Physics in the classroom

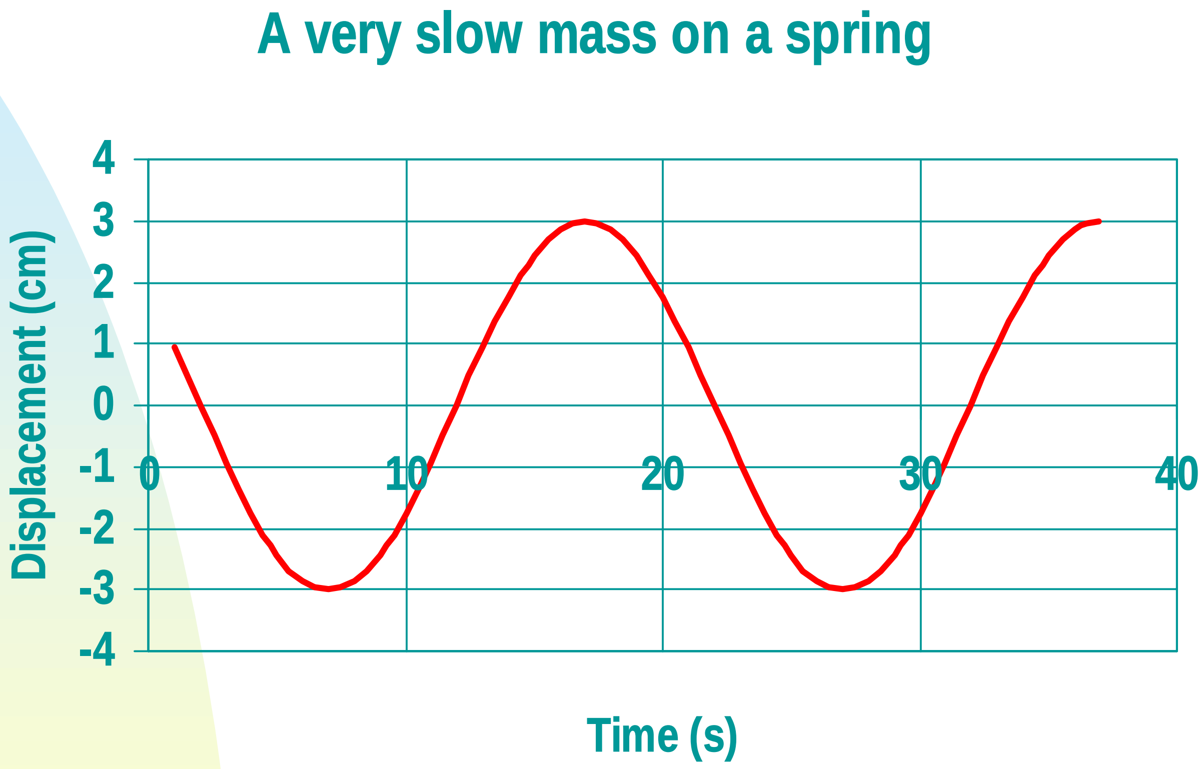
Lecture 4

Oscillations

Oscillations are things which repeat themselves in a regular way.

Examples:

