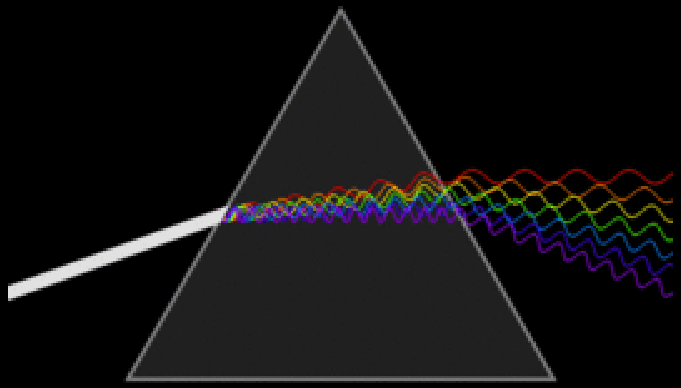
AP Physics

Chapter 13: Vibrations and Waves



What is a wave?

- A disturbance in a medium that transfers energy from one point to another without transferring matter.

- The transport of energy without the transport of matter.

What is a wave?

- There are many different types of waves.
- We will be looking into the types of waves that exist.
- All waves are mathematically represented by sine and cosine functions. (We will get more into this later)

Periodic Motion – It's a wave

- Periodic Motion - A physical motion that has a repeating pattern in repeating intervals of time.

- There are two types of periodic motion

- Simple Harmonic Motion

- Anharmonic Motion

Simple Harmonic Motion

- **A periodic motion where the amplitude of the force acting on our object is proportional to the displacement of the object.**

- **Anything that obeys Hooke's Law**

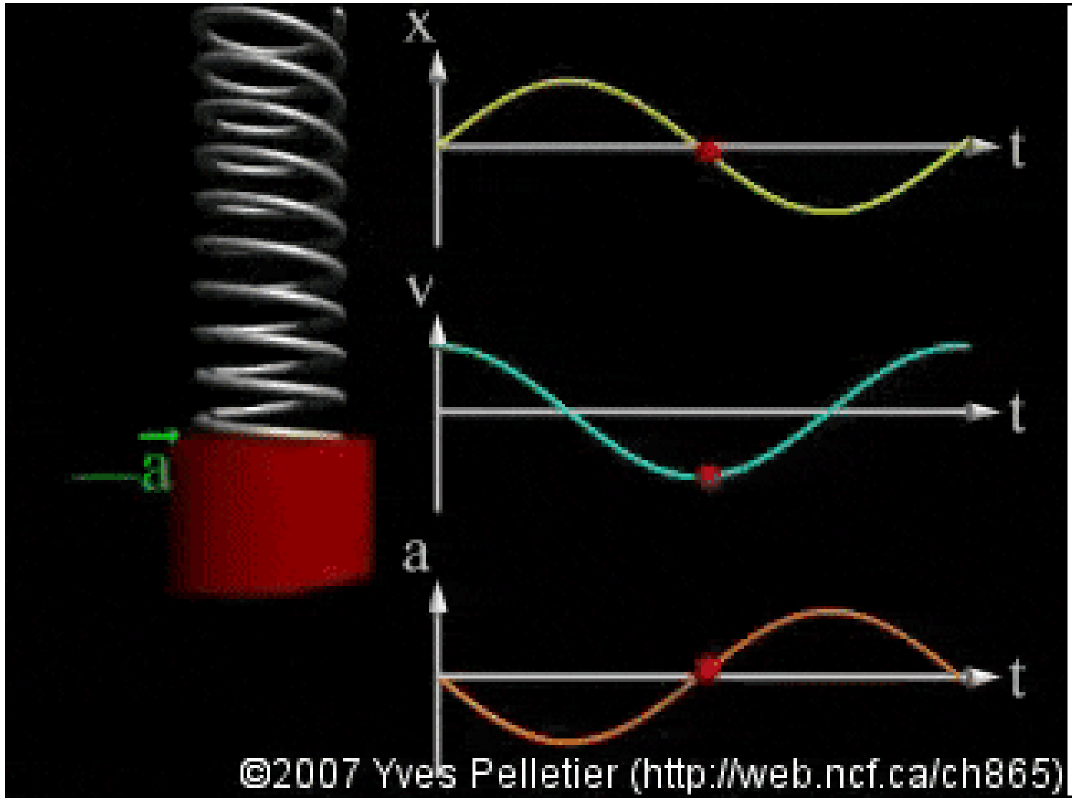
$$\boldsymbol{F = kx}$$

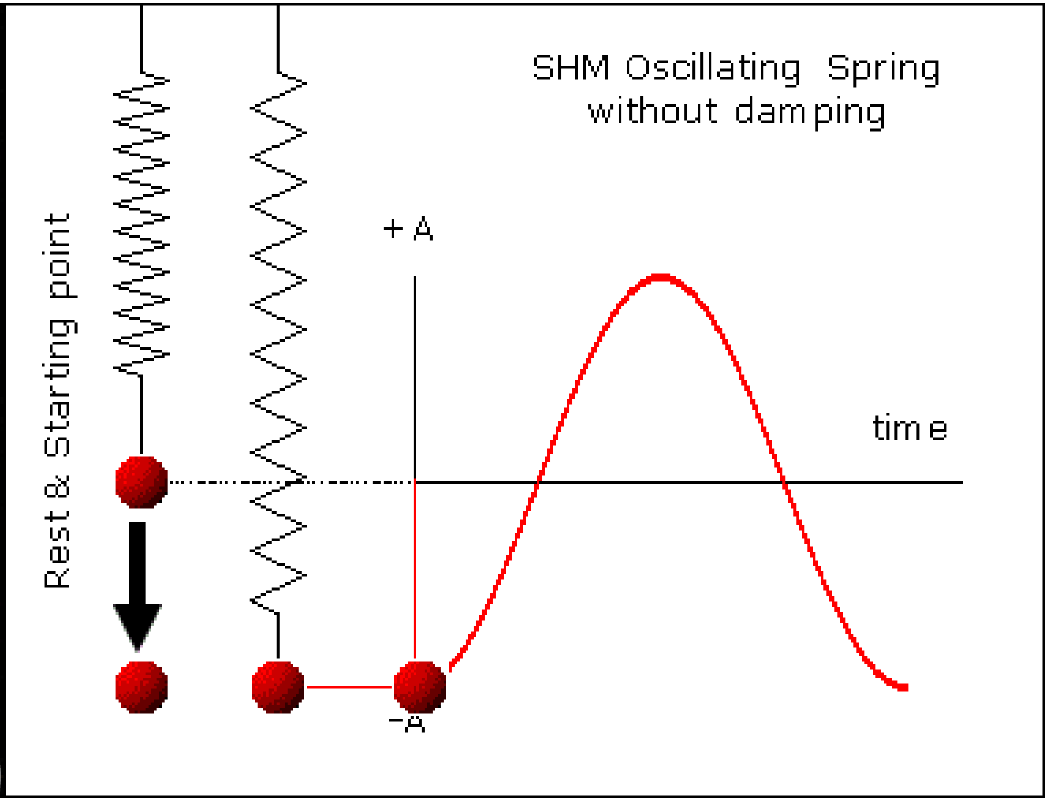
Simple Harmonic Motion

- **Another way to think about this is that it is a repeating motion where the amplitude and frequency of our displacement does not change.**

Simple Harmonic Motion

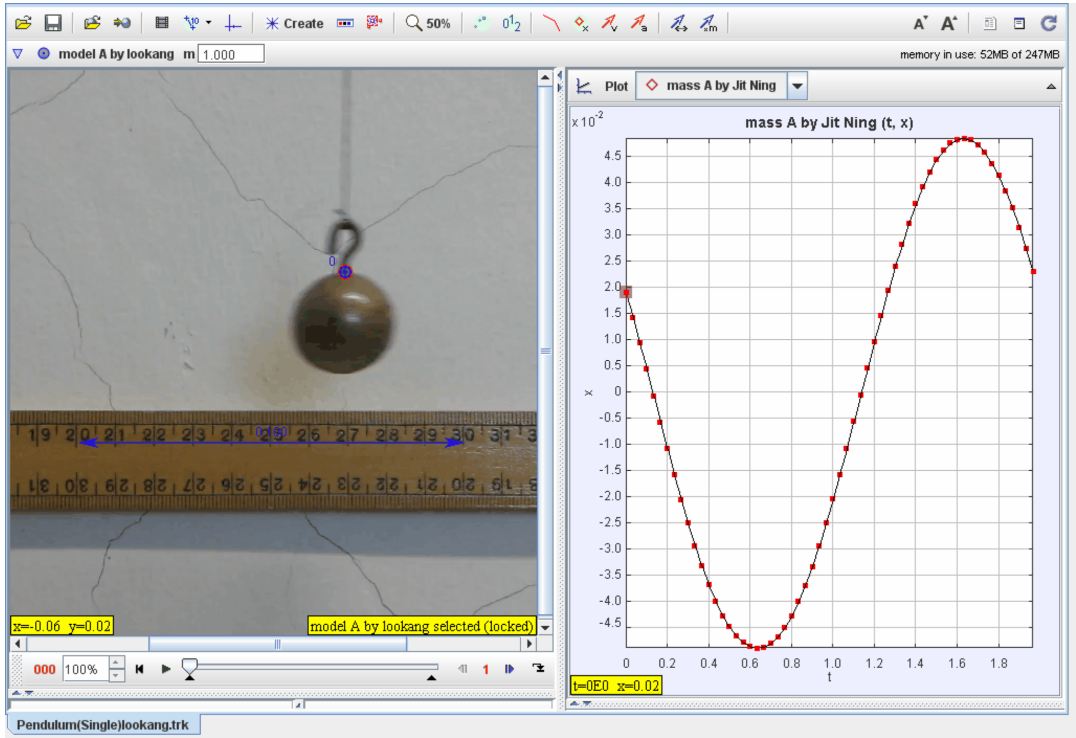
Example of a spring in simple harmonic motion





