

### Unit 3.3: Waves and Harmonic Motion

EQ1: What is the relationship between speed, frequency, and wavelength?

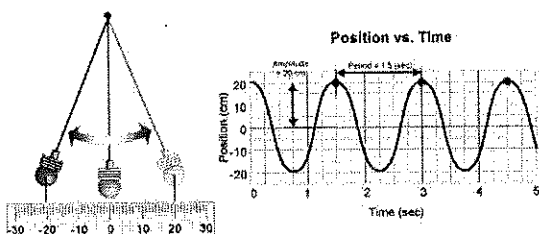
EQ2: How does the medium through which waves pass affect the properties of the wave?

EQ3: How is energy transferred by waves?

### Harmonic Motion

- What is Harmonic Motion?
  - Motion that repeats
- A system that repeats harmonic motion is called an oscillator.
- Example: A pendulum

### Harmonic Motion Graphs



What do we notice about the graph of an object in harmonic motion?

### Oscillators

- What examples of oscillators can you think of?
  - Earth
  - Sound (speakers and even our voices are oscillators!)
  - Color
  - Communication devices (radio, cell phones, wi-fi)

### The parts of Harmonic Motion

- Amplitude
  - The “size” of a cycle.
  - This can be measured as the distance from the center point, the angle, voltage, or pressure.

### Amplitude

$$\text{Amplitude} = \frac{1}{2} (\text{high point} - \text{low point})$$

- Also measured from the equilibrium to the highest (or lowest) point.

### The parts of Harmonic Motion

- Period
  - The amount of time it takes for one cycle to occur
  - The number of seconds per cycle
- Frequency
  - The number of cycles per unit time (usually seconds)
  - The number of cycles per second
  - Measured in Hertz (Hz)
    - 1 Hz = 1 cycle/second

### Period and Frequency

$$\begin{matrix} \text{Period (seconds)} \rightarrow & T = \frac{1}{f} & \text{Frequency (hertz)} \\ & \text{Frequency (hertz)} \rightarrow f & f = \frac{1}{T} \leftarrow \text{Period (seconds)} \end{matrix}$$

**A period is the time to complete one cycle of harmonic motion.**

### Example 1

- What is the period of Manny's swing?
- What is the frequency of Manny's swing?
- What is the amplitude of Manny's swing?

### Example 2

A car engine's pistons and crank shaft have a frequency of 15 Hz (about 900 rpm). What is the period of the engine?

Looking for	Solution
Given	
Relationships/Formula	

### Try these

- 1) If it takes 8 seconds for an object to swing back and forth 10 times...
  - What is the period of the object?
  - What is the frequency of the object?
- 2) If a computer takes .000005 seconds to compute a piece of information, how many pieces of information can it compute per second?

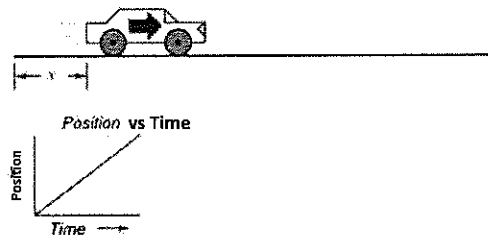
### Warm Ups

- 1) If it takes 12 seconds for an object to spin around 15 times...
  - What is the period of the object?
  - What is the frequency of the object?
- 2) If the record for eating tacos is 130 in 10 minutes, what is the frequency of taco consumption in Hz?