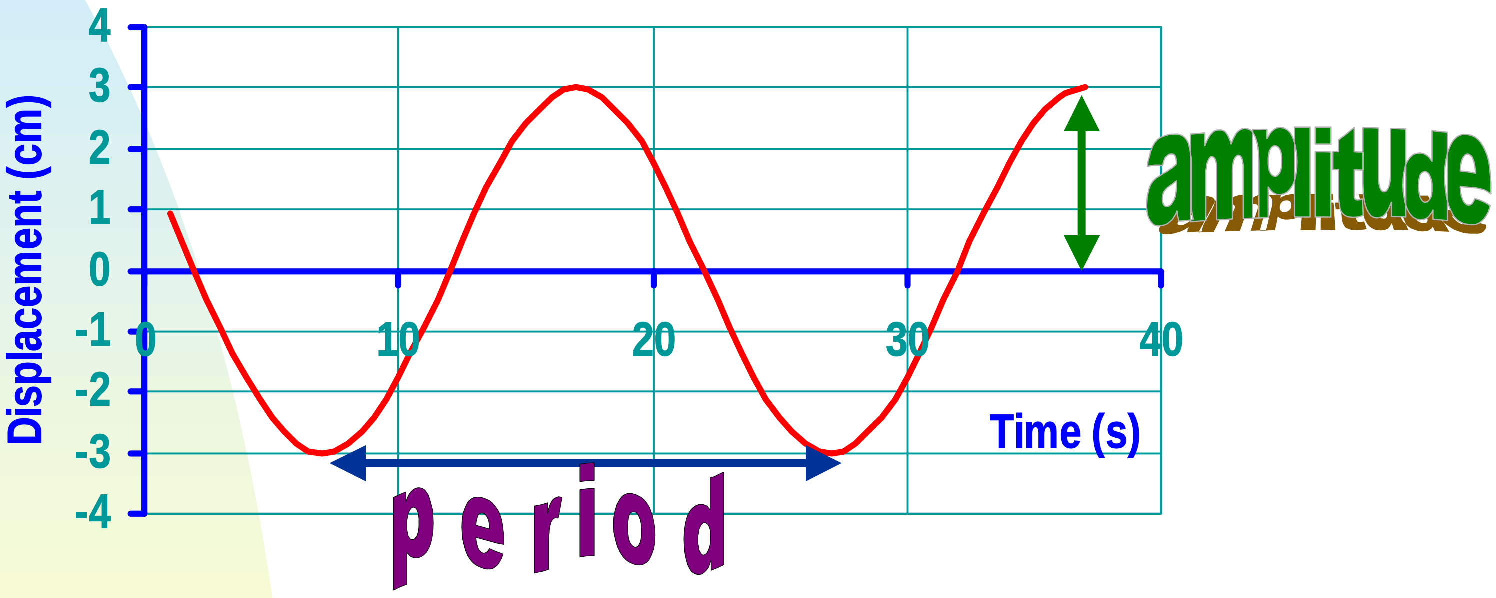
Mass bouncing on a spring.
Mass swinging.
A beating heart.
A bouncing ball.
Person on a pogo stick


A very slow mass on a spring
Displacement (cm)
4
3
2
1
0
-1
-2
-3
-4
0
10
20
30
40
Time (s)

Amplitude: Distance from equilibrium point to maximum displacement in either the positive or negative direction.

Period: TIME for one complete oscillation. Units: seconds

A very slow mass on a spring



Period (T). The time for one complete oscillation.
Units: seconds [s].

Frequency (f). The number of oscillations in a given time.
Units: per seconds [1/s] or Hertz [Hz]

Period (T) and Frequency (f) are just the inverse of each other.

$$T = 1/f \quad \text{or} \quad f = 1/T$$

Example:
To say that something takes only half a second to oscillate once, is the same as saying that it oscillates twice per second.

A period of ½ = 0.5 seconds corresponds to a frequency of 2 Hz

And now for something different, but related.