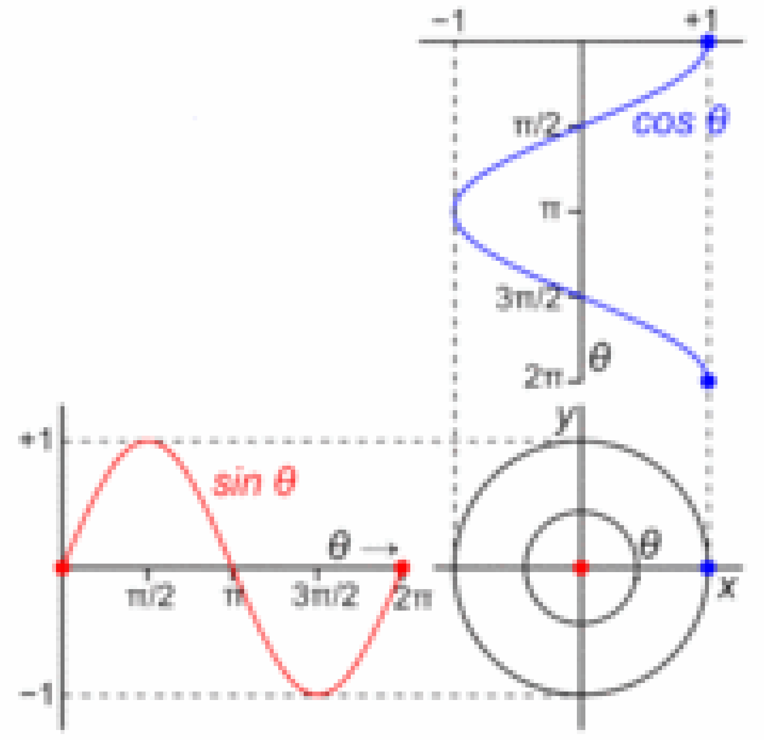
Simple Harmonic Motion

Example of a pendulum



Simple Harmonic Motion

The unit circle from math. (All Circles in general)



Properties of waves

- There four main properties that all waves share.

- The Amplitude
- The Frequency

- Two of these properties depend on what dimension we are looking at for the waves.

- Period
- Wavelength

Properties of waves

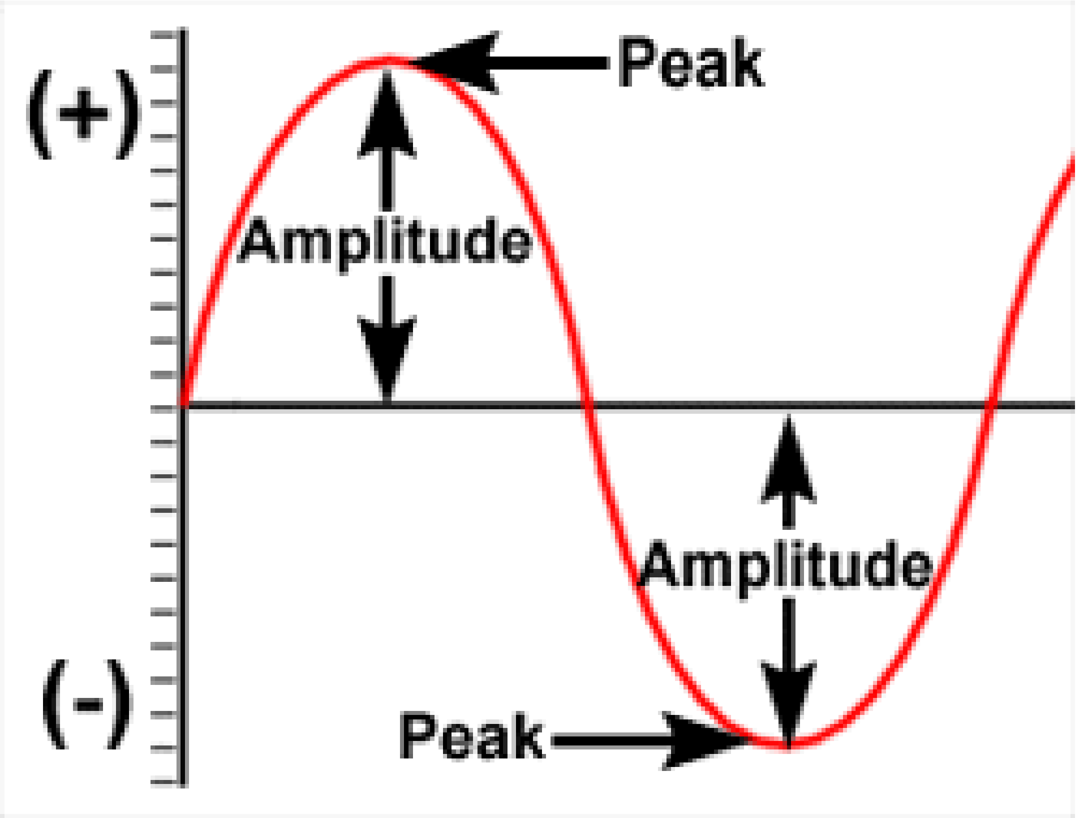
- **The mathematical expression for a wave**

$$Wave = Asin(2\pi ft)$$

A = Amplitude
f **= frequency**
t **= time**

Amplitude

- The height of the wave function.



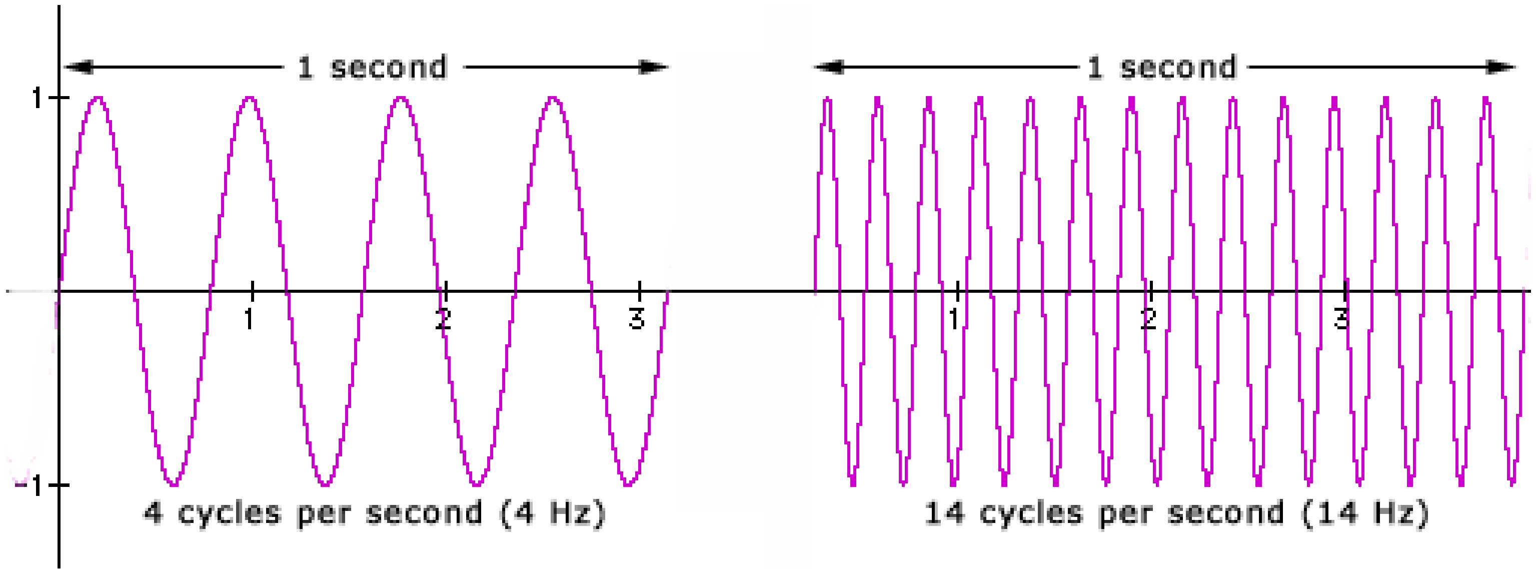
Frequency

- **The amount of oscillations that occur within one second.**

- **The amount of repeating motions that can occur in one second.**

- f **is always measured in Hz**

Frequency



1 second
1 second
1
-1
1
2
3
1
2
3
4 cycles per second (4 Hz)
14 cycles per second (14 Hz)

