Name: _____

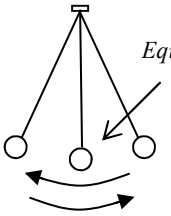
Period: _____



# Harmonic Motion

**Harmonic Motion** is motion that repeats itself, oscillating back and forth. Eventually it will lose energy (called dampening) and come to rest in the middle, known as its **equilibrium position.**

A pendulum




To be harmonic motion there must be a **restoring force** that tries to return an object to its equilibrium position. When a pendulum is disturbed (moved), gravity pulls down to restore the pendulum back to the center. Because of momentum, it goes past the center to the other side and back again.

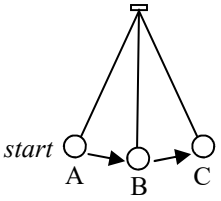
*A bird flying **is not** harmonic motion: one force pulls up and a different force pulls down. Also, each force pulls from the ends not the middle.*

## Harmonic Motion Basics

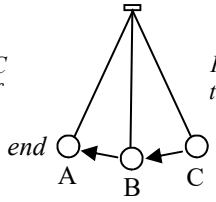
**Cycle**: the repeated part of the motion; must include all of the steps of the motion.

**Period (T in sec)**: length of time for one cycle; how long it takes for one repetition. A slower object has a bigger (longer) period .

**Frequency (f in Hz)**: number of cycles per second. Motion that repeats more often is more frequent and has a higher frequency.




*From A to C is only half a cycle.*




*From C to A is the second half of the cycle.*


*The period (T) is the time from A back to A. T = 2 sec.*


*Only half of the cycle occurs in the first second, so the frequency is ½ cycle per second. f = 0.5 Hz.*

**Period and Frequency are inversely related.**

Period (in *secs*) → $T = \frac{1}{f}$ OR $f = \frac{1}{T}$ ← Period (in *secs*)

Frequency (in *hertz*)

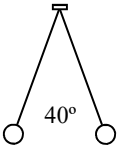
*As period increases, the frequency decreases.*
*As period decreases, the frequency increases.*

| Ex: A pendulum has a frequency of 4 Hz. Find its period. | |
|---|---|
| f = 4 Hz<br>T = ____ | T = 1/f<br>T = 1/4<br>T = 0.25 sec |

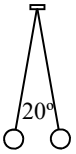
| Ex: A wheel has a period of 2 seconds. Find its frequency. | |
|---|---|
| T = 2 sec<br>f = ____ | f = 1/T<br>f = 1/2<br>f = 0.5 Hz |

**Amplitude (A in m, cm, or degrees):** maximum distance or angle from the equilibrium (center) position. Wider swing = more energy = more amplitude.

**Amplitude = ½(distance side-to-side)**




*Amplitude = 20 º*
*More energy*




*Amplitude = 10 º*
*Less energy*

**Amplitude never affects period or frequency!** A pendulum with more amplitude moves fast, but travels a long distance. A pendulum with less amplitude moves slow, but only travels a small distance. Either way, the period is the same.

## Harmonic Motion Graphs

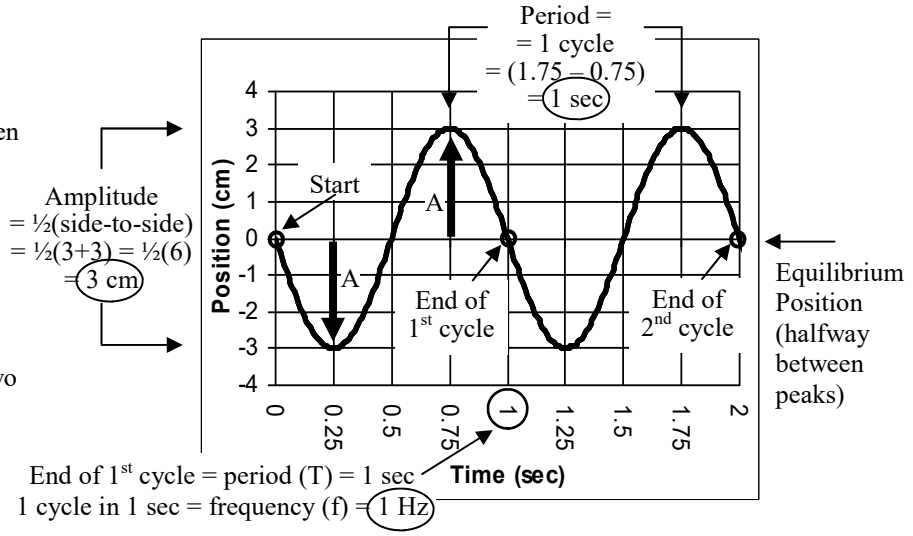
Imagine a pen attached to the bottom of a pendulum. If a piece of paper is moved beneath the pendulum as it swings, a harmonic motion graph is drawn.

**Cycle**—from any point on the line to that same point going the same way. This graph shows 2 complete cycles.

**Period**—measure the time for one cycle between any two identical points on the graph (top-to-top, bottom-to-bottom, etc.).

**Frequency**—count the number of cycles in 1 second OR find the period and use f = 1/T.

**Amplitude**—measure the total distance from side-to-side (or top-to-bottom) and divide by two OR measure the distance from the equilibrium position (halfway between the peaks) to one of the peaks.

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Name: _____ Unit 10:1

Period: _____

## Harmonic Motion: Yes or No?

Pendulum: _____

Ocean waves: _____

A child on a swing: _____

Jumping Jacks: _____

Bouncing spring: _____

A bouncing ball: _____

A ruler pulled from one side and released: _____

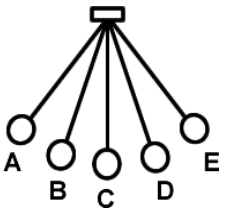
A person jumping up and down: _____

A spinning ball: _____

| | |
|---|---|
| 1. Period | A. The number of cycles per second. |
| 2. Equilibrium position | B. A unit of one cycle per second. |
| 3. Amplitude | C. The size or strength of a cycle. |
| 4. Damping | D. Time it takes to complete one cycle. |
| 5. Frequency | E. A part of motion that repeats over and over with a set series of events. |
| 6. Cycle | F. Halfway between the two sides and where the motion comes to rest. |
| 7. Hertz | G. The motion dying out over time. |

*Period, Frequency, or Amplitude?*

____ Doesn't change period.
____ More of this means more energy.
____ Increases as a pendulum swings back and forth faster.
____ Measured in cycles per second.
____ Measured in meters or centimeters.
____ This decreases with a smaller swing.
____ If the frequency increases, this decreases.
____ Measured in Hertz.
____ Measured in seconds.
____ If it swings back and forth slower, this decreases.
____ As it dampens, this decreases.



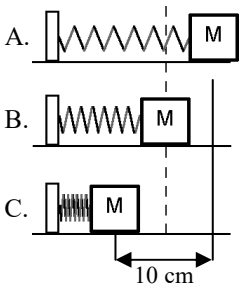

Where is the equilibrium position for this pendulum?

If the pendulum starts at C going to the right, where does 1 cycle end?

From letter ____ to letter ____ would be the amplitude.

If the pendulum starts at A, how many times does it pass point C in 1 cycle?

*A moving spring*




Where is its equilibrium position?

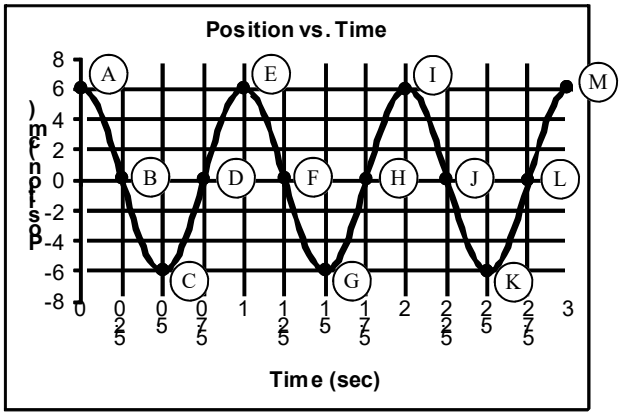
If the spring starts at position A, how much of a cycle does it complete from A to C?

If the spring moves 10 cm from C to A (side to side), how big is it's amplitude?

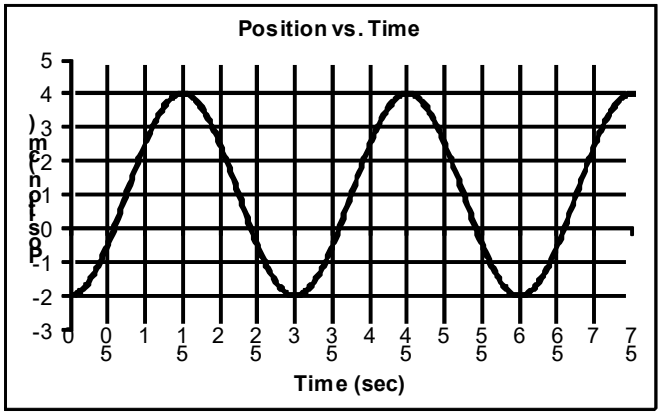
An spring has a period of 4 seconds. What is its frequency?

A pendulum has a frequency of 3 Hz. What is its period?

A pendulum takes 10 seconds to complete 2 cycles.
A) What is its period?
B) What is its frequency?




1 cycle after A is ____; 2 cycles after D is ____.
1/2 cycle after G is ____; 1/4 cycle before M is ____.
# of complete cycles shown is ____.
Period (T) = Frequency (f) =
Equilibrium position = Amplitude (A) =




Mark 1 cycle of the harmonic motion.
Starting at 1.5 secs, when does the 2nd cycle end:
Number of cycles shown is ____.
Period (T) = Frequency (f) =
Equilibrium position = Amplitude (A) =

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Name: _____ Unit 10:1

Period: _____

## Which of these is Harmonic Motion?

Pendulum: Y

Ocean waves: Y

A child on a swing: Y

Jumping Jacks: N

Bouncing spring: Y

A bouncing ball: N

A ruler pulled from one side and released: Y

A person jumping up and down: N

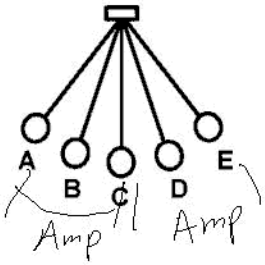
A spinning ball: N

1. Period D
2. Equilibrium position F
3. Amplitude C
4. Damping G
5. Frequency A
6. Cycle E
7. Hertz B

A. The number of cycles per second.
B. A unit of one cycle per second.
C. The size or strength of a cycle.
D. Time it takes to complete one cycle.
E. A part of motion that repeats over and over with a set series of events.
F. Halfway between the two sides and where the motion comes to rest.
G. The motion dying out over time.

## ☆ *Period, Frequency, or Amplitude?*

A Doesn't change period.
A More of this means more energy.
F Increases as a pendulum swings back and forth faster.
F Measured in cycles per second.
A Measured in meters or centimeters.
A This decreases with a smaller swing.
T If the frequency increases, this decreases.
F Measured in Hertz.
T Measured in seconds.
T If it swings back and forth slower, this decreases.
A As it dampens, this decreases.