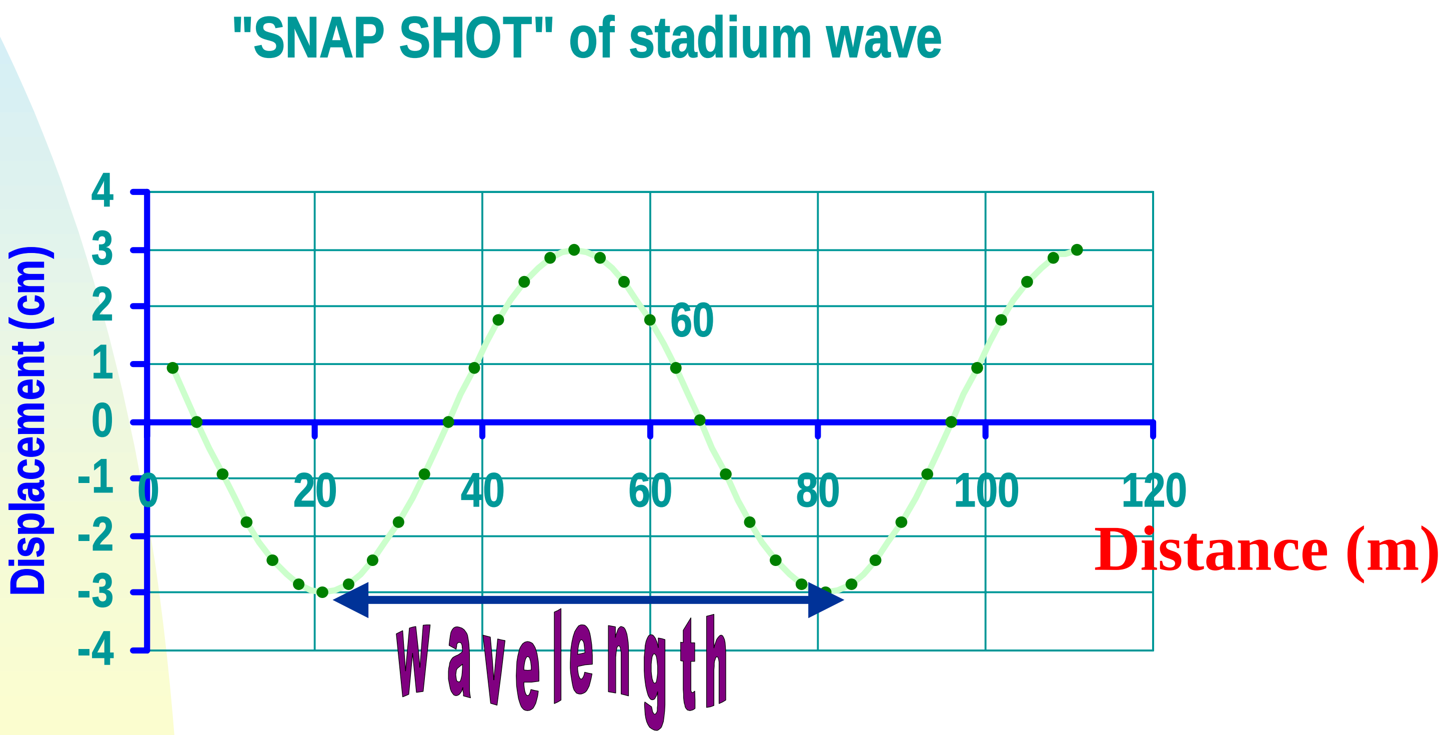
Wave

An oscillation is the periodic motion of a single object.
When many objects oscillate cooperatively so as to propagate a disturbance, that disturbance is called a wave.

Examples:
Water waves
Light waves
Sound waves
Stadium waves (my favorite)
Many, many others!

If we focus on one person in the stadium wave, that one person is oscillating, like our mass on a spring.

However, if we take a snap shot of the whole stadium wave, we get a deceptively similar graph as the one we saw before.



Wavelength (λ) The DISTANCE between similar disturbances in a wave.
Unit: meter [m].

Virginia is a big sports fan, she is also a bit of a nerd. At a recent game, she noticed that , while participating in a stadium wave, that the person 10 seats down from her was doing the same thing she was. She measured the distance between stadium seats to be 0.5 meters.
So the wavelength of the stadium wave was 5 meters.

Now lets combine the two concepts of oscillations and waves.

If we divide the wavelength by the period, what do we get? What do the units tell us? The wavelength is a distance, measured in meters [m]. The period is a time, measured in seconds [s]. So, the result of dividing the wavelength by the period has units of meters over seconds [m/s], which is a speed!

The speed of a wave is given by the wavelength divided by the Period.

$$v = \lambda/T$$

But, remember that the frequency is the inverse of period. So, substituting f for 1/T we get.

$$v = \lambda f$$

$$v = \lambda f$$

The speed of a wave is equal to the wavelength times the frequency.

Example:

Lets go back to our sports fan, Virginia. She has determined that the wavelength of the stadium wave is 5 meters. Later, she also determines that, while participating in the wave, she stands and sits and stands again about 3 times every 2 two seconds, so her frequency is 3/2 Hz or 1.5 Hz. What is the speed of the stadium wave?