## The parts of Harmonic Motion

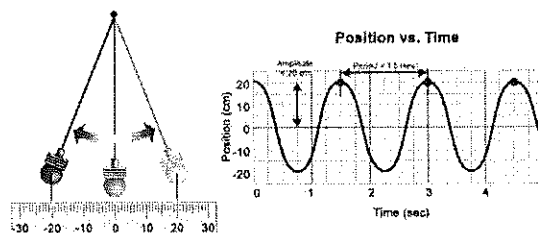
- Amplitude
  - The “size” of a cycle.
  - This can be measured as the distance from the center point, the angle, voltage, or pressure.
- Period
  - The amount of time it takes for one cycle to occur
- Frequency
  - The number of cycles per unit time (usually seconds)

## Graphs of linear Motion



- <T:\Science Dept. Information\aa Physics\aa Phys. 1st 2011 curr\Unit 3.3 Waves\Pendulum Graph applet.htm>

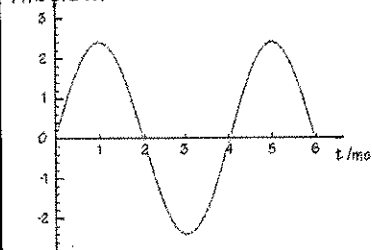
## Using graphs to determine Amplitude, Period, and Frequency Harmonic Motion Graphs



### Interpreting graphs of HM

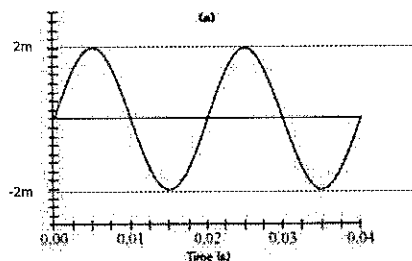
Determine the number of cycles, amplitude, period, and frequency of the graph shown

below.



### Interpreting graphs of HM

Determine the number of cycles, amplitude, period, and frequency of the graph shown below.



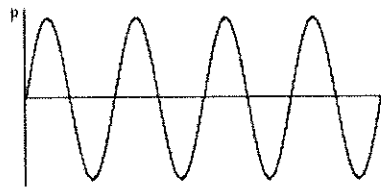
### Homework

- Textbook
- Page 422 #1-5
- page 431 #6-7

### Warm-Up

Name: \_\_\_\_\_

1. How many complete cycles are shown on the graph below?
2. Label the amplitude and period on the graph.
3. Explain how you can determine the frequency of the harmonic motion?



## Waves

EQ: How is energy transferred by waves?  
EQ: What is the relationship between speed, frequency, and wavelength?

## Waves

A wave is an oscillation that travels from one place to another.

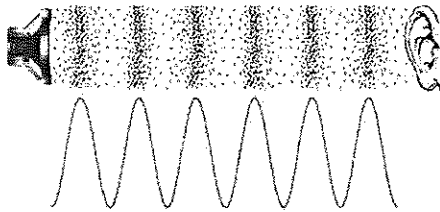
Examples of waves:

- Light
- Electricity
- Data signals (wireless and wired!)
- Mechanical energy (water, ruffling of a flag)

Most of these are examples of waves caused by vibrations!

## Waves

**Waves are a traveling form of energy**  
they carry information; all info. that your eyes and ears receive



## Medium

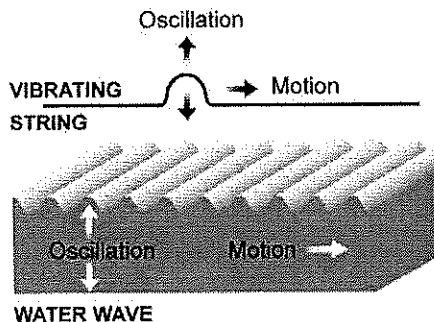
A medium is some substance that a wave travels through.

- gas – air
- liquid – water
- solid – string or a wall

Without some medium, a wave cannot travel.

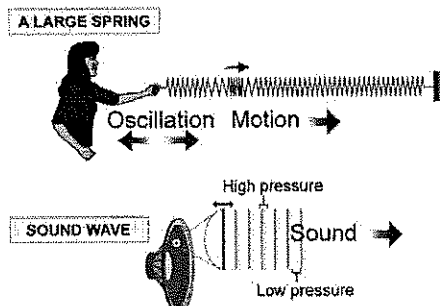
### Transverse Waves

Has its oscillations perpendicular to the direction the wave moves.