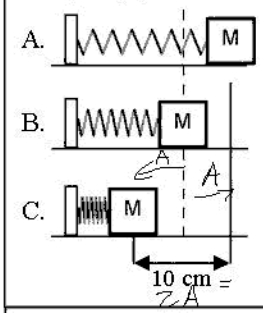

Where is the equilibrium position for this pendulum? C

If the pendulum starts at C going to the right, where does 1 cycle end? C going right

From letter A to letter C would be the amplitude. or C to E

If the pendulum starts at A, how many times does it pass point C in 1 cycle? two times

*A moving spring*




Where is its equilibrium position? at B

If the spring starts at position A, how much of a cycle does it complete from A to C? half cycle

If the spring moves 10 cm from C to A (side to side), how big is it's amplitude? 5 cm

An spring has a period of 4 seconds. What is its frequency?

T = 4 sec $f = \frac{1}{T} = \frac{1}{4} = .25$ Hz

f = ____

A pendulum has a frequency of 3 Hz. What is its period?

f = 3 Hz $T = \frac{1}{f} = \frac{1}{3} = .33$ sec

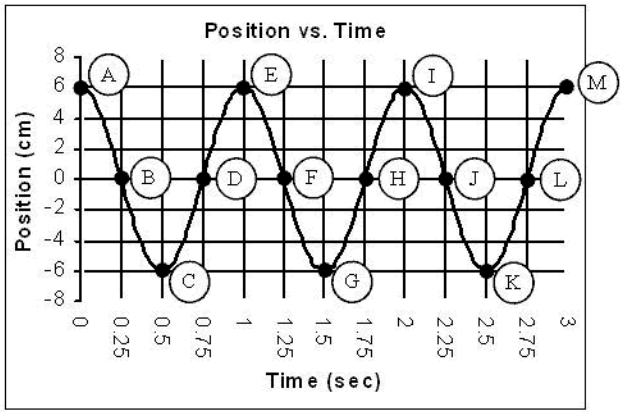
T = ____

A pendulum takes 10 seconds to complete 2 cycles.

A) What is its period? 5 sec

B) What is its frequency?

$f = \frac{1}{5} = .2$ Hz



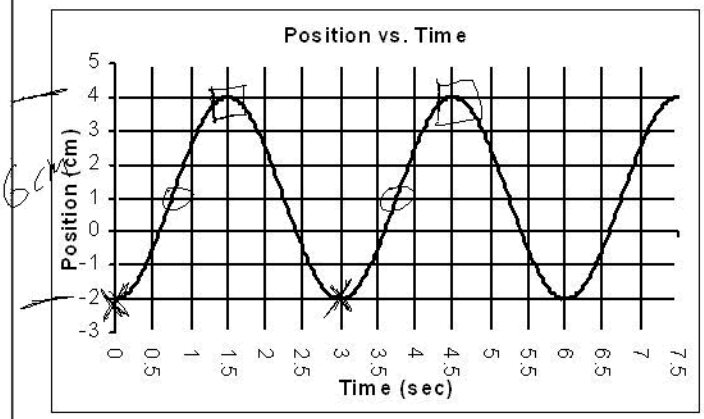

1 cycle after A is E; 2 cycles after D is L.

1/2 cycle after G is I; 1/4 cycle before M is L.

# of complete cycles shown is 3.

Period (T) = 1 sec Frequency (f) = $\frac{1}{T} = \frac{1}{1} = 1$ Hz

Equilibrium position = 0 cm Amplitude (A) = 6 cm




Mark 1 cycle of the harmonic motion.

Starting at 1.5 secs, when does the 2nd cycle end: 7.5 sec

Number of cycles shown is 2.5 cycles

Period (T) = 3 sec Frequency (f) = $\frac{1}{T} = \frac{1}{3} = .33$ Hz

Equilibrium position = 1 cm Amplitude (A) = 3 cm



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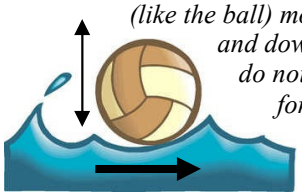
Name: _____

Period: _____

Unit 10:2

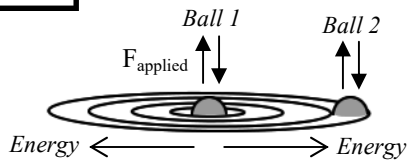
# Waves

**Waves are harmonic motion that moves** thru a medium (matter). Water is the medium for water waves; a slinky is the medium when you shake a slinky. **The particles in the medium vibrate, but do not move. Only the energy of the wave moves**, transferring the energy. This is why waves seem to go thru things, like sound moving thru air.



*Individual water molecules (like the ball) move up and down, but do not move forward.*

*Only the wave's energy moves forward.*

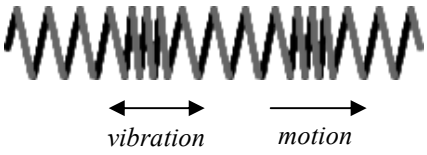



*When ball 1 is moved, waves transfer the energy thru the water to ball 2. Ball 2 will vibrate with the same frequency as ball 1. Cell phones and radios work the same way: microwaves moving thru the air.*

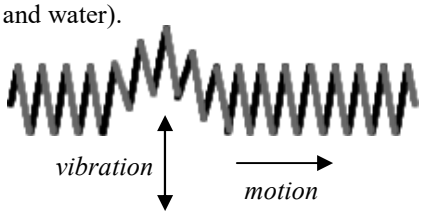
## Types of Waves

There are two simple forms of waves: transverse (across) and longitudinal (the long way).

**Longitudinal (compression) waves vibrate parallel** to (same direction as) the direction of motion. Sound is a longitudinal wave: a speaker vibrates in and out pushing the sound forward. Only longitudinal waves can move thru fluids (liquids and gases).




**Transverse waves vibrate perpendicular** (90º) to the direction of motion. Because the energy moves forward while the vibration is up and down, water waves look like transverse waves, but are actually surface waves, which occur between materials (air and water).

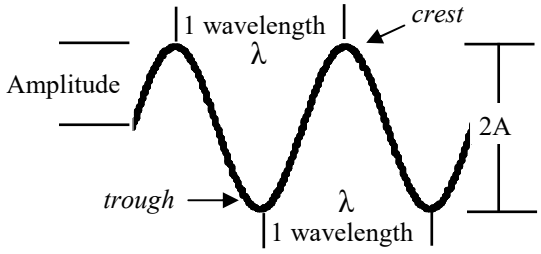



**Earthquakes (seismic waves)**

Earthquakes are made up of both types of waves. Longitudinal waves are the fastest and hit first, so they are called primary waves (P waves). Transverse (T) waves are slower, but do more damage because the up and down break thing by shearing (cutting), so are called S-waves. Only the P waves travel thru the earth's center, which proves the earth has a liquid center.

## Wavelength (λ)

The wavelength—λ [lambda] (in m) is the length of one wave between any two identical points on the wave (crest-to-crest or trough-to-trough, etc).




*Amplitude **does not** affect wavelength, just like amplitude doesn't affect period and frequency. Likewise, in the ocean bigger waves (greater amplitude) don't overtake (catch) smaller waves.*

## Wave Speed (v)

Because waves move, it is obvious that they must have a speed. However, you may be surprised to know that amplitude, frequency, and wavelength don't change speed: only the medium it travels thru.

**The Speed (velocity) of a Wave**

velocity (m/sec) → $v = f\lambda$ ← frequency (Hz), wavelength (m)

*Wave speed equals frequency times wavelength.*

*Since f = 1/T, the wave speed equation could also be written as:*

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

*Ex. What is the speed of a 20 Hz wave that has a 5 meter wavelength.*

| | |
|---|---|
| f = 20 Hz<br>λ = 5 m<br>v = ____ | v = fλ<br>v = (20 Hz) x (5 m)<br>v = 100 m/s |

**The speed of a wave changes only if the medium changes**. Sound moves faster in more elastic substances. Sound is faster in colder water and in solids (rather than liquids) because the molecules are closer. The wave on a slinky moves faster if the slinky is pulled tighter. Yet, if the medium stays the same, the speed stays the same. **Different waves will have the same speed in the same medium.**

*Changing frequency or wavelength does not change speed. Changing the wave changes what moves thru the medium, not the medium itself!*

***Closer Molecules—Faster Wave***

*A push: giving energy (starts the wave)* →

*Close dominos will fall quickly because they hit each other quickly.*

| *Faster* | *Slower* |
|---|---|
| *Tighter* | *Liquids* |
| *Solids* | *Looser* |
| *Warm air* | *Cool air* |

***More Distant Molecules—Slower Wave***

*Energy* →

*Dominos that are farther apart will fall slower because they take more time to hit each other.*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Name: _____ Unit 10:2

Period: _____

| | |
|---|---|
| 1. Transverse wave | A. A wave where the oscillation is perpendicular to the direction of motion. |
| 2. Longitudinal wave | B. The bottom of a wave. |
| 3. Crest | C. The top of a wave. |
| 4. Trough | D. A wave where the oscillation is in the same direction (parallel) as the motion. |
| 5. Wavelength | E. The length of one wave cycle. |

Wave Motion, Yes or No?

FM radio: _____ Music: _____

A car going 70 m/s: _____ A bulldozer: _____

Clock pendulum: _____ Earthquakes: _____

Ocean waves: _____ Cellphones: _____

f is the variable for _____ and is measured in _____.

λ is the variable for _____ and is measured in _____.

T is the variable for _____ and is measured in _____.

v is the variable for _____ and is measured in _____.

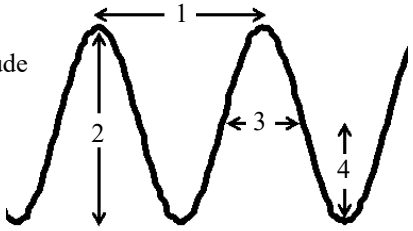
Transverse or Longitudinal Waves?

A. _____ You move the slinky left and right.
B. _____ You push the slinky forward.
C. _____ Sound, if a radio's speaker moves in and out.
D. _____ Earthquakes.
E. _____ Vibrates up and down and moves to the right.

A wave is 8 meters long and has a frequency of 3 Hz. Find speed.

Which number shows:

A._____ Double the amplitude
B._____ Amplitude
C._____ Wavelength
D._____ Half λ




Wave A has a wavelength of 2 meters and a frequency of 1.5 Hz. Calculate the wave's speed.

Wave B has a frequency of 18 Hz in the same medium. What is Wave B's speed?

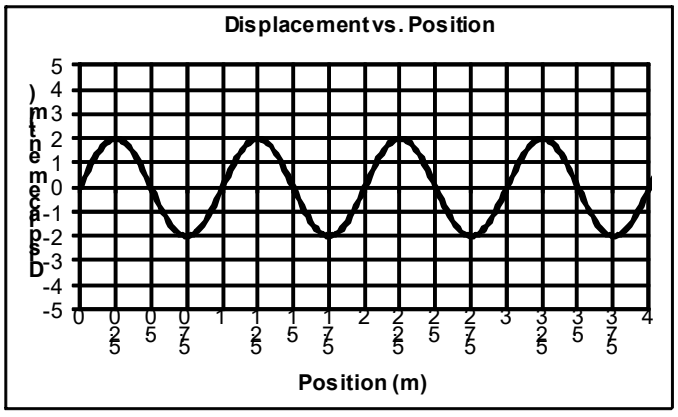
Calculate Wave B's wavelength.

So, as f increases in the same medium, λ _____.

Faster or slower wave speed?

A. ____ The medium gets colder.
B. ____ The amplitude gets bigger.
C. ____ A slinky gets looser.
D. ____ The medium turns from solid to liquid.
E. ____ The wavelength gets shorter.

