Waves

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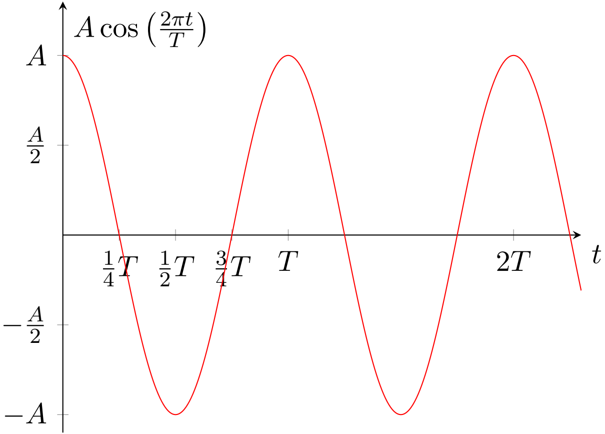
Oscillation vs. Wave

- An oscillation is a periodic disturbance in time.
- A wave is a periodic disturbance in space and time.
- A wave has an amplitude and a period, like an oscillation, but a wave also has a *wavelength*.

If we sit at one point in space, a wave looks like an oscillation.



- A is amplitude, T is period

Period, frequency, and angular frequency are related in the same way for waves that they are for oscillations.

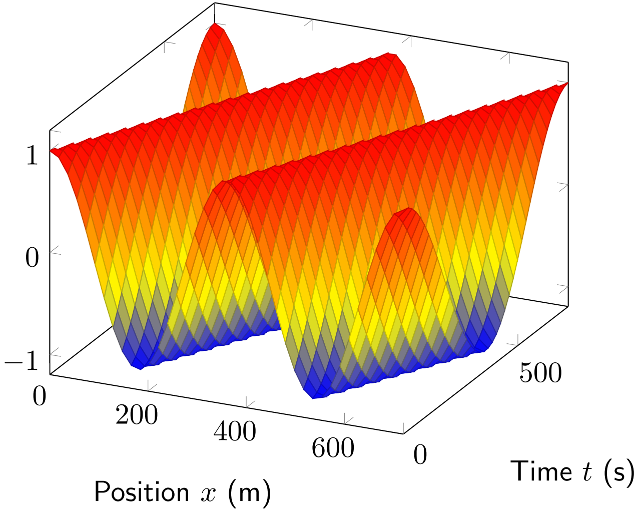
Quantity	Symbol	Unit
Period	T	s
Frequency	f	Hz = cycle/s = rev/s
Angular frequency	ω	rad/s

$$f = \frac{1}{T}$$

$$\omega = 2\pi f$$

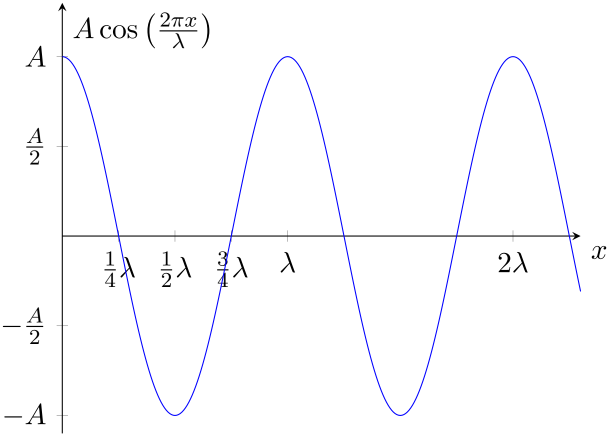
Animation of a 1D traveling wave

A wave moves in space and time



- This wave moves in the positive x direction.

Wavelength is the distance between crests.



- A is amplitude, λ is wavelength

A traveling wave has a wave speed

$$v = \frac{\lambda}{T}.$$

(You can remember this because a speed is a length divided by a time.)

- How are wavelength and frequency related? Since

  $$f = \frac{1}{T},$$

  we know that

  $$v = \lambda f.$$

  So, wavelength times frequency is wave speed.