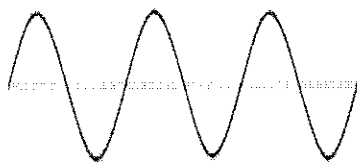
### Longitudinal Waves

A wave which has its oscillation in the same direction as the wave moves.



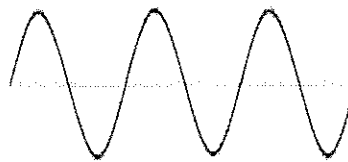
### Properties of Waves

This is different than graphs of harmonic motion!



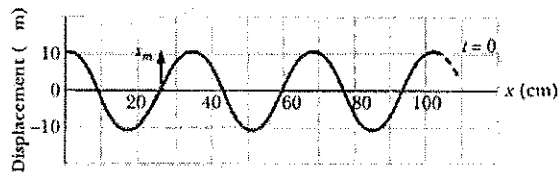
### Parts of a Wave

The parts are similar to a graph of harmonic motion, but now the x-axis is distance, so the x-direction (horizontal axis) has a different meaning!



### Graphs of Waves (example)

Determine the amplitude and wavelength of the following wave.

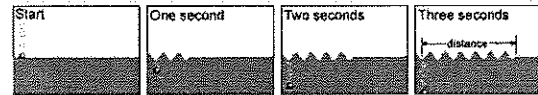


### The speed of a wave...

#### The Speed of a Wave

$$\text{Speed (m/sec)} \rightarrow v = f \lambda \rightarrow \text{Wavelength (meters)}$$

Frequency (hertz)



### Example 1

A series of waves travels through the slinky at a speed of 15 m/s. The frequency of the waves is 0.5 Hz. How far apart are the wave crests (wavelength)?

### Example

Narragansett Bay has an average wavelength of 20 meters between waves, with waves passing every 8 seconds. What is the speed of these ocean waves?



### Try a few!

1. What is the wavelength of a sound wave with a frequency of 50 Hz? (Speed of sound is 342 m/s)
2. A sound wave in a steel rail has a frequency of 620 Hz and a wavelength of 10.5 m. What is the speed of sound in steel?
3. Determine the frequency of a microwave 6.0 cm in length. (A microwave is an electromagnetic wave. It travels through space at a speed of  $3.0 \times 10^8$  m/s)
4. What is the period of the microwave in problem 3?

### Homework

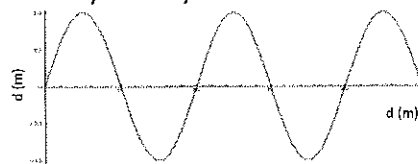
- Page 450 "Reviewing Concepts" #1-6
- Page 451 "Solving Problems" #1-4
- Outline pages 441-443

### Warm-Up (part 1)

1. The speed of sound in dry air at 70 degrees F is about 343 m/s. If a speaker vibrates at 15 Hz, what is the wavelength of the note it's producing?

### Warm-Up (part 2)

1. How many wave cycles are shown in the graph?



2. Determine the wavelength of the wave shown. If the frequency of the wave is 3 Hz, how fast is the wave traveling?

### Waves In Motion and Wave Interactions

Today:

- 1) Quiz on waves
- 2) Discuss waves in motion (water waves)
- 3) Wave Interactions
- 4) Start Standing waves

Mini-Quiz Next class

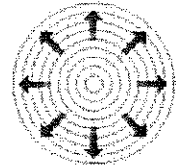
EQ: How is energy transferred by waves?

EQ: How do waves interact with their surroundings?

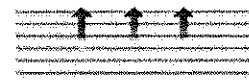
### Waves in Motion

- Waves have crests and troughs.
- The crest of a wave is sometimes called a wave front.
- The shape of a wave is determined by its wave front.