Period

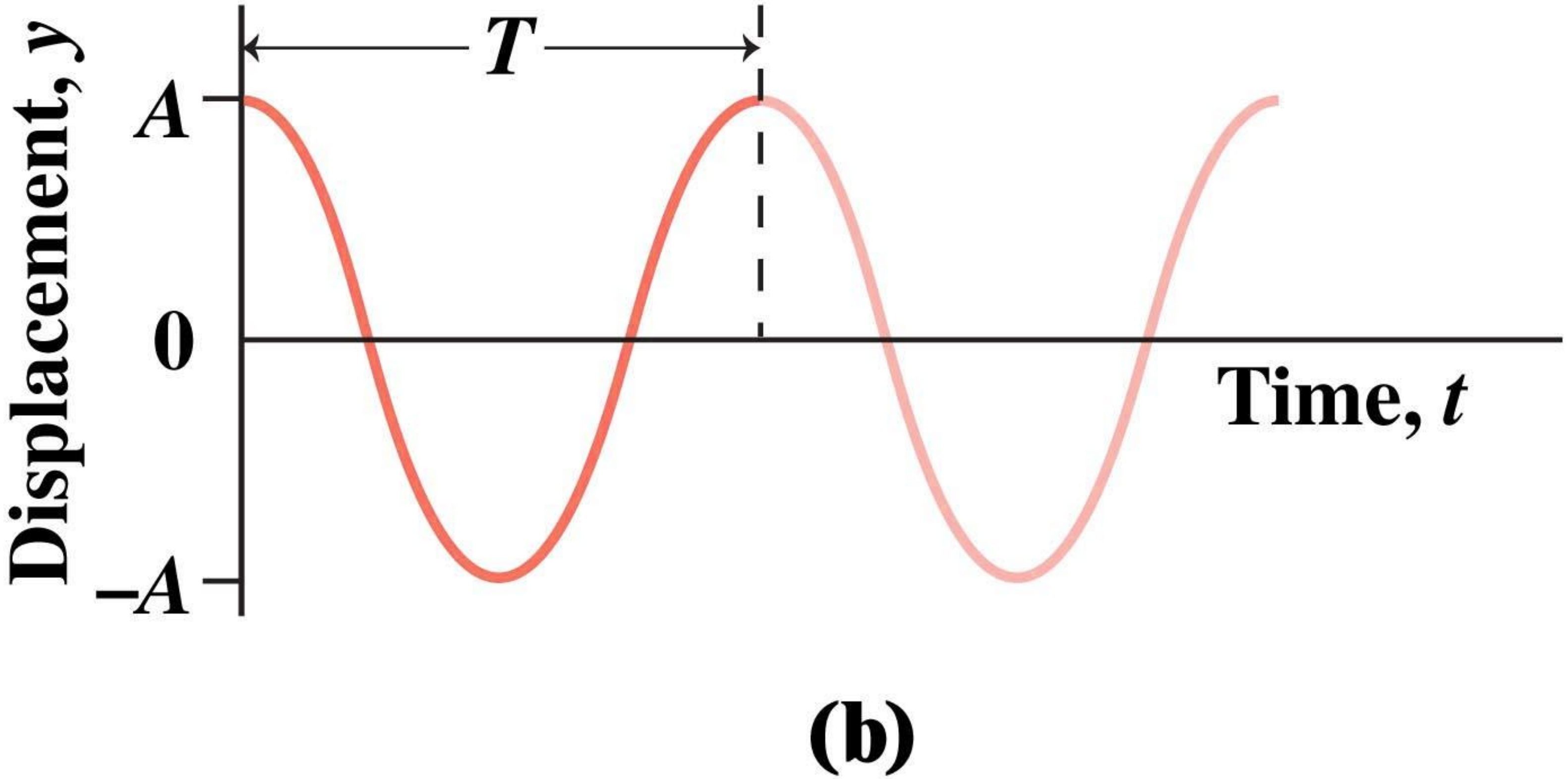
- **The amount of time it takes to complete one oscillation/cycle.**

- **Period = 1/f**

- **It is always measured in a unit of time.**

- **It is usually represented by T**

Period

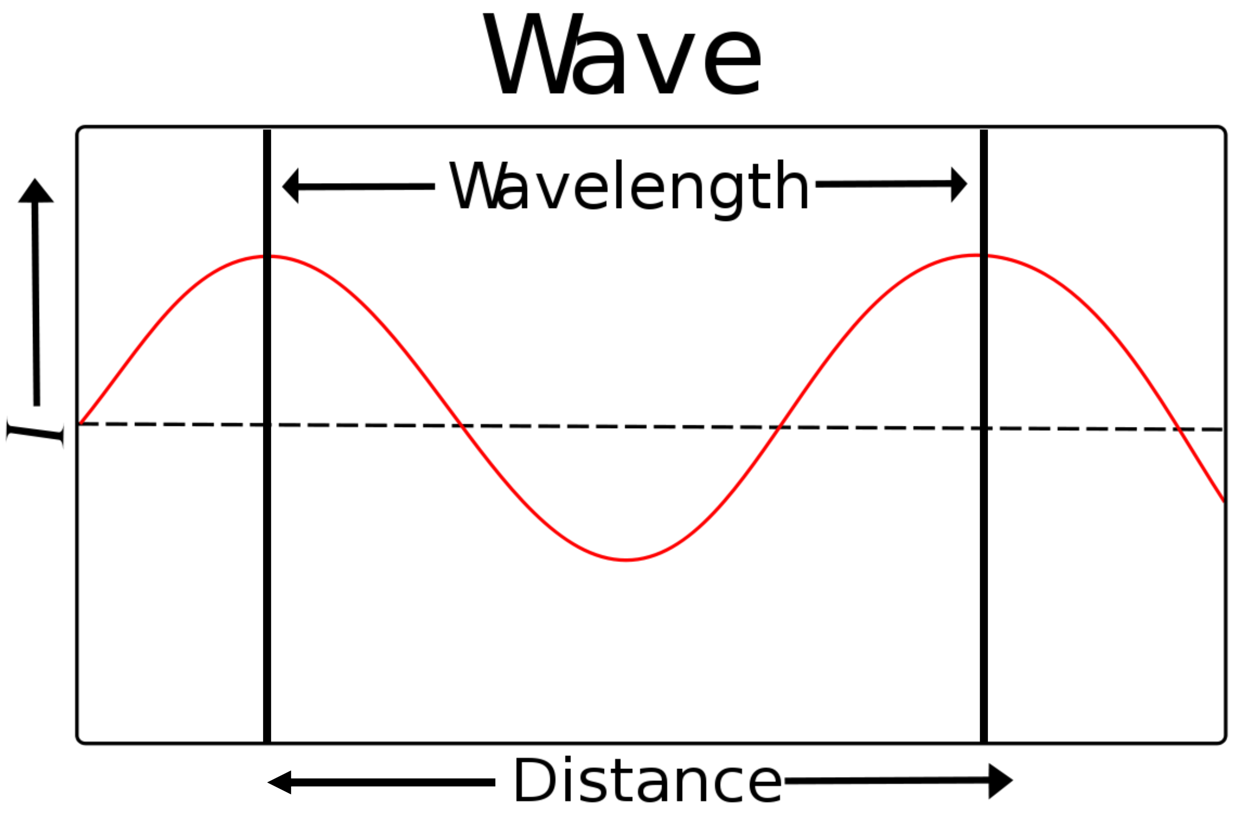


Wavelength

- Similar to period, but instead it is the distance between peaks on a wave.

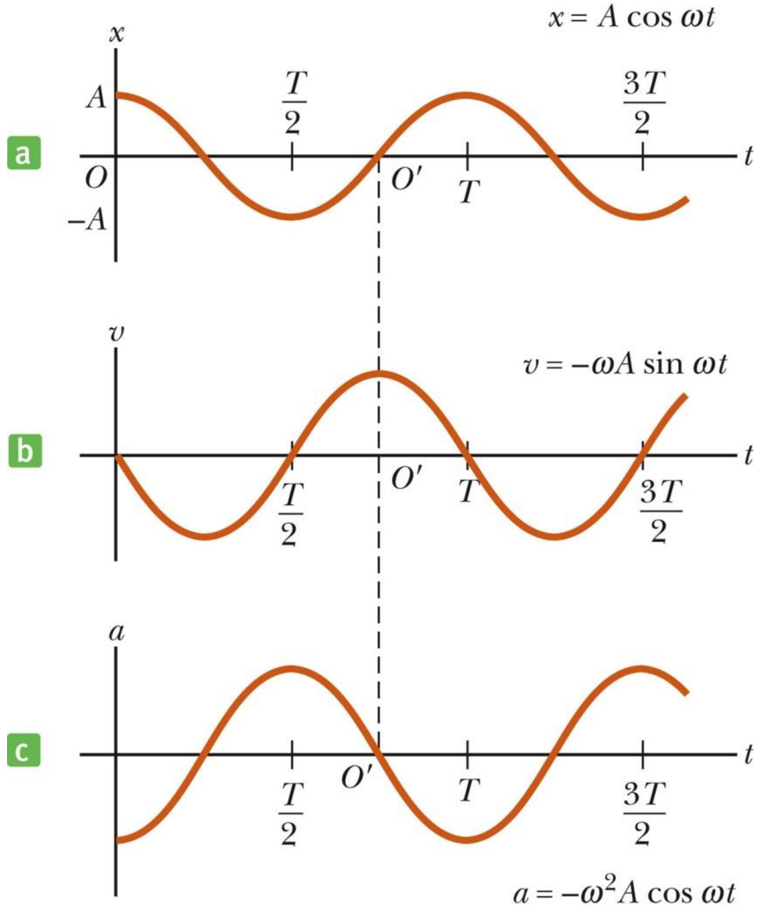
- It is always represented with a lower case lambda, (λ)