Wave 1: f = 25 Hz; Wave 2: f = 40 Hz. Which one will be faster in water?



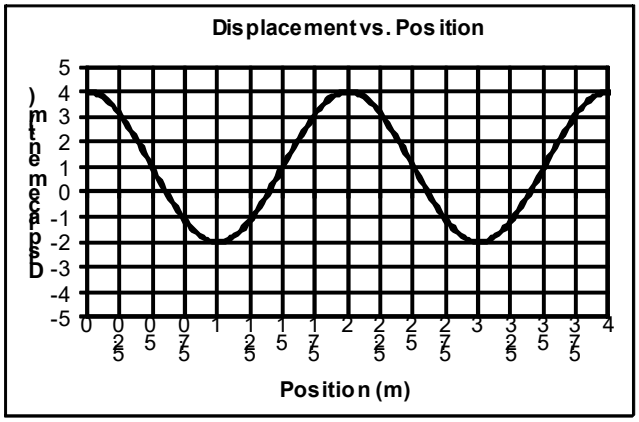

Mark 1 cycle of the wave.

Starting at 0.75 m, where does the 2nd cycle end:

Number of complete cycles: Mark the third crest.

Wavelength: Amplitude:

If f = 4 Hz, find speed:




Mark 1 cycle of the harmonic motion.

Starting at 1.5 secs, when does half a cycle end:

Number of complete cycles: Number of troughs:

Wavelength: Amplitude:

If f = 50 Hz, find speed:

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Name: _____ Unit 10:1

Period: _____

| | |
|---|---|
| 1. Transverse wave A | A. A wave where the oscillation is perpendicular to the direction of motion. |
| 2. Longitudinal wave D | B. The bottom of a wave. |
| 3. Crest C | C. The top of a wave. |
| 4. Trough B | D. A wave where the oscillation is in the same direction (parallel) as the motion. |
| 5. Wavelength E | E. The length of one wave cycle. |

**Wave Motion, Yes or No?**

| | |
|---|---|
| FM radio: yes | Music: yes |
| A car going 70 m/s: no | A bulldozer: no |
| Clock pendulum: No | Earthquakes: yes |
| Ocean waves: Yes | Cellphones: yes |

F is the variable for frequency, measured in Hz.

λ is the variable for wavelength, measured in m.

T is the variable for period, measured in sec.

v is the variable for speed, measured in m/s.

Transverse or Longitudinal Waves?

A. T You move the slinky left and right.

B. L You push the slinky forward.

C. L Sound, if a radio's speaker moves in and out.

D. both Earthquakes?

E. T Vibrates up and down and moves to the right.

A wave is 8 meters long and has a frequency of 3 Hz. Find speed.

$v = f\lambda$

$v = 3(8) = 24\ m/s$

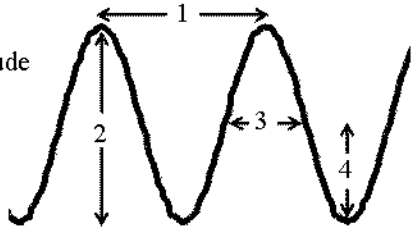
Which number shows:

A. 2 Double the amplitude

B. 4 Amplitude

C. 1 Wavelength

D. 3 Half λ




A wave has a wavelength of 2 meters and a frequency of 1.5 Hz. Calculate the wave's speed.

$v = f\lambda = 1.5(2) = 3\ m/s$

If a second wave with a frequency of 18 Hz enters the same medium, what will its speed be?

3 m/s speed stays the same.

Calculate the second wave's wavelength.

$v = f\lambda$ $\quad 3 = 18(\lambda)$ $\quad \lambda = \frac{3}{18} = \frac{1}{6} = .167\ m$

So, as f increases in the same medium, λ decreases.

higher f, shorter λ.

Faster or slower wave speed?

A. F The medium gets colder.

B. N/a The amplitude gets bigger.

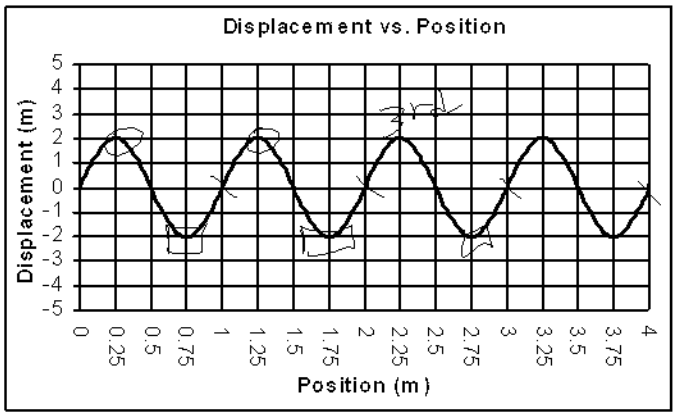
C. S A slinky gets looser.

D. S The medium turns from solid to liquid.

E. n/a The wavelength gets shorter.

Wave 1: f = 25 Hz; Wave 2: f = 40 Hz. Which one will be faster in water?

same, but wave 2 will have shorter λ.



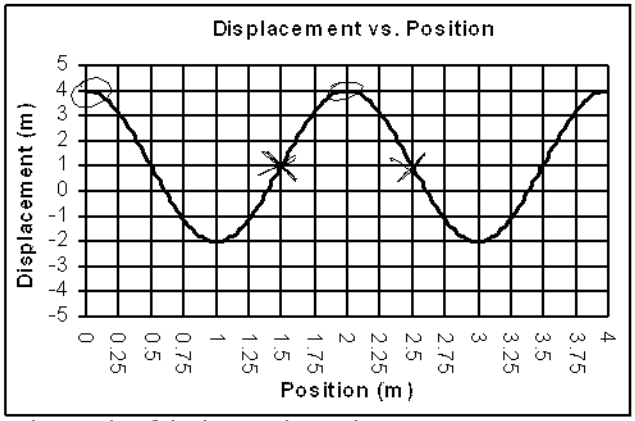

Mark 1 cycle of the wave.

Starting at 0.75 m, where does the 2nd cycle end: 2.75m

Number of complete cycles: 4 Mark the third crest.

Wavelength: 1m Amplitude: 2m

If f = 4 Hz, find speed: $v = f\lambda = 4(1) = 4\ m/s$




Mark 1 cycle of the harmonic motion.

Starting at 1.5 secs, when does half a cycle end: 2.5m

Number of complete cycles: 2 Number of troughs: 2

Wavelength: 2m Amplitude: 3m

If f = 50 Hz, find speed: $v = f\lambda = 50(2) = 100\ m/s$



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Name: _____ Unit 10:

Period: _____

Teacher explanation:

A teacher asked me some questions that he and I thought would help everyone.

Teacher:

I noticed that on the Waves worksheet you state in your answer key that a clock pendulum is not an example of wave motion. Can you explain why not?

Me:

A pendulum is an example of oscillating, or repeating, motion. Wave motion requires the energy to move, like a water wave or sound. The pendulum doesn't move anywhere. Also, circular motion isn't harmonic either. It repeats, but doesn't follow a path through the "equilibrium position". For a pendulum, the equilibrium position is where it comes to rest.

Teacher:

That makes sense when you talk about energy moving. Initially I was thinking differently since when you graph a pendulum it takes a wave-like form but I understand what you are saying. Thanks.

Me:

Yes, the graphs for SHM (pendulums, springs) and waves look the same.

For SHM it is possible to have a position vs time graph, where position is for the back and forth motion, centered at the equilibrium point. Think of a pendulum with a pen attached. To make this graph you would have to pull the paper one direction to signify time.

For wave motion you could make the same graph, but this time the back and forth of the pendulum would be the up and down of the amplitude of the wave motion (like the top of a wave going up and down) over time.

But for wave motion you could also make a graph of position vs location (or displacement vs position). Here position would be the up and down and the location would be how far away from your starting position. In this case the distance between two crests gives the wavelength.

All of the above graphs are sinusoidal (sin or cos-like).

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Name: _____

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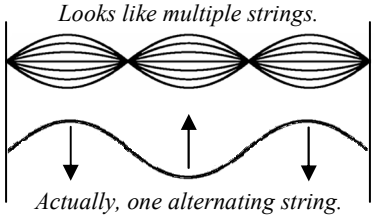
Unit 10:3

# Standing Waves

Sometimes waves are trapped in boundaries. If the length of a wave matches the space it is in, **resonance** occurs, causes maximum amplitude. The wave seems to stand still. **Standing waves occur only at certain frequencies.**

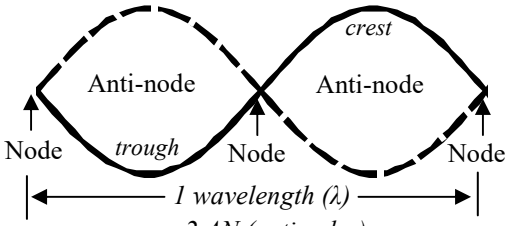
*A jump rope looks like a standing wave, but is not because it moves in a circle and can exist at any frequency (you can speed up a little at a time). A standing wave can't exist at any frequency.*

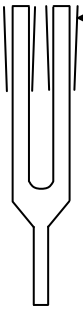



**Resonance**—When an object vibrates sympathetically and amplifies the energy of a wave.

*Guitar strings would be quiet without the resonance (amplification) of the guitar's body.*

*The places of no amplitude are called **nodes**. The places of greatest amplitude are called **anti-nodes**.*

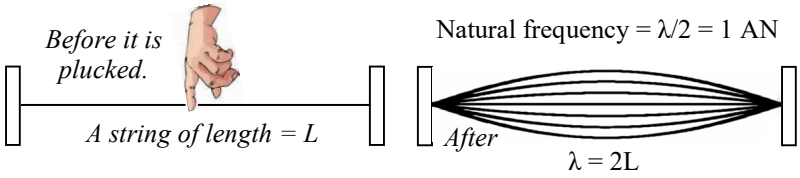



*Some standing waves have open boundaries, like a tuning fork.* ***Open boundaries move and must be anti-nodes.***

## Natural Frequency

When a string is plucked it will vibrate with only **one anti-node**. This is known as **the natural frequency** and always equals **one half of a wavelength**. The natural frequency is also called the fundamental frequency ($f_f$) or harmonic one ($H_1$).

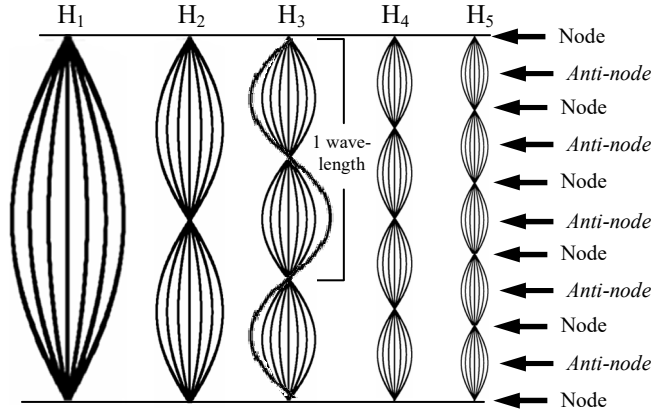



*The wavelength of the fundamental always equals 2L!*

## Harmonics

***Harmonics*** are standing waves that fit in the same boundaries as the fundamental (natural frequency). As with any wave, changing the frequency does not change the wave speed. So if f changes, λ changes, not v.

