Weds: Read

Mon: Nov 4 HW8

Waves

A wave is a pattern that propagates in some material (medium).

DEMO: PhET Waves Intro

* water waves, side view

Such water waves can, in principle, be described using Newton's Laws. However, the large number of particles involved makes this challenging and physics has adapted to this by developing a language for waves. This is used to describe:

* water waves
* sound (in air and other materials) → how sound travels, beats, sound recording/production by electronics → Doppler effect.
* light → how light propagates, resolution limits, reflection coatings.
* waves on strings → How string instruments work

DEMO: PhET waves intro

* sound - show both
* light

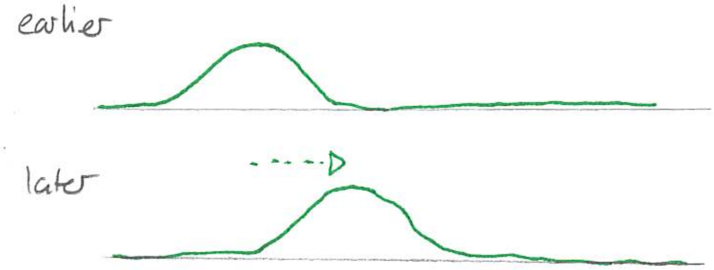
Waves on a string

We can describe the basic phenomena of waves by considering a situation where the wave travels along one line.

DEMO: Stretched Slinky

- produce pulse

This shows



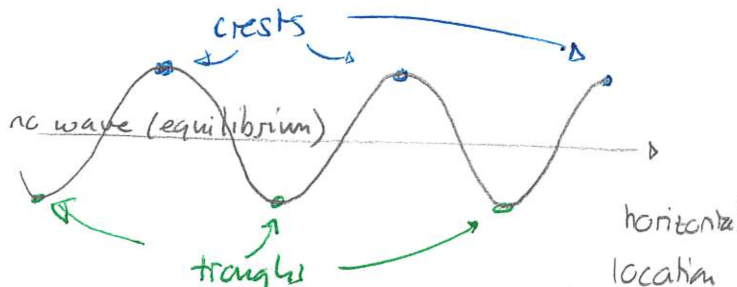
* a pattern that propagates along the length of the string
* individual pieces or segments of the string move perpendicular to the pattern.

The basic details can be described in an idealized situation, where the string is infinitely long.

DEMO: PhET W.o.a.S.

* produce ~~p'~~ oscillating wave on ~~open~~ no end

The mathematical description of this uses sine or cosine functions but the important features can be described with simpler concepts. We first consider a snapshot at one instant. We can identify:



* crests - high points
* troughs - low points

Then, the following quantities describe the spatial aspects of this wave

1) Amplitude (vertical aspect)

The amplitude is the maximum vertical displacement from equilibrium

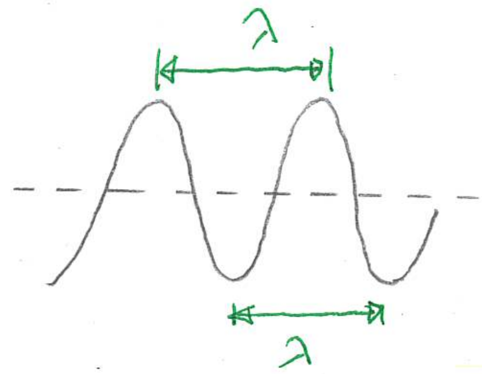
Slide 1

The theory of waves usually relates the amplitude of the wave to the energy that it transports. Thus

* amplitude of sound wave ⟶ intensity of sound (how loud)
* amplitude of light wave ⟶ intensity of light (how bright)

2) . Wavelength (horizontal aspect)

Wavelength describes the horizontal "stretch" of the pattern. The definition is



> wavelength = horizontal distance from one crest to the next
>
> λ "lambda"
>
> units : meters

Slide 2 60%

Quiz1 90%

Alternatively the wavelength is the distance between successive troughs or successive points at the same place in the pattern

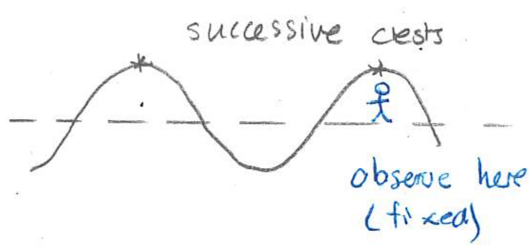
DEMO: PhET W.o.a.S → Show wavelength.

Quiz 2

We also need to describe the temporal aspects of the wave - how the pattern changes as time passes.

3) Period (temporal aspect)

The period is a time that describes. This requires observation at one horizontal location. Then



> The period of wave = time between arrival of successive crests
>
> units: seconds

Quiz3

DEMO: Do actual timing

4) Frequency (temporal aspect)

The frequency describes the rate at which the pattern repeats. It will roughly give the number of crests that pass any given location in one second. The definition is

$$\text{frequency} = 1/\text{period} \qquad \text{units: Hertz} \qquad Hz = 1/sec$$

DEMO: W.o.a.S
- no end
- no damping
- tension low - adjust frequency and observe higher vs lower.

5 Wave speed (spatial and temporal)

This describes the speed with which the pattern moves. To determine this, observe the wave at two instants. Then

$$\text{wave speed} = \frac{\text{distance traveled by pattern}}{\text{time elapsed between instants}} \qquad \text{units} = \text{meter/second}$$

s

m/s

Slide 3

In general one can show that it is always true that

$$\text{wave speed} = \text{wavelength} \times \text{frequency} \qquad s = \lambda \times f$$

The speed of a wave depends on the medium:

* string ⇝ depends on tension, mass per meter.
* sound ⇝ air temperature
* light ⇝ in a vacuum

$$\text{speed of light} = c = 3.0 \times 10^8 \, m/s$$

1 Wavelength, frequency and speed for continuous waves

The PhET animation "Waves on a String" allows you to visualize transverse waves on a string. Find the animation at

`https://phet.colorado.edu/en/simulation/wave-on-a-string`

and open it. Adjust the settings as follows:

- Check the button "No end" at the upper right.
- In the control panel at the bottom, adjust "Damping" to none.
- In the control panel at the bottom, adjust "Tension" to medium.
- In the control panel at the bottom, check the "Rulers" and "Timer" buttons.
- Leave the frequency on its default setting 1.50 Hz.
- Check the button "Oscillate" at the upper left.

a) Pause the wave and use the ruler to determine the wavelength of the wave.

b) Play the animation and use the timer to determine the period of the wave. Determine its frequency. *You can use the "Slow Motion" option. This does not affect the timing.*

c) Use the rulers and timer to determine the speed of the wave

A general rule for any continuous wave of this type is

$$\text{speed} = \text{wavelength} \times \text{frequency}.$$

d) Using your data verify whether this general rule is correct.

Answer: a) Appears to be 2,5cm

b) 5 crests pass in 3.36s

Time between successive crests is

$$\frac{3.36\text{s}}{5} = 0.672\text{s} \qquad \text{period} = 0.672\text{s}$$

$$\text{Frequency} = \frac{1}{\text{period}} = \frac{1}{0.672\text{s}} = 1.49\text{ Hz}$$

c) One crest travels 5cm in 1.34s

$$\text{speed} = \frac{5\text{cm}}{1.34\text{s}} = 3.7\text{ cm/s}$$

d) wavelength × freq = 2.5cm × 1.49Hz = 3.7cm/s