Wavelength

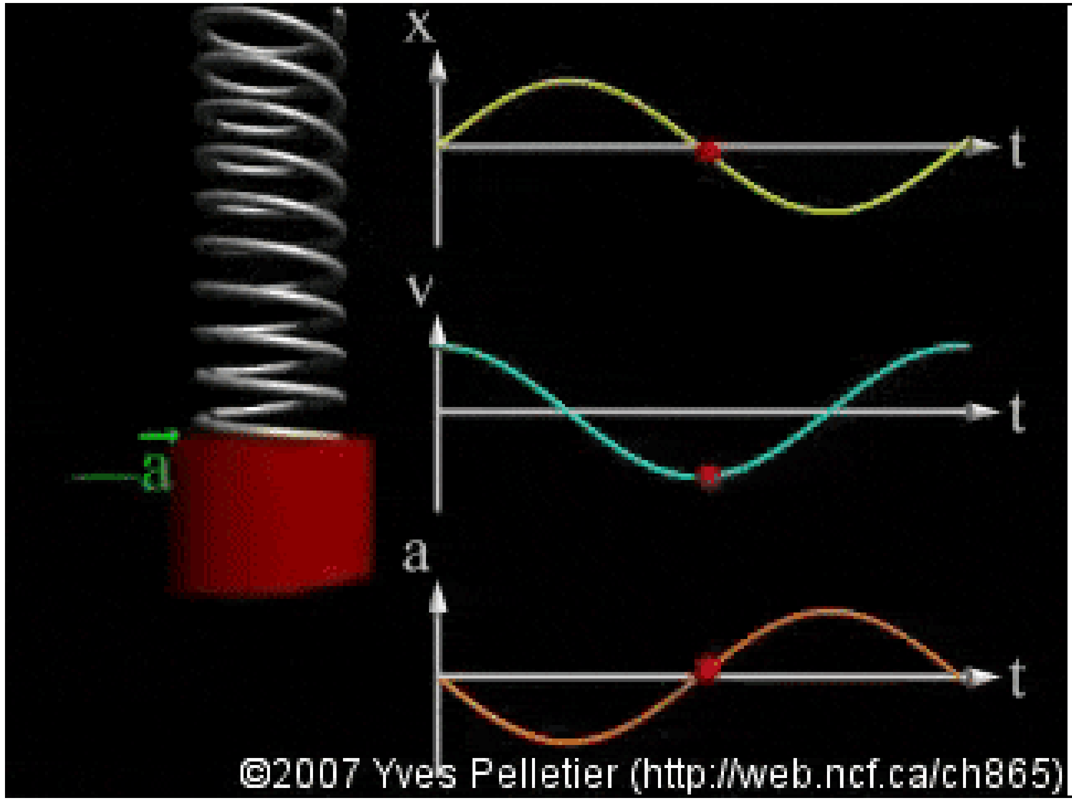


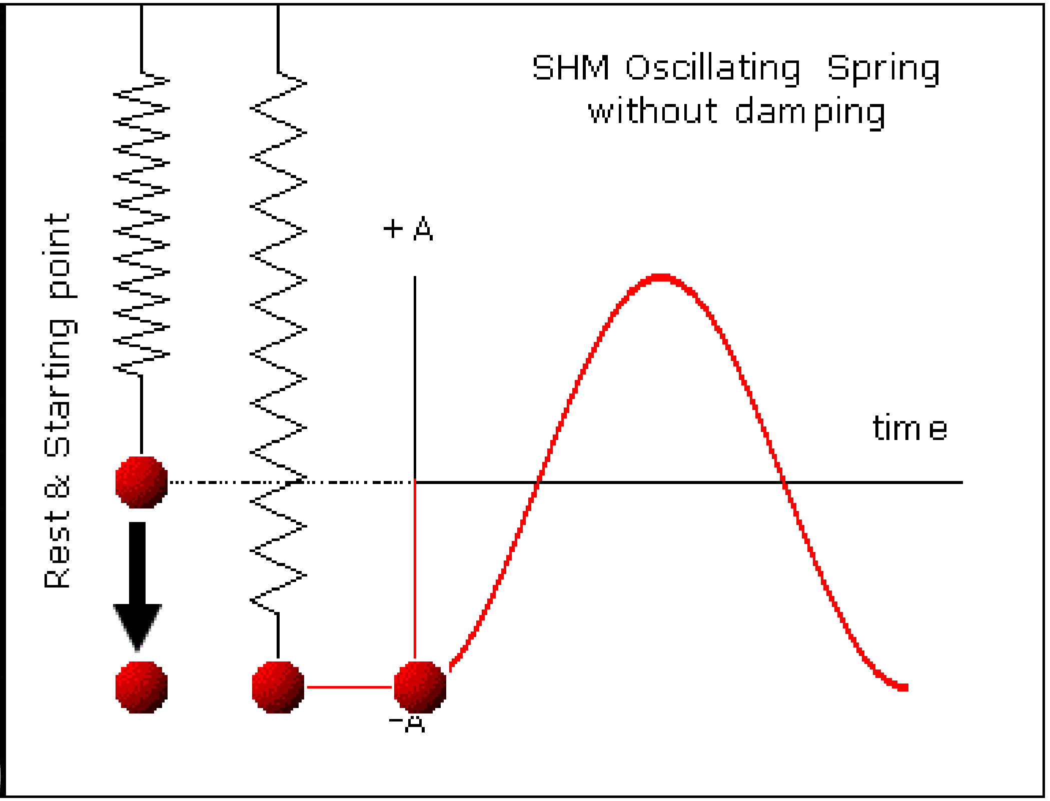
Graphical representation of motion

- When x is a maximum or minimum, velocity is zero
- When x is zero, the velocity is a maximum
- When x is a maximum in the positive direction, a is a maximum in the negative direction