***First 5 Harmonics of a Vibrating String***




| Fundamental 1st harmonic | 2nd har-monic | 3rd har-monic | 4th har-monic | 5th har-monic |
|---|---|---|---|---|
| $f = f_f$ =H | $f_2$ =2H | $f_3$ =3H | $f_4$ =4H | $f_5$ =5H |

| ***Examples of Fundamentals and their Harmonics*** | | | | |
|---|---|---|---|---|
| ***$H_1$ ($f_f$)*** | ***$H_2$*** | ***$H_3$*** | ***$H_4$*** | ***$H_5$*** |
| H | 2H | 3H | 4H | 5H |
| 2 Hz | 4 Hz | 6 Hz | 8 Hz | 10 Hz |
| 5 Hz | 10 Hz | 15 Hz | 20 Hz | 25 Hz |
| 10 Hz | 20 Hz | 30 Hz | 40 Hz | 50 Hz |

**Frequency of a Harmonic**

Frequency of the harmonic N (in *Hz*) → $f_{HN} = N(H)$

$N$ = # of the harmonic

$H$ = Frequency of the fundamental (in *Hz*)

*Ex. Find the frequency of the third harmonic ($H_3$) of a 4 Hz fundamental.*

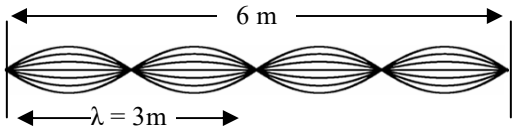
| | |
|---|---|
| H = 4 Hz<br>N = 3<br>$H_3$ = ? | $f_{Hn} = N(H)$<br>$f_{H3} = 3(4)$<br>$f_{H3}$ = 12 Hz |

*Ex. If the fifth harmonic has a frequency of 55 Hz, find the fundamental frequency.*

| | |
|---|---|
| $f_{H5}$ = 55 Hz<br>N = 5<br>$f_{H1}$ = H = ? | $f_{Hn} = N(H)$<br>55 = 5H<br>H = $f_{H1}$ = 11 Hz |

## Speed of a Standing Wave

To find the speed of a fixed string you would need to know the frequency of any harmonic and that harmonic's wavelength.




***Remember that λ (wavelength) = 2 antinodes!***

λ = 3m
f = 21 Hz
v = _____

v = fλ
v = 21(3)
v = 63 m/s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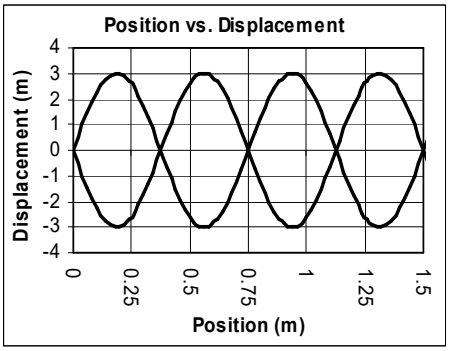
Name: _____ Unit 10:3

Period: _____

| | |
|---|---|
| 1. Standing wave | A. Where wave's amplitude is greatest. |
| 2. Harmonic | B. Where the wave has no motion. |
| 3. Fundamental | C. A wave that is a multiple of another wave. |
| 4. Natural Frequency | D. A wave that is trapped within boundaries. |
| 5. Node | E. The first harmonic of a standing wave, equal to 1/2 its wavelength. |
| 6. Anti-node | F. The frequency at which any space will vibrate when disturbed. |




# of cycles: _____

Wavelength: _____

Amplitude: _____

# of Anti-nodes: ____

Harmonic #: _____

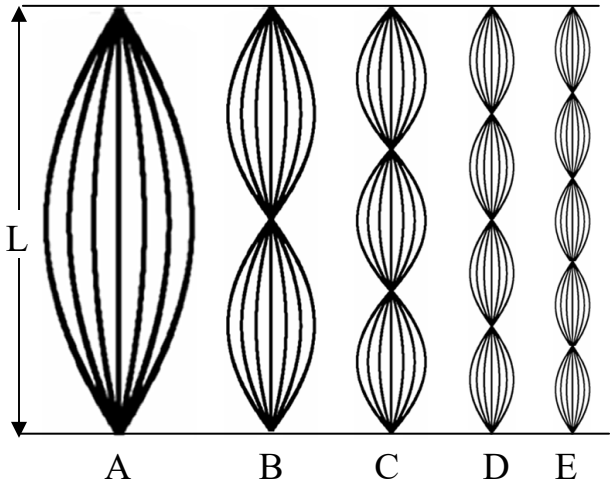
Why does a violin have a wood body instead of just strings?

Sometimes when talking or singing in a room, certain notes get very loud. Why?

A string has a fundamental (first harmonic) of 15 Hz, find the frequency of harmonic 3 ($H_3$).

If 20 Hz is the fundamental, find $H_6$.

If 35 Hz is $H_7$, what is the fundamental frequency?




____ Is the second harmonic. _____Has a wavelength of L.

____ Has 4 anti-nodes. _____Is the highest frequency.

____ Has 3 nodes. _____Longest wavelength.

____ Has a length of 1.5λ. _____Fastest wave speed.

____ Is the fundamental. _____Is the natural frequency.

String A has a fundamental with a period of 0.25 seconds.

A) What is the fundamental's frequency?

B) How many antinodes does it have?

C) If the fundamental is on a 6 m long string, what is its wave length?

D) Find the speed of the wave on that string.

E) What would be the frequency of the third harmonic?

F) What is the wave speed of the fourth harmonic?

*The following table shows the frequencies of the first 5 harmonics of different strings. Fill in the blank spaces.*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 4 Hz | | | | |
| 6 Hz | | | | |
| | 4 Hz | | | |
| | | 36 Hz | | |
| | | | 44 Hz | |

A fellow student shows you the frequencies of four harmonics of a string. Which one would you question and why?
Frequencies: 12 Hz; 24 Hz; 29 Hz; 48 Hz

Find its period: _____

Mark the nodes and anti-nodes.

What harmonic is this? _____

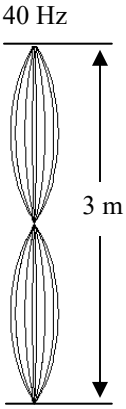
Fundamental frequency = _____

3rd harmonic frequency = _____

Wavelength = _____

Speed of the wave =

Speed of 5th harmonic =

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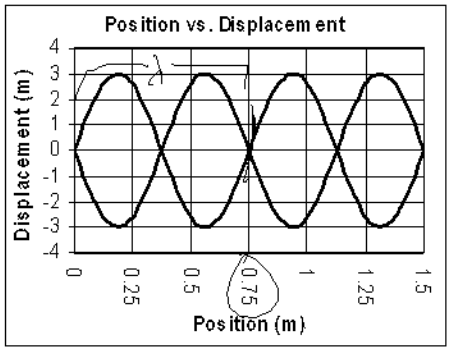
Name: _____ Unit 10:3

Period: _____

| | |
|---|---|
| 1. Standing wave D | A. Where wave's amplitude is greatest. |
| 2. Harmonic C | B. Where the wave has no motion. |
| 3. Fundamental E | C. A wave that is a multiple of another wave. |
| 4. Natural Frequency F | D. A wave that is trapped within boundaries. |
| 5. Node B | E. The first harmonic of a standing wave, equal to 1/2 its wavelength. |
| 6. Anti-node A | F. The frequency at which any space will vibrate when disturbed. |




# of cycles: 2

Wavelength: .75m

Frequency: _____

Amplitude: 3m

# of Anti-nodes: 4

Harmonic #: 4th

Why does a violin have a wood body instead of just strings?

The wood gives resonance to amplify the strings.

Sometimes when talking or singing in a room, certain notes get very loud. Why?

If note matches size of room, then resonance occurs.

A string has a fundamental (first harmonic) of 15 Hz, find the frequency of harmonic 3 ($H_3$).

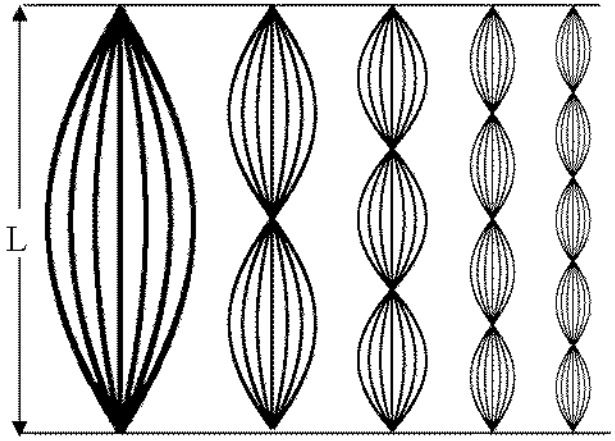
45Hz

If 20 Hz is the fundamental, find $H_6$.

120 Hz

If 35 Hz is $H_7$, what is the fundamental frequency?

$\frac{35}{7} = 5$ Hz




B Is the second harmonic.

D Has 4 anti-nodes.

B Has 3 nodes.

C Has a length of 1.5λ.

A Is the fundamental.

B Has a wavelength of L.

E Is the highest frequency.

A Longest wavelength.

all same Fastest wave speed.

A Is the natural frequency.

String A has a fundamental with a period of 0.25 seconds.

A) What is the fundamental's frequency?

$f = 1/.25 = 4$ Hz

B) How many antinodes does it have? 1

C) If the fundamental is on a 6 m long string, what is its wave length? 12m $\lambda_{fund.} = 2(\text{length})$

D) Find the speed of the wave on that string.

$v = f\lambda = 4(12) = 48$ m/s

E) What would be the frequency of the third harmonic?

4(3) = 12 Hz

F) What is the wave speed of the fourth harmonic? 48 m/s

*The following table shows the frequencies of the first 5 harmonics of different strings. Fill in the blank spaces.*

| 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| 4 Hz | 8 | 12 | 16 | 20 |
| 6 Hz | 12 | 18 | 24 | 30 |
| 2 | 4 Hz | 6 | 8 | 10 |
| 12 | 24 | 36 Hz | 48 | 60 |
| 11 | 22 | 33 | 44 Hz | 55 |

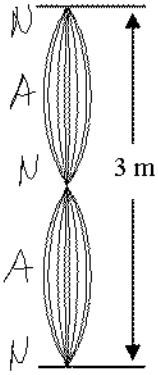
A fellow student shows you the frequencies of four harmonics of a string. Which one would you ~~question~~ and why?

Frequencies: 12 Hz; 24 Hz; 29 Hz; 48 Hz

Not a mult. of 12 (not div. by 12)

Find its period: $T = 1/f = 1/40 = .025$ sec 40 Hz

Mark the nodes and anti-nodes.




What harmonic is this? 2

Fundamental frequency = 20 Hz

3rd harmonic frequency = 60 Hz

Wavelength = 3m

Speed of the wave = $v = f\lambda = 40(3) = 120$ m/s

Speed of 5th harmonic = 120 m/s doesn't change



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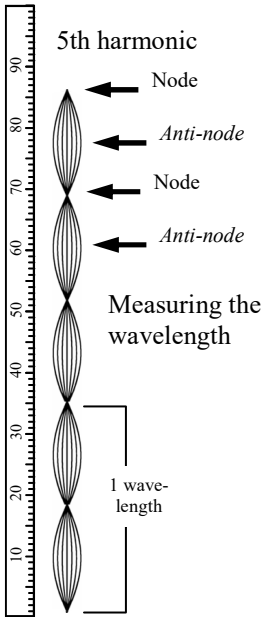
**Standing Wave Lab**

Change the frequency of the oscillator until you find a harmonic. You will know because the amplitude (antinode) will be big and the oscillator will be quieter.