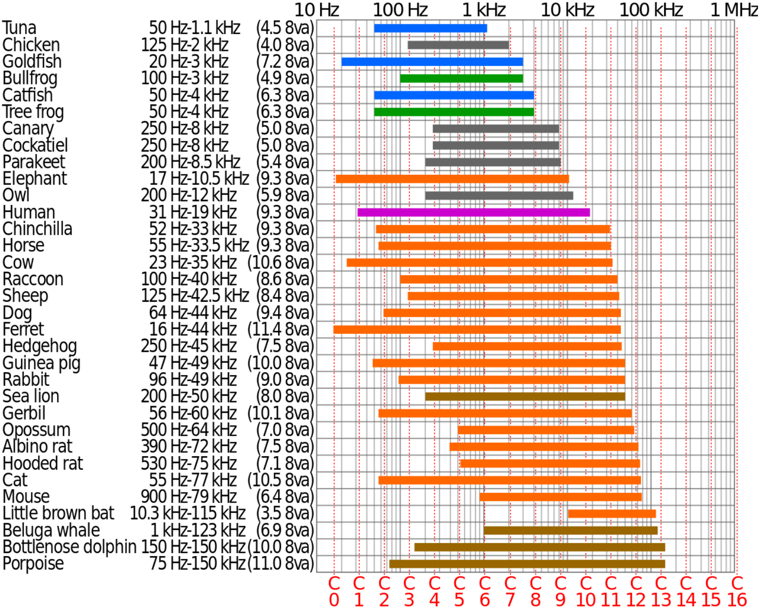
Traveling waves and standing waves

- A traveling wave appears to travel.
- A standing wave has nodes.
- Animation of a standing wave.

Kinds of waves

- Sound waves (piano is 27.5 Hz to 4186 Hz)
- Ultrasound waves (2 MHz to 15 MHz)
- Light waves (400 THz to 790 THz)
- Microwaves (like the oven, 2.45 GHz)
- Radio waves (like WXPN, 88.5 MHz)
- Water waves
- Waves on a string (like a guitar string, 82 Hz to 330 Hz)

Animals hear in different frequency ranges.



Speeds of waves

Wave	type	speed
Sound	mechanical (3D)	≈ 340 m/s (in air)
Ultrasound	mechanical (3D)	≈ 1500 m/s (in water)
Light	electromagnetic	3×10^8 m/s
Microwaves	electromagnetic	3×10^8 m/s
Radio	electromagnetic	3×10^8 m/s
Water waves	mechanical (2D/surface)	≈ 2 m/s
Guitar string	mechanical (1D)	≈ 250 m/s

Mechanical waves need a medium

- Sound waves can't travel in empty space.
- Sound waves have a different speed in air than in water. (Speed depends on medium.)

Electromagnetic waves don't need a medium

- Light waves can travel in empty space.
- Light waves have a different speed in air than in water.

Sound wave: What determines wave speed, wavelength, and frequency?

- Wave speed in air near Earth's surface is about 340 m/s. The speed changes a little with atmospheric pressure, temperature, and humidity.
- The frequency of the wave is determined by the source (voice, guitar, clap, gun shot, etc.).
- Wavelength is determined by

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

Guitar string: What determines wave speed, wavelength, and frequency?

- String ends are fixed 65 cm from each other, so $\lambda = 130$ cm for all of the strings.
- Wave speed

  $$v = \sqrt{\frac{F_T}{\mu}}$$

  depends on tension F_T in the string and mass per unit length μ.
- Each guitar string has a different heaviness (different μ). So, wave speed is different on each string.
- When we tune the guitar, we adjust the tension, changing the wave speed, changing the frequency.
- We want 196 Hz for the G string on the guitar.

Guitar waves on string and in air

- We pluck G string on guitar. Pluck produces wave on string with fundamental frequency 196 Hz.
- Air transmits frequency of 196 Hz, with a different speed and wavelength than the string.

medium	speed	wavelength	frequency
on string	255 m/s	130 cm	196 Hz
in air	340 m/s	173 cm	196 Hz

A wave can exhibit interference

Wave summary

Property	Symbol	Unit
Wavelength	λ	m
Period	T	s
Frequency	f	Hz
Speed	v	m/s
Amplitude	depends	depends

$$f = \frac{1}{T}$$

$$v = \frac{\lambda}{T} = \lambda f$$