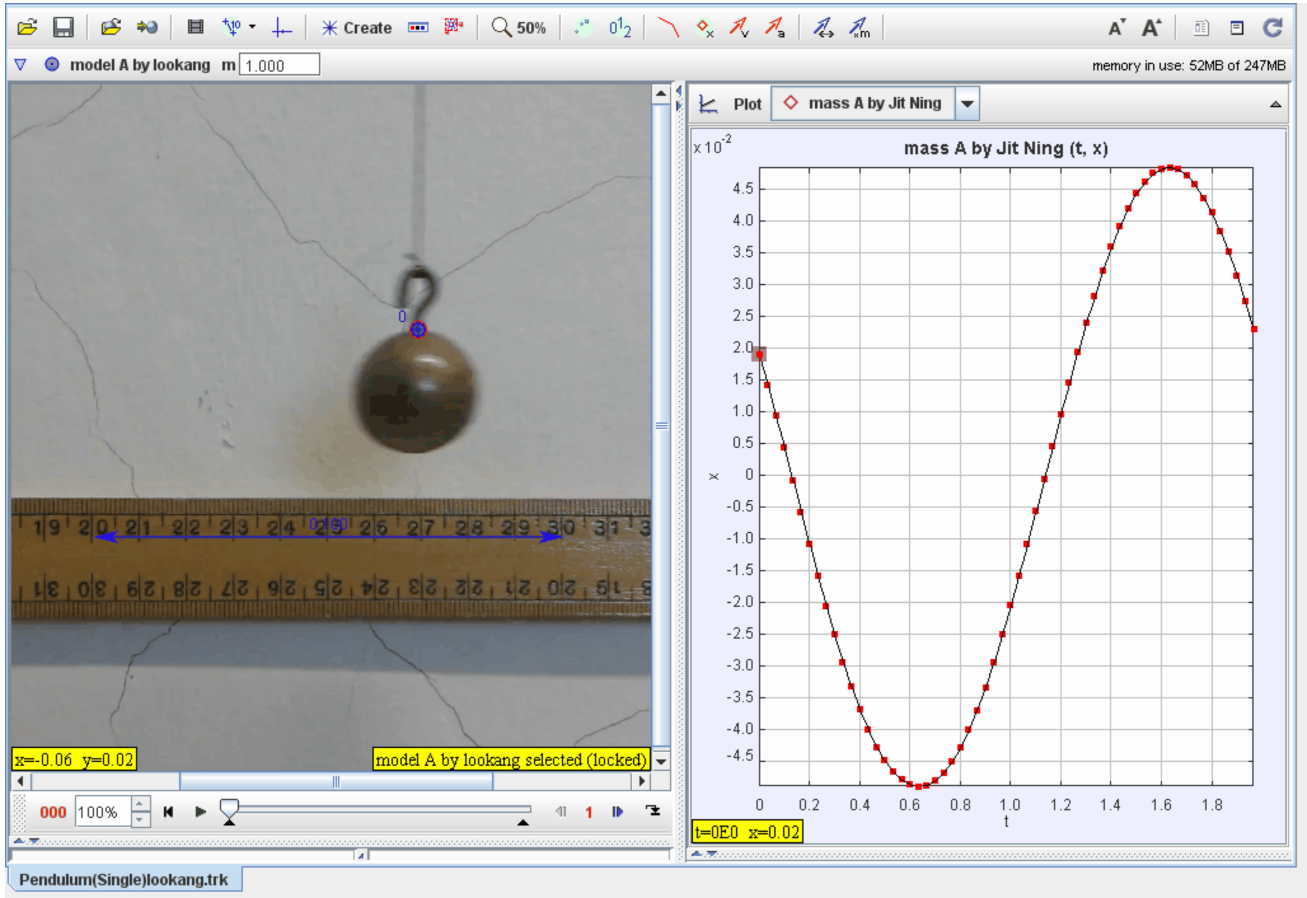


Returning to our springs

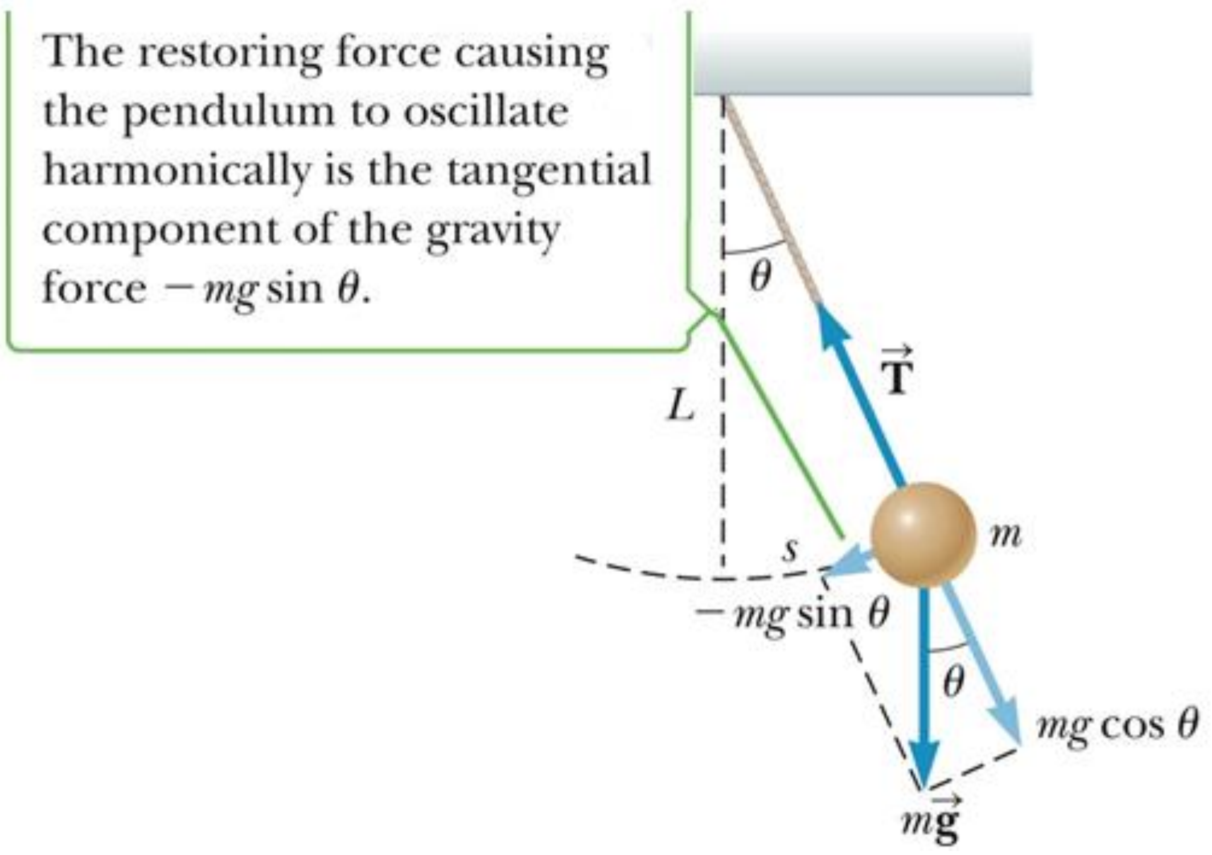




Returning to the pendulum



The simple pendulum



The force is the component of the weight tangent to the path of motion

$F_t = - mg \sin \theta$

The simple pendulum

So really a simple pendulum doesn't exhibit simple harmonic motion because

$$simple\ harmonic\ motion\ must\ abide\ by\ f = kx$$

$$kx \neq mgsin(\theta)$$

However, when the angle is small enough

$$sin(\theta) \approx \theta$$

Thus

$$kx = mg\theta, \text{where k} = \text{mg and } \theta = x$$

The simple pendulum

- The period of a pendulum is represented by

$$T = 2\pi\sqrt{\frac{L}{g}}$$

- The period of a pendulum only depends on the length of the string and the acceleration due to gravity

Dampened Oscillations

- ideal systems oscillate indefinitely. They only exist in a “perfect world.”
- In the real world friction exists, this friction will cause the energy in a system to decrease.
- When the total energy of our system decreases this causes dampening.

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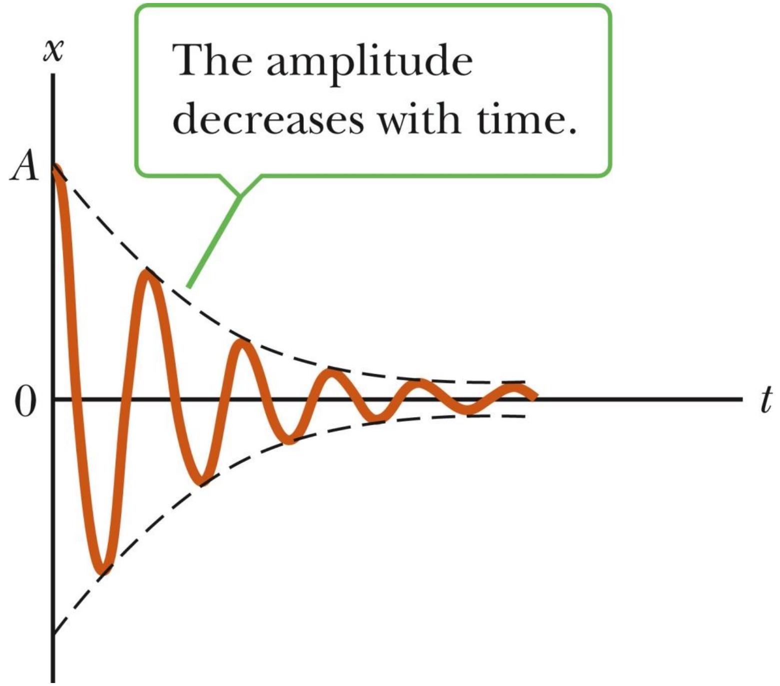
Dampened Oscillations

- Dampening = The amplitude of our wave decreases with time.

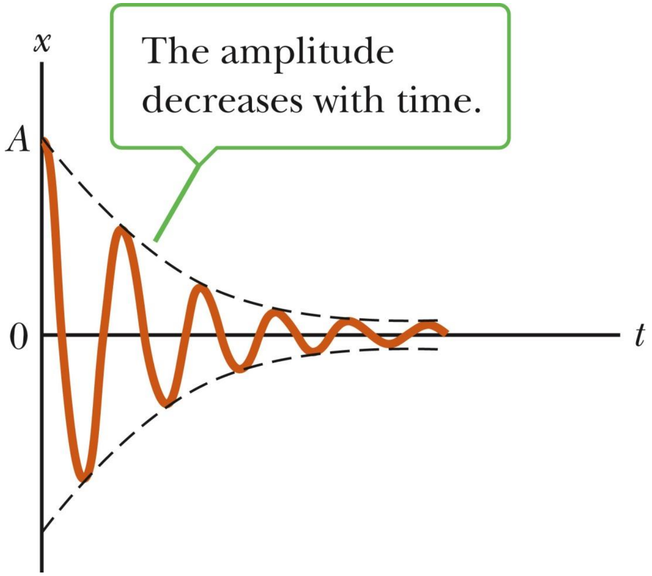


Dampened Oscillations

- There are three kinds of dampened oscillators.
- Underdamped
- Critically Damped
- Overdamped

Underdamped Oscillations

- When an oscillation occurs within a low viscosity fluid/medium the amplitude of the wave decreases steadily but the vibration is conserved.



Critically Damped + Overdamped Oscillations

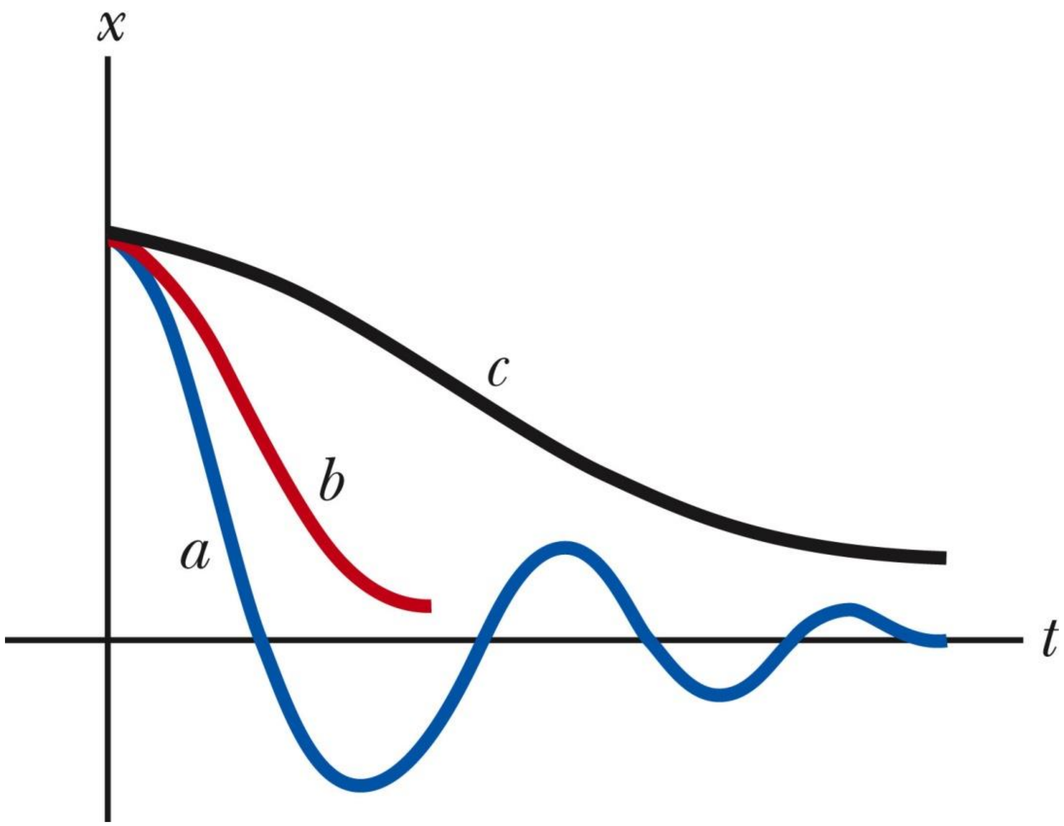
- Critically Damped -

In higher viscosity fluids/mediums the object will return to equilibrium rapidly without oscillating.