1 wavelength (λ) = 2 antinodes.

You will need to find the first 6 harmonics for your string.




Fill in the following table for each harmonic.

Difference between frequencies:

$f_2 - f_1 =$
$f_3 - f_2 =$
$f_4 - f_3 =$
$f_5 - f_4 =$
$f_6 - f_5 =$

| *H (# of AN)* | *f (Hz)* | *λ (m)* | *V (= f λ) (in m/s)* |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |

Answer the questions on the back.

**Standing Wave Lab**

Change the frequency of the oscillator until you find a harmonic. You will know because the amplitude (antinode) will be big and the oscillator will be quieter.

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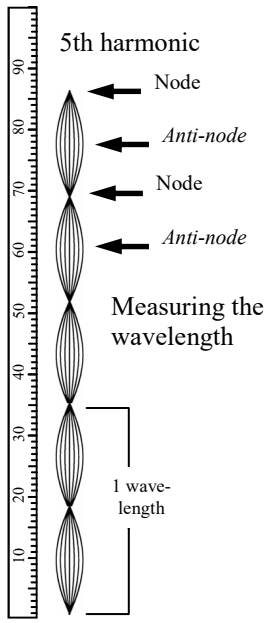


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$f_5 - f_4 =$
$f_6 - f_5 =$

| *H (# of AN)* | *f (Hz)* | *λ (m)* | *V (= f λ) (in m/s)* |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |

Answer the questions on the back.

**Standing Wave Lab**

Change the frequency of the oscillator until you find a harmonic. You will know because the amplitude (antinode) will be big and the oscillator will be quieter.

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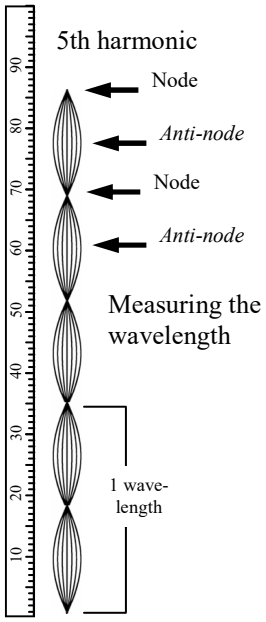


Fill in the following table for each harmonic.

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$f_2 - f_1 =$
$f_3 - f_2 =$
$f_4 - f_3 =$
$f_5 - f_4 =$
$f_6 - f_5 =$

| *H (# of AN)* | *f (Hz)* | *λ (m)* | *V (= f λ) (in m/s)* |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |
| 5 | | | |
| 6 | | | |

Answer the questions on the back.

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**Lab Questions:**

1. How many antinodes is one wavelength?
2. How many wavelengths is the first harmonic?
3. How do you find the wavelength of the first harmonic?
4. What did you notice about the difference between the frequencies each harmonic (left side of the table)?
5. What did you notice about the speed of the wave (v)?
6. As the frequency went up (bigger number) the wavelength went:

*Tighten the string by looping the string around the top twice.*

7. Find the fourth harmonic and fill in the following information.

| *H (# of AN)* | *f (Hz)* | *λ (m)* | *V (= f λ) (in m/s)* |
|---|---|---|---|
| 4 | | | |

8. Did the length of the string change?
9. What did change for the harmonic?

**Lab Questions:**

1. How many antinodes is one wavelength?
2. How many wavelengths is the first harmonic?
3. How do you find the wavelength of the first harmonic?
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|---|---|---|---|
| 4 | | | |

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2. How many wavelengths is the first harmonic?
3. How do you find the wavelength of the first harmonic?
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5. What did you notice about the speed of the wave (v)?
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*Tighten the string by looping the string around the top twice.*

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| *H (# of AN)* | *f (Hz)* | *λ (m)* | *V (= f λ) (in m/s)* |
|---|---|---|---|
| 4 | | | |

8. Did the length of the string change?
9. What did change for the harmonic?

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Name: _____

Period: _____

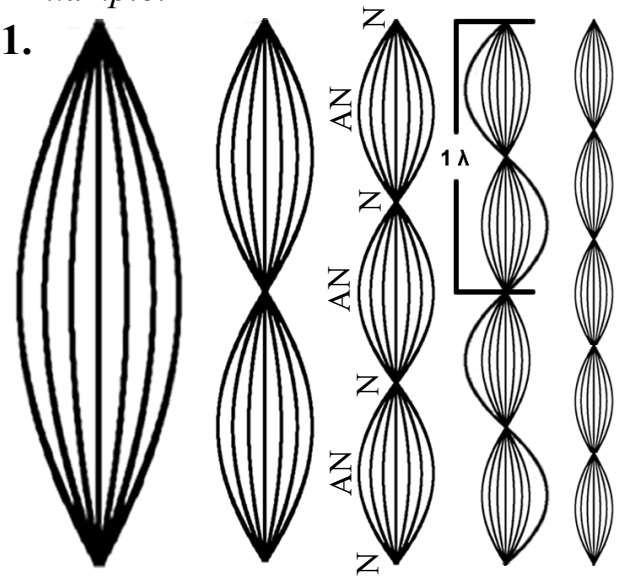
# Understanding Harmonics



***Each set shows the harmonics for a fixed string with a particular tension and length.***

*Example:*

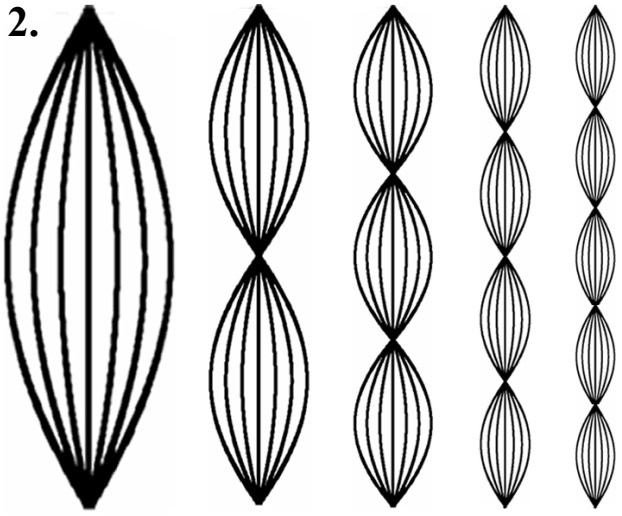
**1.**




| H# = | $H_1$ | $H_2$ | $H_3$ | $H_4$ | $H_5$ |
|---|---|---|---|---|---|
| | 1X = | 2X = | 3X = | 4X = | 5X = |
| f = | 6 Hz | 12 Hz | 18 Hz | 24 Hz | 30 Hz |

1. Mark the nodes (N) and antinodes (AN) for harmonic 3.
2. Show the waveform of $H_4$ at one moment in time.
3. Mark one wavelength of $H_4$. *(Notice that 2 AN = 1 λ)*

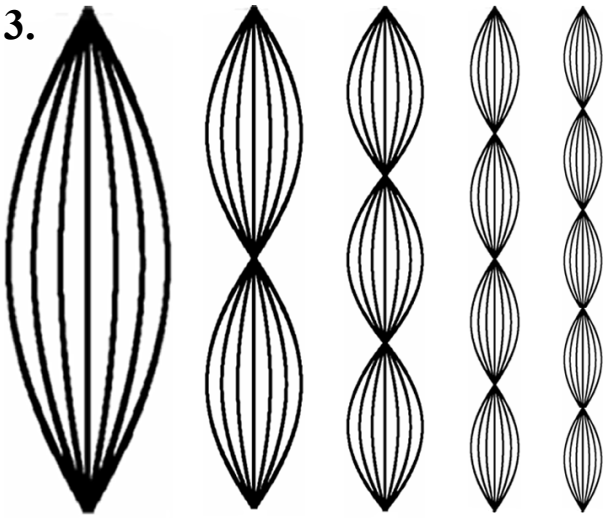
**2.**



| H# = | | | $H_3$ | | |
|---|---|---|---|---|---|
| f = | | 20 Hz | | | |

1. Mark the nodes (N) and antinodes (AN) for harmonic 2.
2. Show the waveform of $H_3$ at one moment in time.
3. Mark one wavelength of $H_3$.

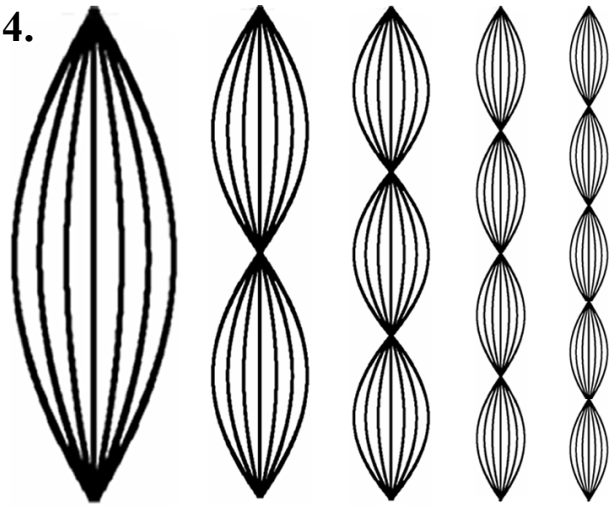
**3.**



| H# = | $f_{fundamental}$ | | | | |
|---|---|---|---|---|---|
| f = | | | | 80 Hz | |

1. Mark the nodes (N) and antinodes (AN) for harmonic 4.
2. Which harmonic is one wavelength long? _____
3. Which harmonic is also called the fundamental? _____

**4.**



| H# = | $f_f$ | | | | |
|---|---|---|---|---|---|
| f = | | | 33 Hz | | |

1. Mark the nodes (N) and antinodes (AN) for harmonic 5.
2. Show the waveform on $H_5$.
3. Mark one wavelength of $H_5$.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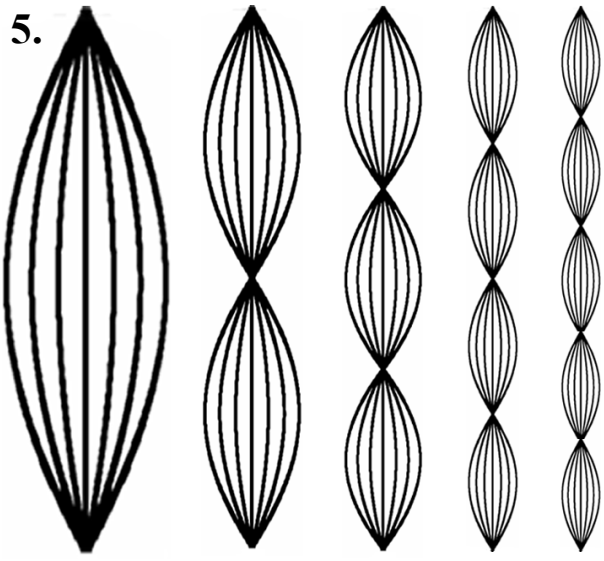
Name: _____ Unit 10:3a

Period: _____

**Note: the fundamental frequency is also known as the natural frequency.**

**5.**

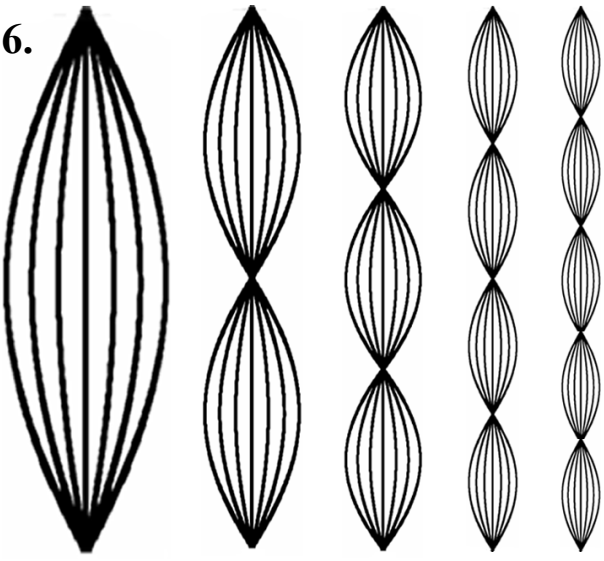


H# = _____ _____ _____ _____ _____

f = _____ _____ _____ _____ 100 Hz

1. Mark the nodes (N) and antinodes (AN) for harmonic 5.
2. Which one is the natural frequency? _____ (*see top)*
3. Which harmonic is 2 wavelengths long? _____

**6.**



H# = _____ _____ _____ _____ _____

f = _____ _____ _____ 48 Hz _____

1. Mark one wavelength on harmonic 2.
2. Mark one wavelength on harmonic 4.
3. The wavelength of $H_2$ is *double* or *half* that of $H_4$?