Circular waves



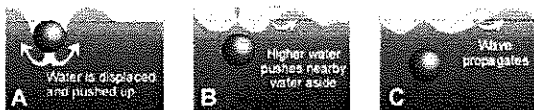
Plane waves



### 14.2 Propagation of waves

The word propagation means "to spread out and grow."

Equilibrium surface



### 14.2 Propagation of waves

- Water waves propagate along surfaces that are continuous.

Continuous surface



Discontinuous surface



- A water wave can not spread across a discontinuous surface.

### Wave Interactions

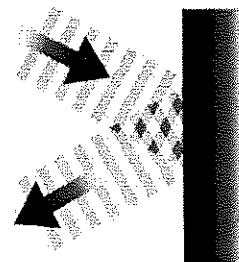
There are 4 categories of wave interactions that we will investigate:

- Reflection
- Diffraction
- Absorption
- Refraction

### Wave Interactions

#### REFLECTION

Wave bounces off a material and goes in a new direction.

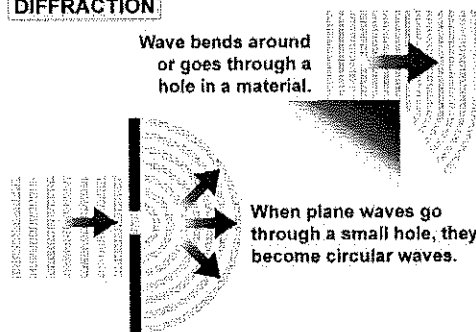


- Where have we seen or experienced wave reflections?

### Wave Interactions

#### DIFFRACTION

Wave bends around or goes through a hole in a material.



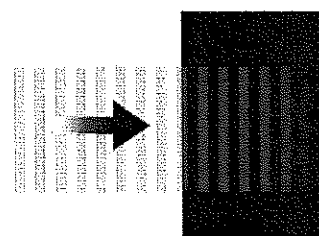
When plane waves go through a small hole, they become circular waves.

- Where have we seen or experienced wave diffraction?

### Wave Interactions

#### ABSORPTION

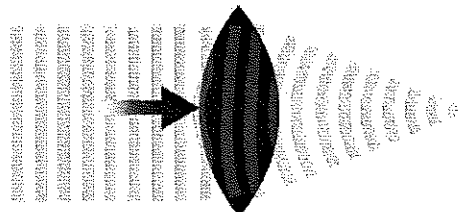
Wave is absorbed by a material and may disappear.



- Where have we seen or experienced wave absorption?

**Wave Interactions**

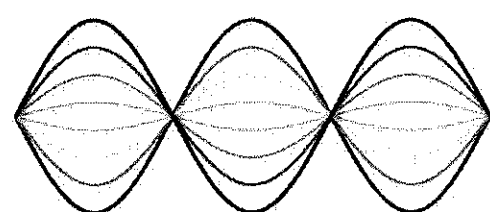
**REFRACTION**      **Wave passes through a material and bends.**



• Where have we seen or experienced wave refraction?

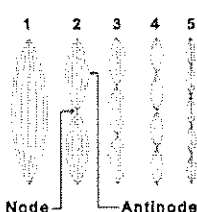
**Parts of a standing wave...**

Node: Point on the wave that doesn't move  
 Antinode: Point on the wave that moves the most



**Harmonics**

Standing waves have other natural frequencies called harmonics.



Watch a 1<sup>st</sup> harmonic, 2<sup>nd</sup> harmonic, and 3<sup>rd</sup> harmonic in the rope at the front of the room.  
 What do you notice about the frequency of the vibration? (rope demo)

**Wavelength**

1 wavelength = 2 antinodes

wavelength of a standing wave

$$\lambda = \frac{\text{total length (of string)}}{\# \text{ of waves}}$$

## The wiggler

Harmonic	Frequency (Hz)
1	
2	
3	
4	
5	
6	

### CLAIMS

- As frequency increases, harmonic increases
- Natural frequencies increase by the same amount
- As harmonic and frequency increase, amplitude decreases