- Overdamped –

In even higher viscosity fluids/mediums the object will return to equilibrium without oscillating but it will take a longer time.

Dampened Oscillations



- a = underdamped
- b = critically damped
- c = overdamped

Waves

- There are two major forms of waves

1. Electromagnetic Waves

2. Mechanical Waves

- Both of which carry energy and momentum.

Electromagnetic Waves

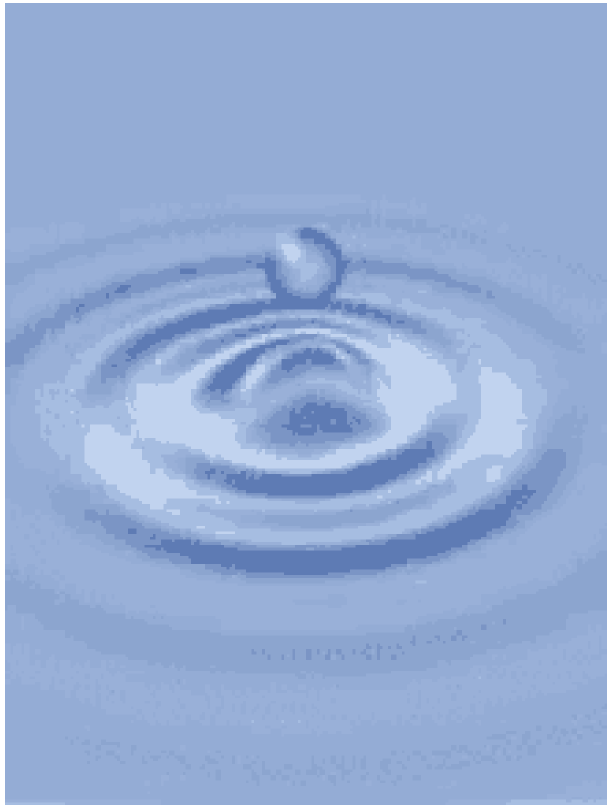
- A wave that has the ability to propagate through a vacuum. It consists of an electric field and a magnetic field. Hence the name.

- This includes radio waves, micro waves, infrared waves, visible light, ultraviolet light ,x-rays, and gamma rays

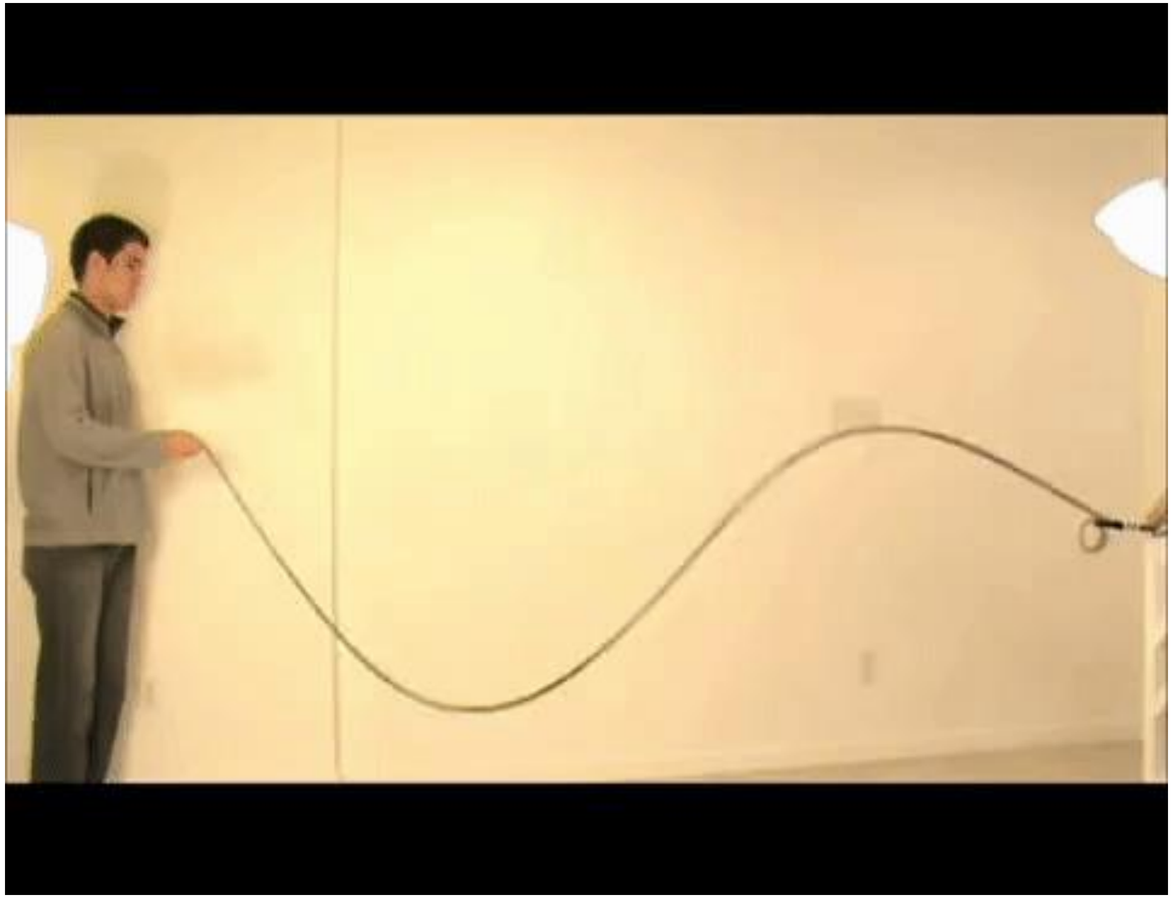
Mechanical Waves

- **A wave that must have a medium to propagate through.**
- **This includes a rope, drum, water, sound, springs, etc.**

Mechanical Waves



Mechanical Waves



Mechanical Waves

Types of Waves

- There also exists certain types of waves. These waves are defined by the orientation by which they propagate.