---

The first harmonic has _____ antinodes.

The third harmonic has _____ antinodes.

The eighth harmonic has _____ antinodes.

The first harmonic has two other names:

_____

_____

If the fundamental frequency is 20 Hz, find $H_3$.

If the natural frequency is 8 Hz, find $H_5$.

If the 4th harmonic is 48 Hz, find the fundamental.

If the 3rd harmonic is 12 Hz, find the fundamental.

---

If the 4th harmonic is 20 Hz,
A) find the fundamental frequency:

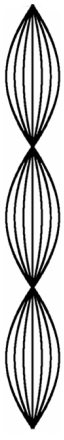
B) find the frequency of the 5th harmonic:

If the 3rd harmonic is 21 Hz, find harmonic 4.

---

What harmonic is this? _____

45 Hz



Mark the nodes and anti-nodes.

Mark one wavelength on the wave.

Find its natural frequency:

Find the frequency of $H_4$.

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Name: _____

Period: _____

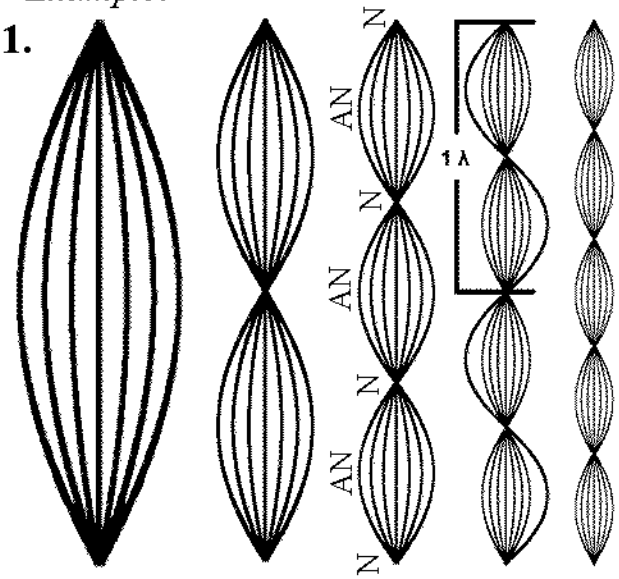
Unit 10:3a

# Understanding Harmonics

***Each set shows the harmonics for a fixed string with a particular tension and length.***

*Example:*

**1.**

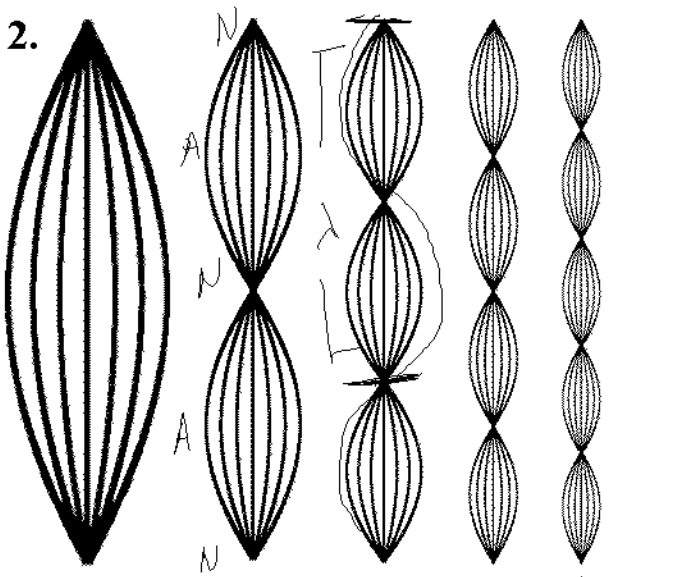



H# = $H_1$ $H_2$ $H_3$ $H_4$ $H_5$

f = 6 Hz 12 Hz 18 Hz 24 Hz 30 Hz

1. Mark the nodes (N) and antinodes (AN) for harmonic 3.
2. Show the waveform of $H_4$ at one moment in time.
3. Mark one wavelength of $H_4$. *(Notice that 2 AN = 1 λ)*

**2.**

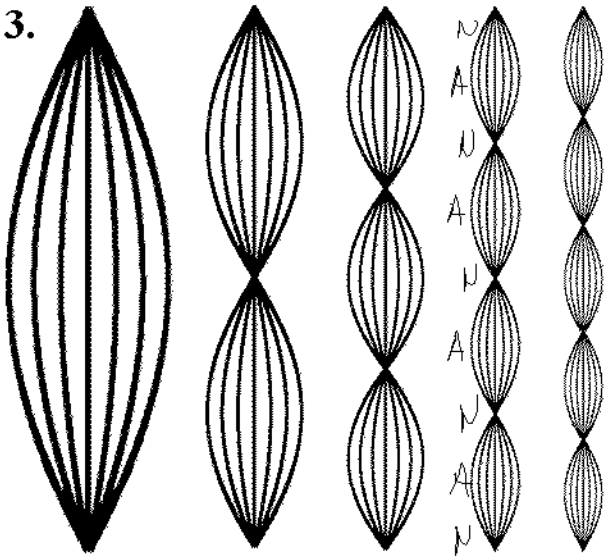



H# = $H_1$ $H_2$ $H_3$ $H_4$ $H_5$

f = 10 Hz 20 Hz 30 40 50 Hz

1. Mark the nodes (N) and antinodes (AN) for harmonic 2.
2. Show the waveform of $H_3$ at one moment in time.
3. Mark one wavelength of $H_3$.

**3.**

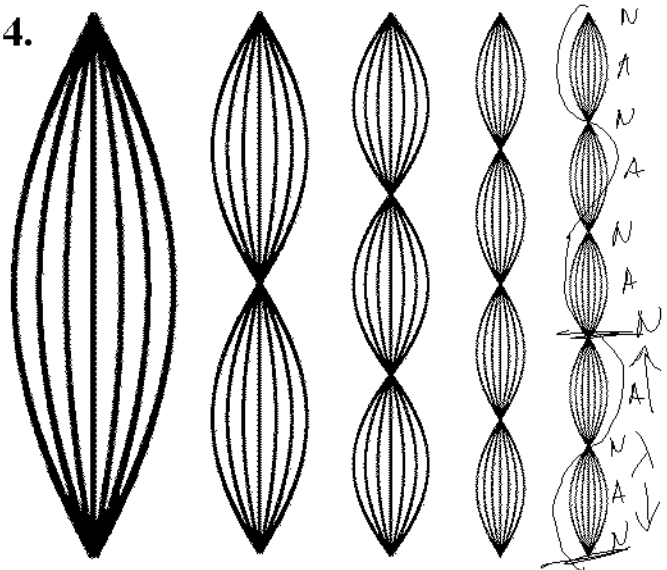



H# = $f_{fundamental}$ $H_2$ $H_3$ $H_4$ $H_5$

f = 20 Hz 40 60 80 Hz 100 Hz

1. Mark the nodes (N) and antinodes (AN) for harmonic 4.
2. Which harmonic is one wavelength long? $H_2$
3. Which harmonic is also called the fundamental? $H_1$

**4.**




H# = $f_f$ $H_2$ $H_3$ $H_4$ $H_5$

f = 11 22 33 Hz 44 55

1. Mark the nodes (N) and antinodes (AN) for harmonic 5.
2. Show the waveform on $H_5$.
3. Mark one wavelength of $H_5$.

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Name: _____ Unit 10:3a

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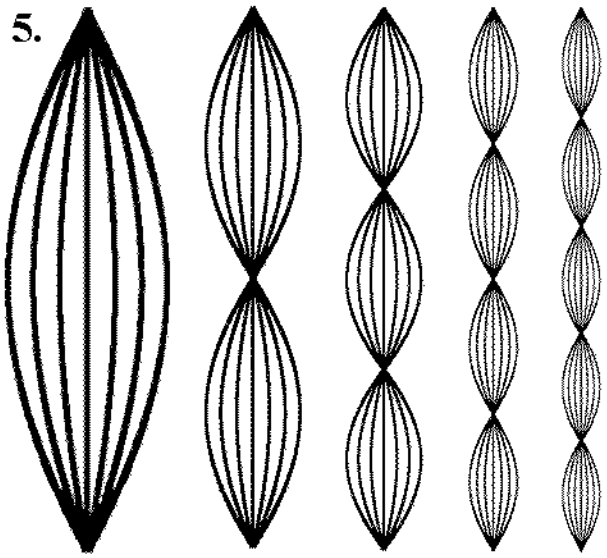
**Note: the fundamental frequency is also known as the natural frequency.**

**5.**

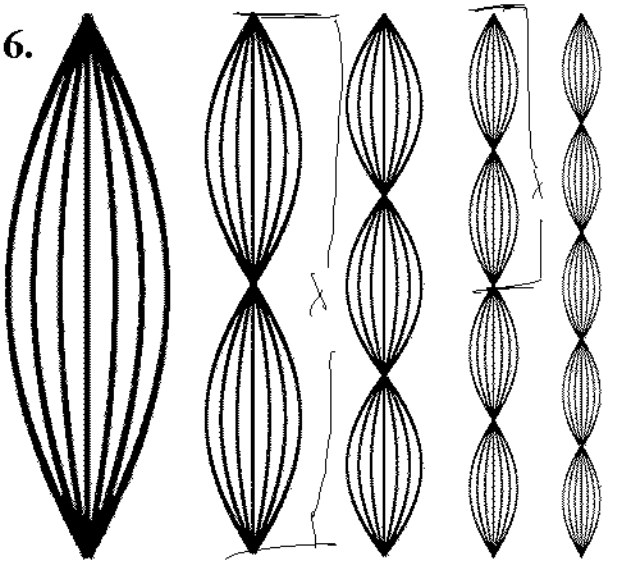


H# = H1 H2 H3 H4 H5

f = 100/5 = 20Hz 40Hz 60Hz 80Hz 100 Hz

1. Mark the nodes (N) and antinodes (AN) for harmonic 5.
2. Which one is the natural frequency? H1 *(see top)*
3. Which harmonic is 2 wavelengths long? H4

**6.**




H# = H1 H2 H3 H4 H5

f = 12 24 36 48 Hz 60

1. Mark one wavelength on harmonic 2.
2. Mark one wavelength on harmonic 4.
3. The wavelength of $H_2$ is *double* or *half* that of $H_4$?

