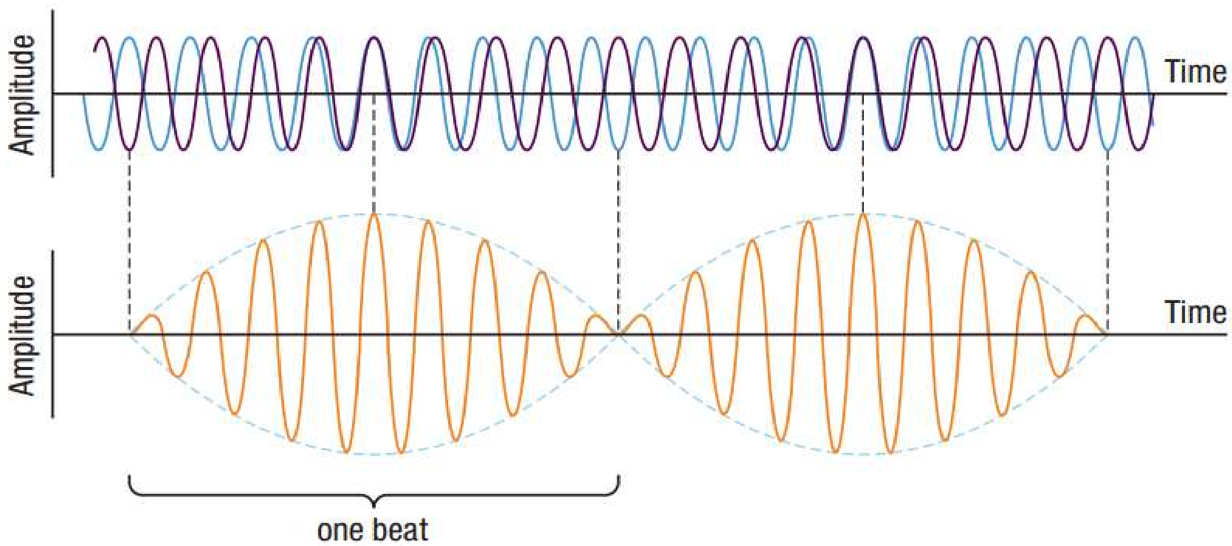
The sixth harmonic of a 65 cm guitar string is heard. If the speed of sound in the string is 206 m/s, what is the frequency of the standing wave?

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

# <u>SPH3U 9.3 Beats</u>

**14. Beats**

| | |
|---|---|
| Beat: | |
| Beat frequency: | |
| equation | |



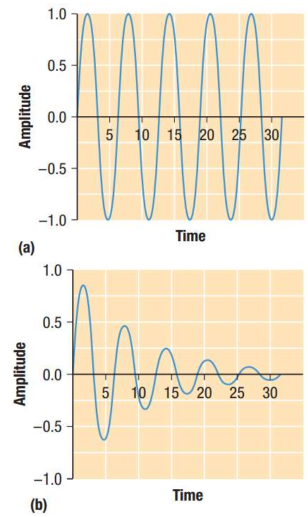

John is tuning his guitar. His string produces a frequency of 442 Hz, and his tuner produces a frequency of 440 Hz. What beat frequency does John hear?

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

# SPH3U 9.4 Damping and Resonance

## 15. Damping and resonance

| | |
|---|---|
| Damping: | |
| Resonant frequency: | |
| resonance | |
| standing waves | |
| Vibrating structures: | |

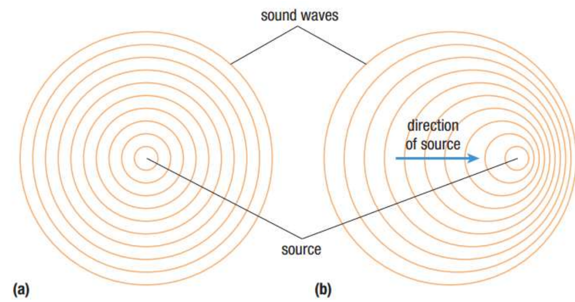



**Homework:** page 432: #1-2

# SPH3U 9.5 The Doppler Effect

## 16. The Doppler Effect

| | |
|---|---|
| The Doppler Effect: | |
| equation | |
| $v_{source}$ | |


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.

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