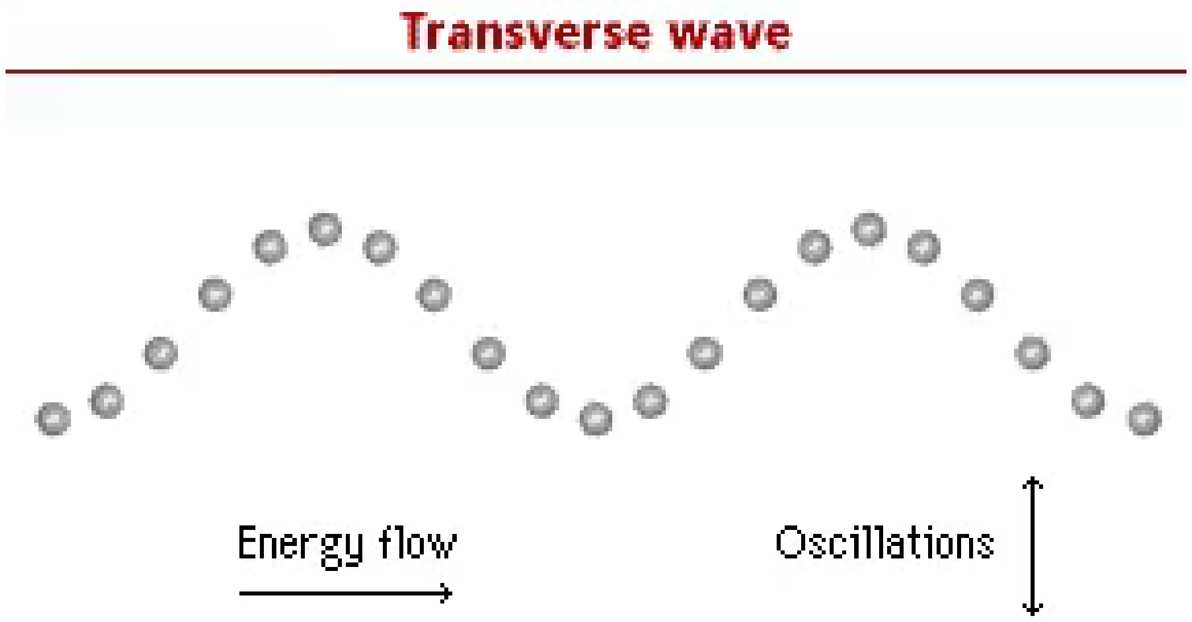
- We will investigate

- Transverse waves

- Longitudinal waves

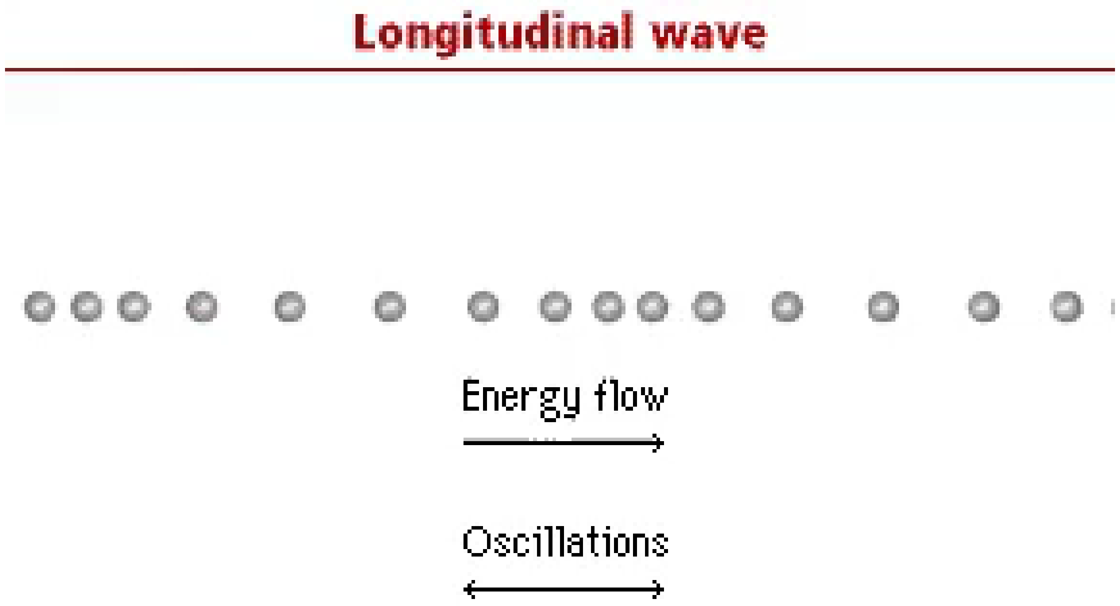
Transverse Waves

- In a transverse wave the orientation of our wave is perpendicular to direction the wave is traveling.



Longitudinal Waves

- In a longitudinal wave the oscillation is oriented parallel to direction that the wave is traveling.



Types of waves

- Waves are not confined to only propagate in these two types.
- Many waves are a mixture of transverse and longitudinal waves.
- In science we call this a superposition of waves. Which basically means waves added together. (We will go into this more later on.)

Types of waves

- **No matter what the wave is, all waves can be represented by sine and cosine curves.**

Speed of a wave

- $Speed = \frac{d}{t}$
- $Wavlength = \lambda = distance$
- $Frequency = f = Hz = \frac{1}{s}$
- $Speed\ of\ Wave = \lambda f$

Wave Behavior

- **Boundary – Change or movement of a wave from one medium to another.**

- **Incident Wave – Wave that strikes a boundary.**

- **Reflected Wave – The return of an incident waves reflection. This can be oriented upward or downward.**

Wave Behavior

Interference of waves

- Two traveling waves can pass through each other without being altered or destroyed.

- Waves obey the superposition principle which basically states: When two or more traveling waves encounter each other while moving through a medium their wave functions are added together to form a new wave.

Interference of waves

- Mathematically this essentially means if one wave $Asin(bx)$ encounters $\mathrm{C}sin(dx)$ then the created wave is

$$New\ Wave = Asin(bx) + \mathrm{C}sin(dx)$$

- Another way to think about this is we just add the y points (displacements) together at the same x points (time).

This will become incredibly important when we talk about sound!

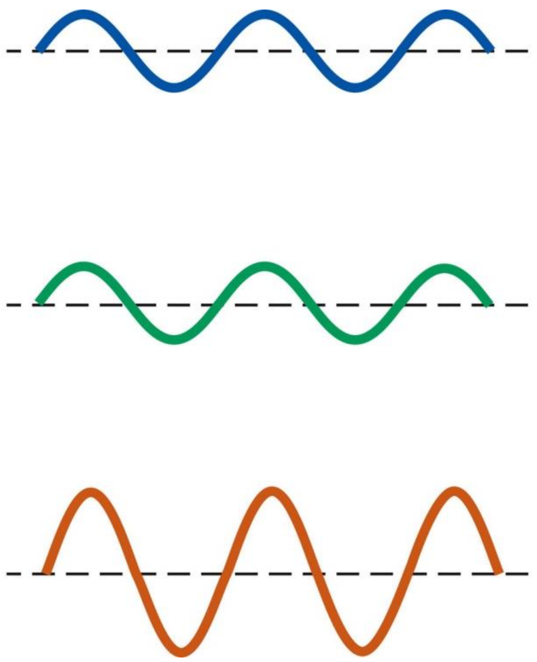
Interference of waves

- There are two types of interference
- Constructive interference
- Destructive interference