$v = \lambda f$

Wavelength, $\lambda = 30\text{m}$

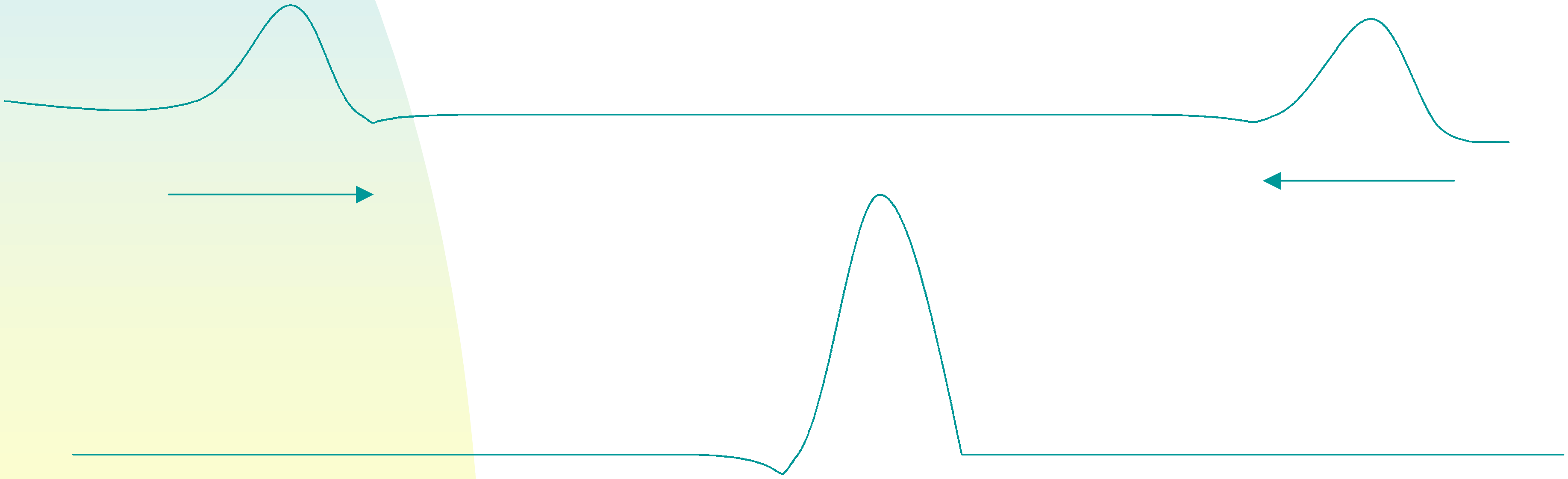
Frequency $f = 1.5\text{Hz}$

So, speed $v = 5\text{m} * 1.5\ 1/\text{s} = 7.5\ \text{m/s}$

Interference

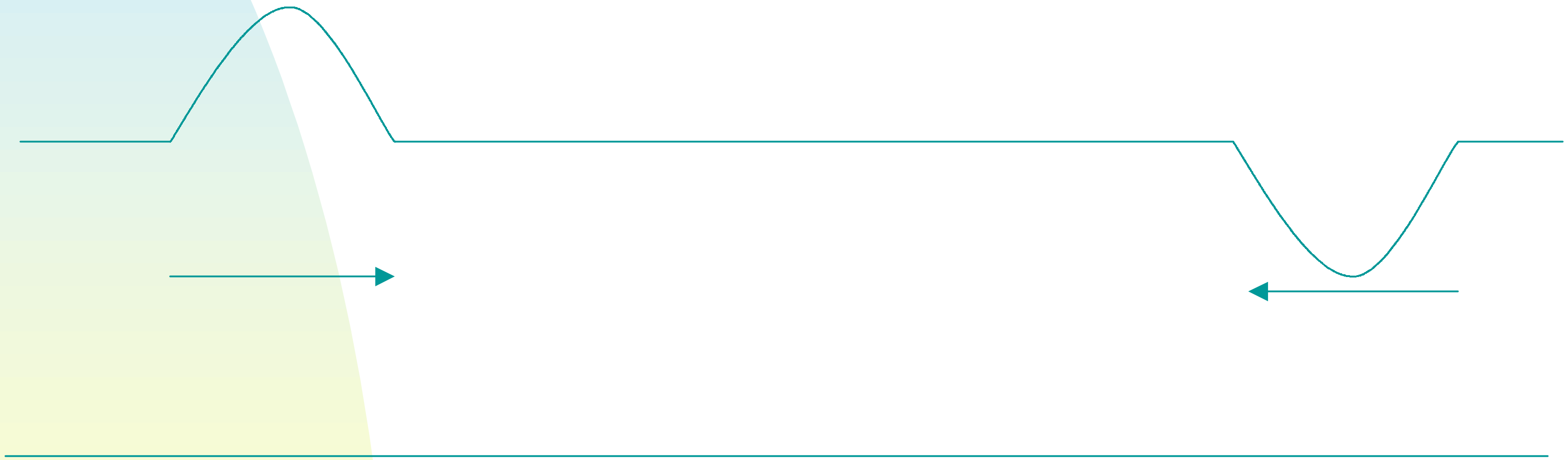
Two or more waves can interfere with each other, constructively, or destructively.

Constructive interference occurs when crest meet crest And/or trough meets trough.