---

The first harmonic has 1 antinodes.

The third harmonic has 3 antinodes.

The eighth harmonic has 8 antinodes.

The first harmonic has two other names:

fundamental

natural freq.

If the fundamental frequency is 20 Hz, find $H_3$.

$H_3 = 60$ Hz

If the natural frequency is 8 Hz, find $H_5$.

$5(8) = 40$ Hz

If the 4th harmonic is 48 Hz, find the fundamental.

$\frac{48}{4} = 12$ Hz

If the 3rd harmonic is 12 Hz, find the fundamental.

$\frac{12}{3} = 4$ Hz

If the 4th harmonic is 20 Hz,

A) find the fundamental frequency: $20/4 = 5$ Hz

B) find the frequency of the 5th harmonic:

$5(5) = 25$ Hz

If the 3rd harmonic is 21 Hz, find harmonic 4.

$F_f = \frac{21}{3} = 7$ Hz $\quad F_4 = 7(4) = 28$ Hz

---

What harmonic is this? 3rd

Mark the nodes and anti-nodes.

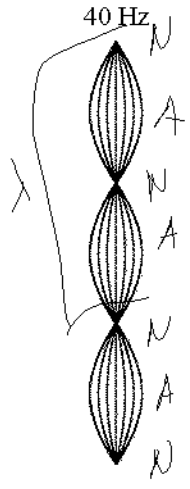
Mark one wavelength on the wave.

Find its natural frequency:

$\frac{40}{3} = 13.33$ Hz

Find the frequency of $H_4$.

$13.33(4) = 53.33$ Hz

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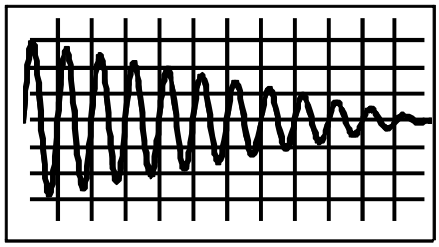
Period: _____

Unit 10:4

# Wave Actions

## Damping

Harmonic motion eventually stops. A pendulum will stop swinging; a wave will eventually weaken and stop. Friction or the restoring force causes the motion to lose its energy and to die out. This gradual reduction of amplitude we call ***damping***.



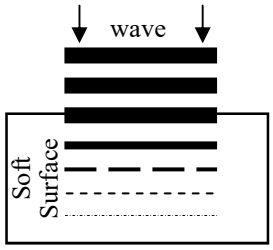
*This graph shows the damping of harmonic motion over time until it stops at its equilibrium position.*

## Boundary Reactions

*There are four ways a wave can react depending on the boundary it encounters:* ***Absorption; Reflection; Refraction; Diffraction.***

### Soft Boundaries Absorb

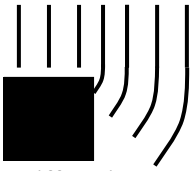
***Absorption***—a wave's energy dies out in a soft material (damping). *Example: Yelling into a pillow. The soft pillow* ***absorbs*** *(dampens) the sound.*



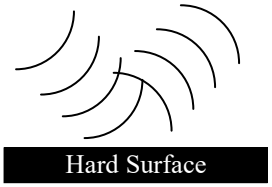

**Absorption**

### Corners Diffract

*Diffraction*—a wave drags against a corner, causing that part of the wave to turn. This is how we can hear around corners and how light can be seen around corners. *Example: talking to someone around a corner.*



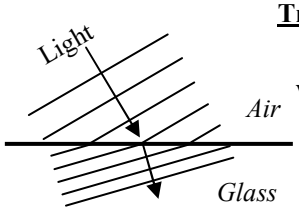
**Diffraction**




**Reflection**

### Hard Boundaries Reflect

***Reflection***—a wave bounces off when it hits a hard boundary. *Example: yelling against a wall, the sound wave* ***reflects*** *back (called an echo).*



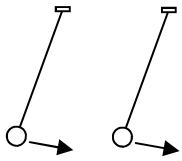

**Refraction**

### <u>Transparent</u> Boundaries Refract

***Refraction***— a wave bends when it crosses a boundary into a different medium and changes speed. *Example: light bends as it passes from air into the lenses of eyeglasses.*

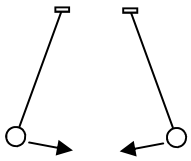
## Phase

Phase—a particular part of a cycle. One cycle = 360º; 1/2 of a cycle = 180º; 1/4 of a cycle = 90º.



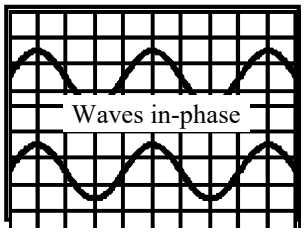
***In-phase*** means they are at the same point in their cycles.

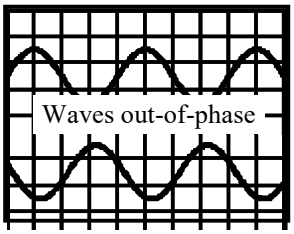
*In-phase*



***Out-of-phase*** means they are at *different points* in their cycles.

*180º out-of-phase*

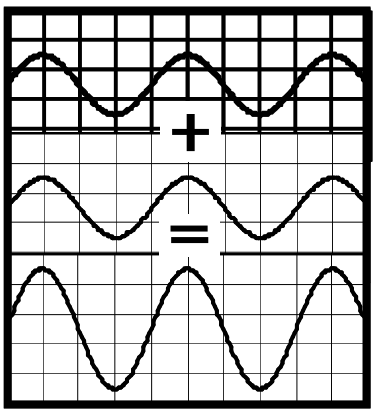



## Interference

*When two waves interact they* ***interfere*** *with each other.*

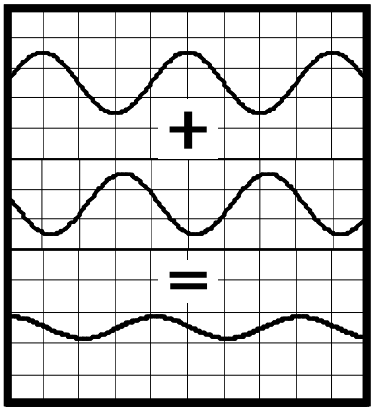
**Constructive Interference—**when the energy of **two waves** add together. This is like pushing on a person on a swing when they are moving away from you: you give them more energy and more amplitude.



Two waves of small amplitude that are ***in-phase constructively interfere,*** combining into a wave of greater amplitude.

Two singers on the same note cause a louder sound—constructive interference.

**Destructive Interference—**when the energy of **two waves** subtract from each other, causing cancellation. Pushing on a person on a swing as they are coming toward you (at the wrong time) causes the amplitude to be smaller.



Two waves that are ***out-of-phase destructively interfere,*** combining into a wave of smaller amplitude. Waves that completely **cancel** each other it is known as **complete destructive interference**.

Modern headphones (and cars) use *noise-canceling technology* that transmits out-of-phase waves toward noise, canceling it out.

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Name: _____ Unit 10:4

Period: _____

| | |
|---|---|
| 1. Phase | A. When two waves increase amplitude. |
| 2. In-phase | B. A single part of a cycle. |
| 3. Out-of-phase | C. When two waves decrease amplitude. |
| 4. Constructive interference | D. When two waves are at different parts of their cycles. |
| 5. Destructive interference | E. When two waves are at the same part of their cycles. |

| | |
|---|---|
| 1. Absorption | A. When a wave bends at a corner. |
| 2. Refraction | B. The process of harmonic motion losing amplitude over time. |
| 3. Diffraction | C. When a wave is dampened inside a soft boundary. |
| 4. Reflection | D. A wave bouncing off of a hard boundary. |
| 5. Damping | E. A wave bending inside transparent objects. |

Absorption, Reflection, Refraction, or Diffraction?

If a wave hits a hard wall, it bounces off by: _____

If a wave hits a soft boundary, it dies by: _____

Waves bending due to different speed mediums: _____

A wave bends around a corner by: _____

A wave bends as it passes thru a boundary by: _____

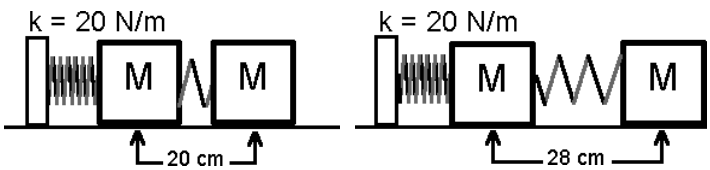
Tile or marble makes for a loud room by: _____

Eyeglasses magnify objects by: _____

How bats see at night with sound (echolocation): _____

Carpet can keep a room quiet by: _____

Light comes back from a mirror by: _____



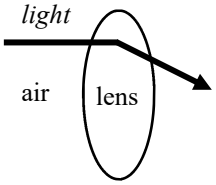

*The above is the same spring, but at different times.*

Amplitude of the left spring = _____. Right spring = _____

Which picture is the before picture?

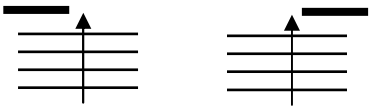
Why?

What is this bending called?

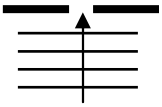



The light ray bends because the lens has a different w_____ s_____ than air.

Draw what will happen to the waves as they pass the two corners.

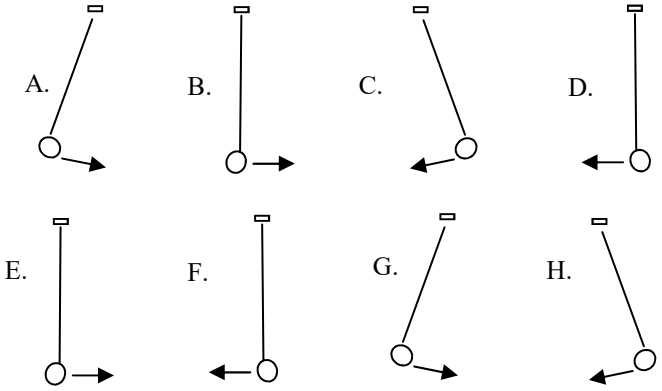


Combining the above, draw what will happen to the wave as it goes through a hole.



What do we call this?

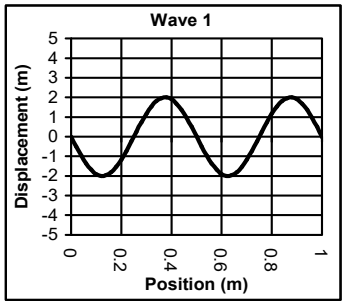
*The following show pendulums in different phases of a cycle.*

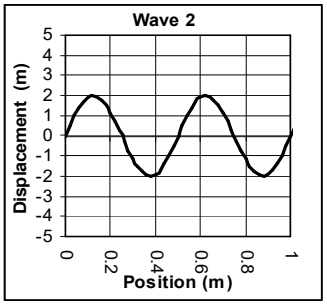



Which letter is in-phase with G? ____ With D? ____

Which letter is 180° out-of-phase of E? ____ With H? ____

Which letter is 90° out-of phase of F?____ with G? ____




What is the amplitude of wave 1? Wave 2?

Are they in-phase?