Constructive Interference

- **When two waves are in phase they add together to enhance their amplitudes.**

- **In phase means they have the same frequency and start at the same point.**

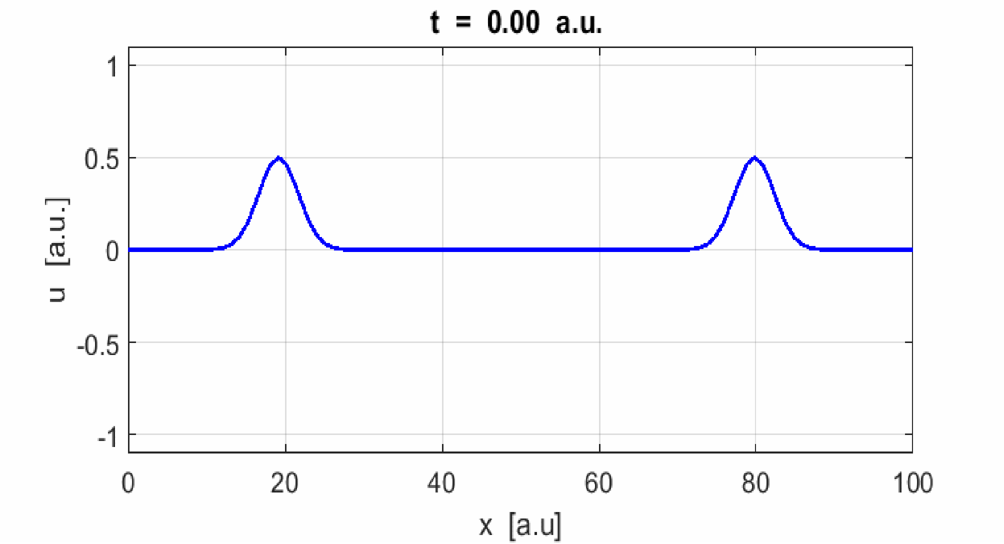


Constructive Interference

- **When two pulses travel in opposite directions a strange phenomena occurs.**

- **When they meet each other their amplitudes add together.**

- **Afterwards they continue along their path unchanged.**

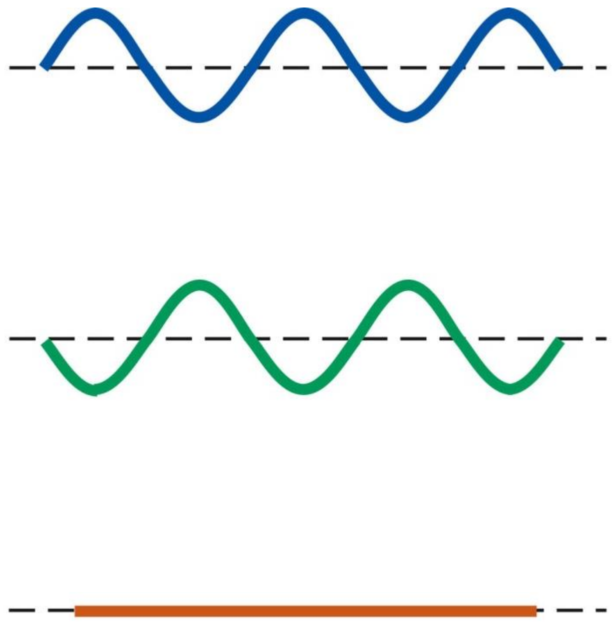


Destructive Interference

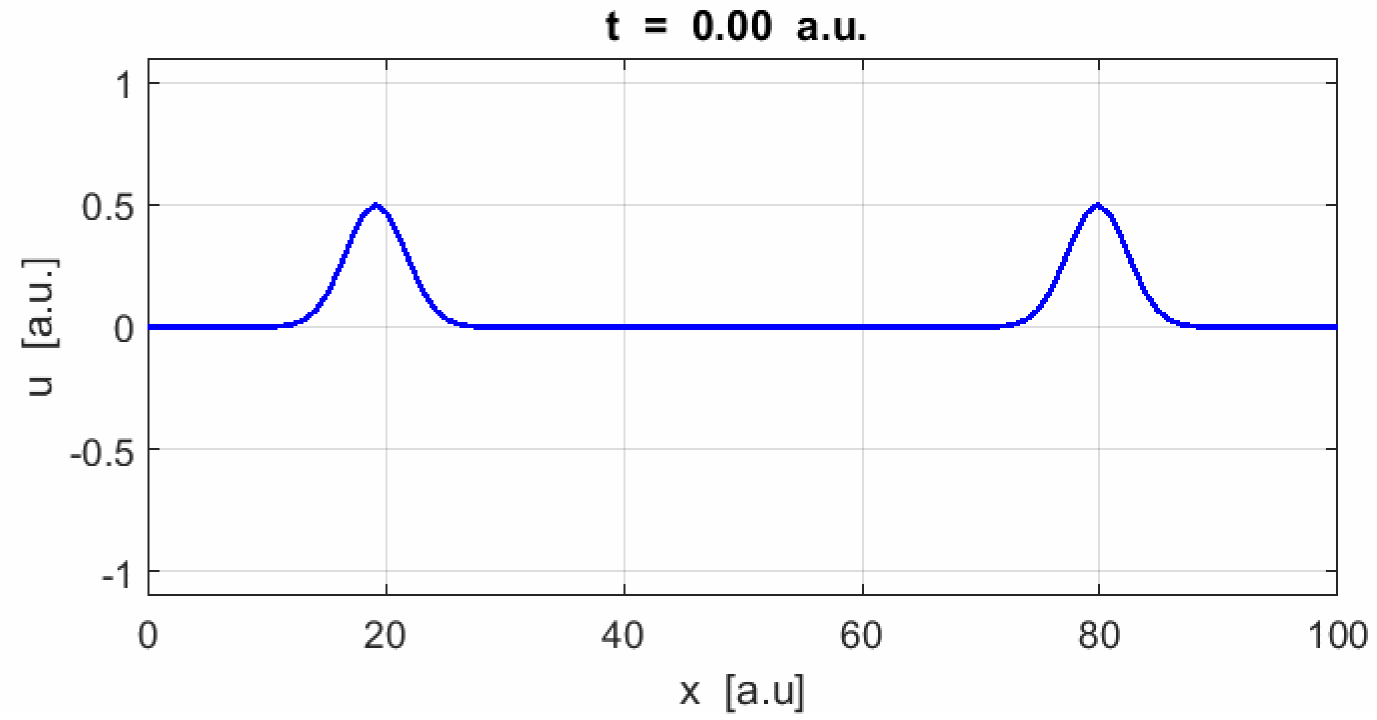
- When two waves are out of phase they add together to decrease the overall amplitude.

- Out of phase means they have the same frequency but start at a different point in the wave.

- EX: sine(x) vs –sine(x)



Destructive Interference

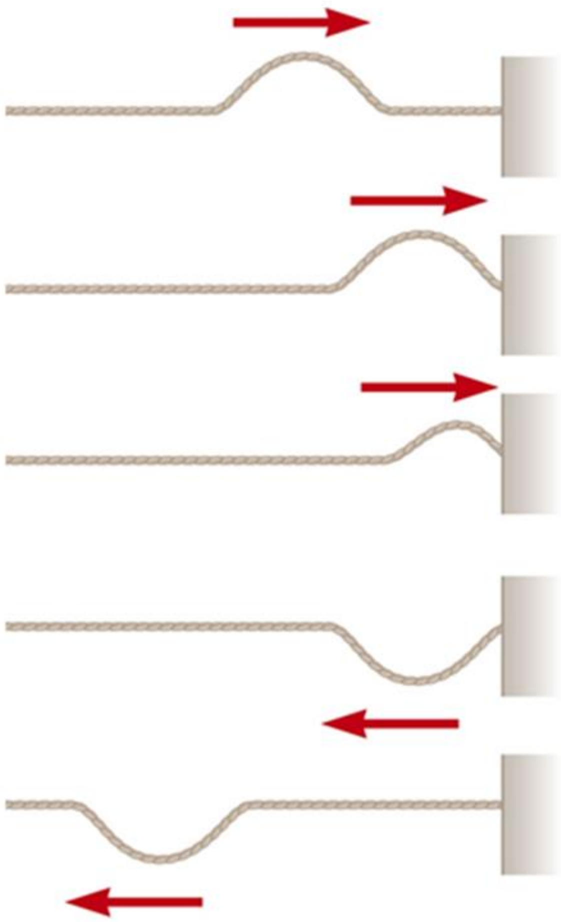


Reflections of Waves

- Whenever a traveling wave reaches a boundary, some or all of the wave is reflected

- When it is reflected from a fixed end, the wave is inverted

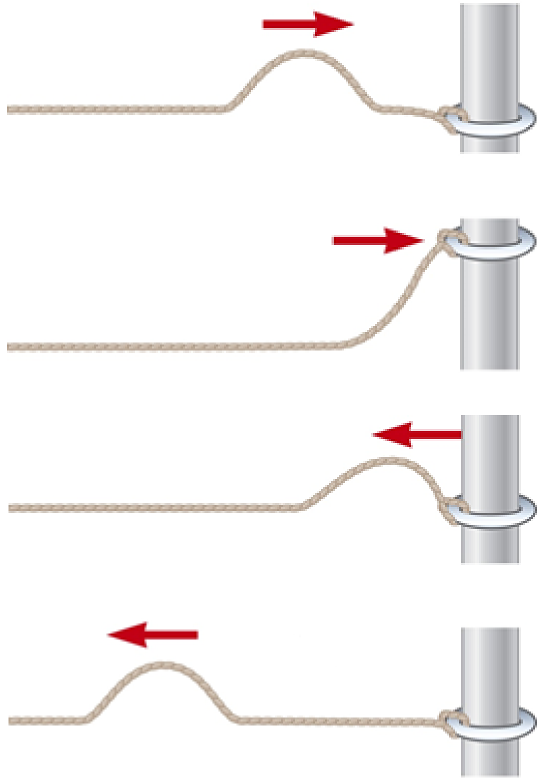
- The shape remains the same



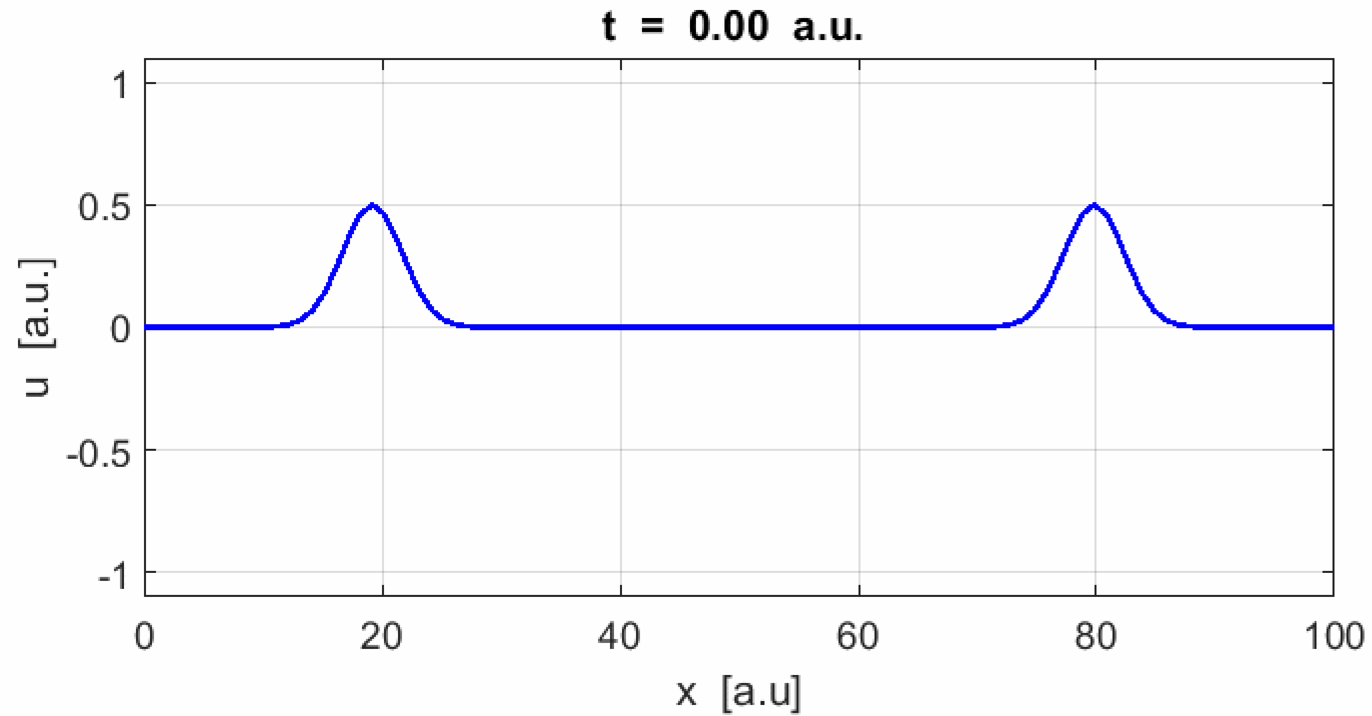
Reflections of Waves

- When a traveling wave reaches a boundary, all or part of it is reflected

- When reflected from a free end, the pulse is not inverted



Reflections of Waves



Chapter 13: Vibrations and Waves

HW: pg 453 – 454
Problems: 41 – 48 and 61

Homework is not graded but is highly recommended