Interference

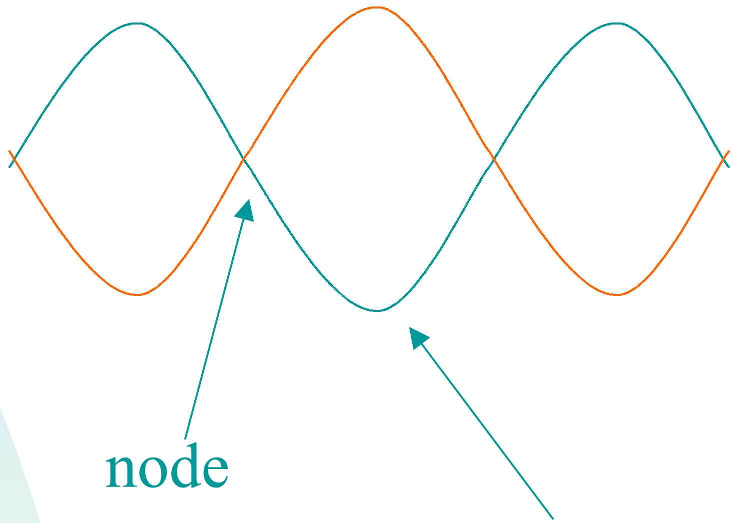
Destructive interference occurs when crest meet troughs.



Standing waves

Under special conditions, waves traveling in opposite
Directions can produce wave patterns which appear
To be standing still. These wave patterns are known as
Standing waves.

Standing wave



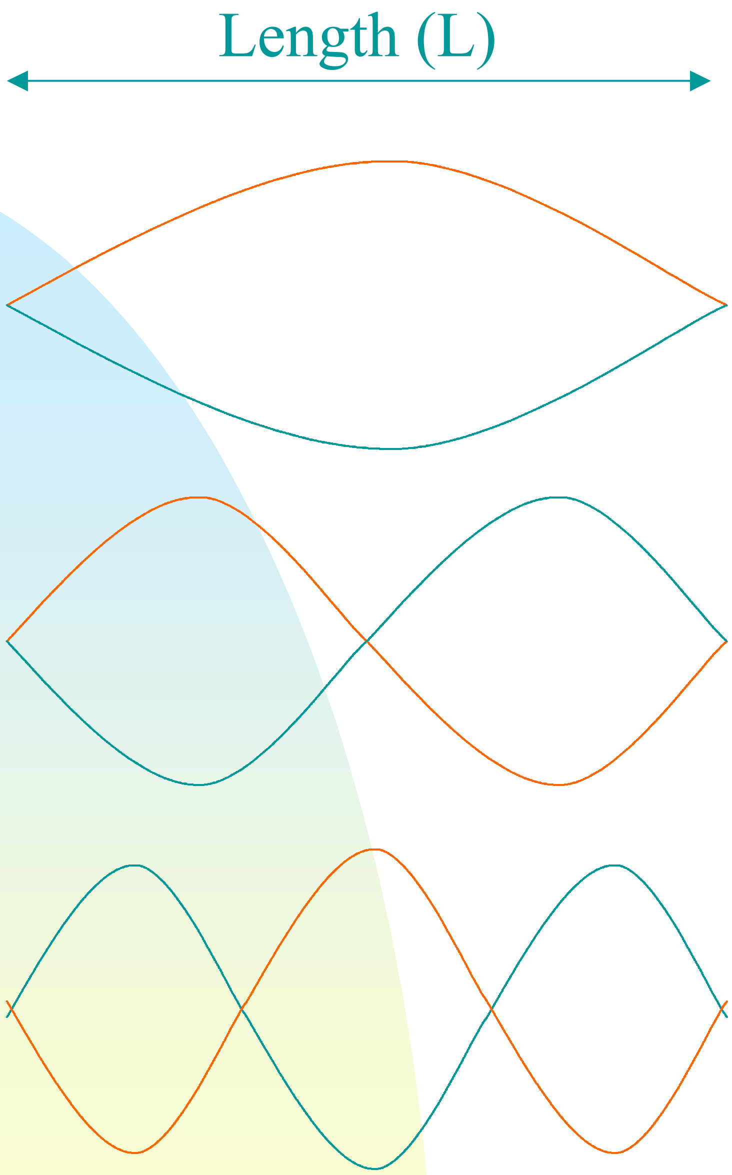
Node: location of no vibration.

Antinode: location of maximum vibration

Notice that the distance between any node and the next Antinode is ¼ of a wavelength.

What is the special condition for a standing wave?

Let's consider a wave on a string, that is tied at both ends. Clearly, a node must be located at each end where the string is tied. So, in order for a standing wave to exist, the length of the string must be ½ of a wavelength, 2/2 of a wavelength 3/2 of a wavelength, etcetera.



$L = (1/2)\,\lambda_1 \longrightarrow \lambda_1 = 2L$

$L = (2/2)\,\lambda_2 \longrightarrow \lambda_2 = L$

$L = (3/2)\,\lambda_3 \longrightarrow \lambda_3 = (2/3)L$