What will happen if the waves combine?

What will be the amplitude of the combined wave?

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Name: _____ Unit 10:4

Period: _____

| | |
|---|---|
| 1. Phase B | ~~A.~~ When two waves increase amplitude. |
| 2. In-phase E | ~~B.~~ A single part of a cycle. |
| 3. Out-of-phase D | ~~C.~~ When two waves decrease amplitude. |
| 4. Constructive A interference | ~~D.~~ When two waves are at different parts of their cycles. |
| 5. Destructive C interference | ~~E.~~ When two waves are at the same part of their cycles. |

| | |
|---|---|
| 1. Absorption C | ~~A.~~ When a wave bends at a corner. |
| 2. Refraction E | ~~B.~~ The process of harmonic motion losing amplitude over time. |
| 3. Diffraction A | ~~C.~~ When a wave is dampened inside a soft boundary. |
| 4. Reflection D | ~~D.~~ A wave bouncing off of a hard boundary. |
| 5. Damping B | ~~E.~~ A wave bending inside transparent objects. |

Absorption, Reflection, Refraction, or Diffraction?

If a wave hits a hard wall, it bounces off by: reflection

If a wave hits a soft boundary, it dies by: absorption

Waves bending due to different speed mediums: refraction

A wave bends around a corner by: diffraction

A wave bends as it passes thru a boundary by: refraction

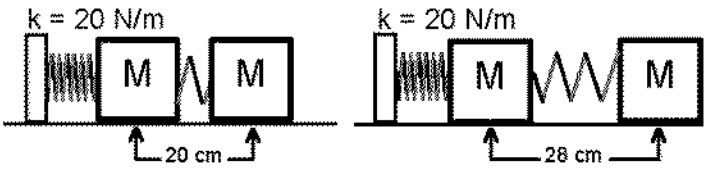
Tile or marble makes for a loud room by: reflection

Eyeglasses magnify objects by: refraction

How bats see at night with sound (echolocation): reflection

Carpet can keep a room quiet by: absorption

Light comes back from a mirror by: reflection




*The above is the same spring, but at different times.*

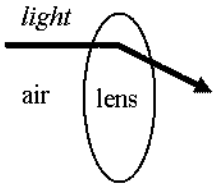
Amplitude of the left spring = 10 cm. Right spring = 14 cm

Which picture is the before picture? Right picture

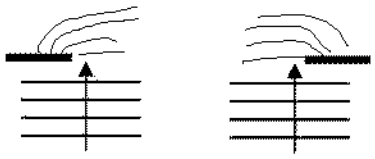
Why? It will dampen over time, so ampl. is smaller afterwards.

What is this bending called? refraction

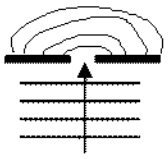
The light ray bends because the lens has a different w ave s peed than air.




Draw what will happen to the waves as they pass the two corners.

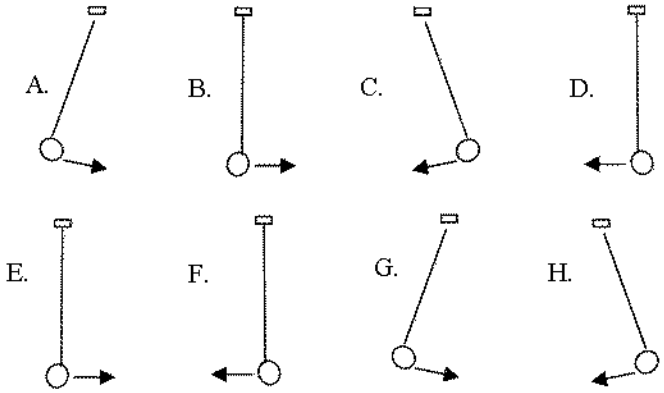


Combining the above, draw what will happen to the wave as it goes through a hole.



What do we call this? Diffraction

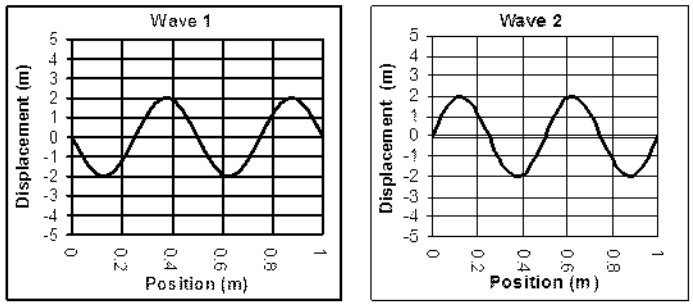
*The following show pendulums in different phases of a cycle.*




Which letter is in-phase with G? A With D? F

Which letter is 180° out-of-phase of E? B (F) With H? A (G)

Which letter is 90° out-of phase of F? G (H), C, A with G? F, D, E




What is the amplitude of wave 1? 2m Wave 2? 2cm

Are they in-phase? No

What will happen if the waves combine? They will cancel each other – destructive interference.

What will be the amplitude of the combined wave? 0 m



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Name: _____

Period: _____

Unit 10:5

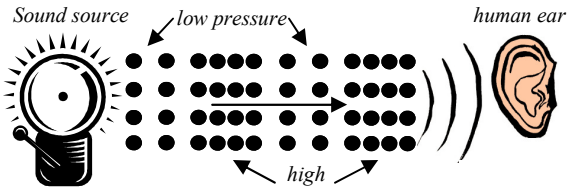
# Sound

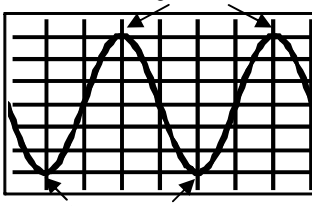
## What is Sound?

***Sound*** is the movement of compression waves (longitudinal waves) hitting our ears. These compression waves are alternating high and low pressure areas. The air molecules vibrate back and forth, but don't travel.

*Speakers imitate sounds by pushing air and causing vibrations.*

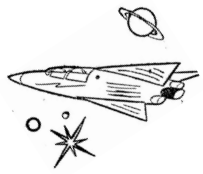
***Sound Wave are Pressure Waves***



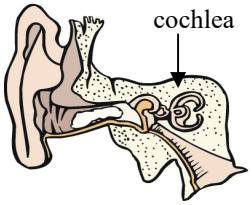




*On graphs, we use crests and troughs to show high and low pressure.*

As a wave sound needs a *medium* to travel through. Sound cannot travel through the vacuum of space. ***Space is silent*** (no matter what you hear in the movies).



Tiny hairs inside the ***cochlea*** (inner ear) translate air pressure into electrical impulses that can be read by the brain. Very loud sounds bend these hairs, causing deafness.




## Frequency = Pitch

We hear the frequency of sound as ***pitch***. A higher frequency we hear as a higher pitch. A lower frequency we hear as a lower pitch.

### *Higher Frequency = Higher Pitch*

| Frequency (f) | Wavelength (λ) | Source |
|---|---|---|
| 20 Hz | 17 m | rumble of thunder |
| 100 Hz | 3.4 m | bass guitar |
| 2,000 Hz | 17 cm | fire truck siren |
| 4,000 Hz | 7 cm | highest note of piano |
| 10,000 Hz | 3.4 cm | whine of a jet turbine |

***Humans can hear frequencies that are between 20 Hz and 20,000 Hz!***

Elephants and submarines use ***infrasonic*** sound (too low to hear) to communicate over long distances. Very low frequencies (very bass) travel very long distances and can penetrate through water (just like thru cars).

Dog whistles use ***ultrasonic*** frequencies (above human hearing [+20,000 Hz]), but perfect for dog ears!

## Amplitude = Loudness

We hear pressure (the amplitude) of sound as ***loudness***. It takes more energy to create a louder sound. Too loud of a sound can cause ***deafness***.

### *Loudness is measured in decibels (dB)*

| | |
|---|---|
| 10 dB | Total silence. |
| 30 dB | Total quiet in the woods at night. |
| 60 dB | Normal conversation. |
| 70 dB | Busy traffic in the city. |
| 90 dB | A jackhammer (hearing damage if not protected) |
| 110 dB | Threshold of pain from sound. |
| 200 dB | Human will die from the sound pressure. |

***A +10 dB change we hear as twice as loud.***

A 30 dB sound is twice as loud as a 20 dB sound.

***A -10 dB change we hear as half as loud.***

A 30 dB sound is half as loud as a 40 dB sound.

## Speed of Sound ($v_s$)

The speed of sound changes. In gases, hotter (faster) gases conduct sound faster. In solids and liquids, generally denser (tighter) materials are faster.

| Material | $V_s$ (m/sec) |
|---|---|
| Air | 340 |
| Helium | 965 |
| Water | 1530 |
| Wood | 2000 |
| Gold | 3240 |
| Steel | 5940 |

### *The speed of sound in air is about 340 m/sec.*

You can use $v_s = f\lambda$. to find frequency or wavelength.
AND use $S = D/T$ to find distance or time.
In both cases, Vs (S) is a constant for sound: 340 m/sec.

*Ex. Find the wavelength of a 200 Hz sound.*

| | |
|---|---|
| $v_s$ = 340 m/s<br>f = 200 Hz<br>λ = ? | $v = f\lambda$ so $\lambda = v/f$<br>λ = (340 m/s) ÷ (200 Hz)<br>λ = 1.7 m |

*Ex. If you hear a sound 3 seconds after you see the motion. How far away is it?*

| | |
|---|---|
| Vs = 340 m/s<br>T = 3 sec<br>D = ? | $v_s = D/T$ so $D = v_sT$<br>D = (340 m/s) X (3 sec)<br>D = 1020 m |

Motion faster than sound is called ***supersonic***. Supersonic planes give their speed in multiples of ***Mach*** (1 × the speed of sound).

Mach 1 = 340 m/s.
Mach 2 = 680 m/s.

A ***sonic boom*** is caused by an object breaking through the sound barrier. Supersonic planes, bullets, and bullwhips all make sonic booms.



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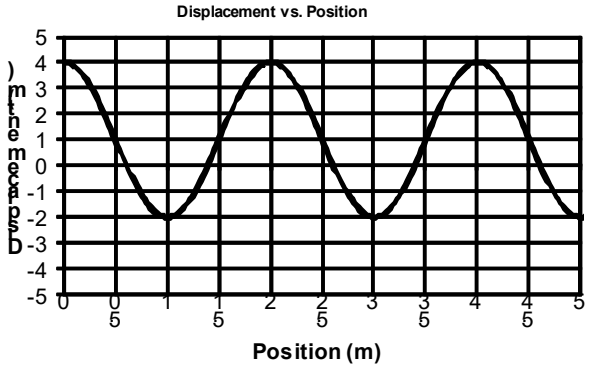
Name: _____ Unit 10:5

Period: _____

| | | | |
|---|---|---|---|
| 1. Sound | A. Faster than the speed of sound. | 1. Pitch | A. Where there is no sound because of its vacuum. |
| 2. Sonic boom | B. A wave caused by alternating high and low pressure. | 2. dB | B. How we hear changes of frequency of sound. |
| 3. Supersonic | C. The organ that detects sound waves. | 3. Space | C. 340 m/s in air. |
| 4. Ultrasonic | D. A pressure wave caused by an object going faster than sound. | 4. Loudness | D. How we measure loudness. |
| 5. Cochlea | E. A sound higher than humans can hear. | 5. $v_s$ | E. The amplitude or strength of a sound. |




Use the graph to answer these questions: λ = _____

1 cycle is from 1 m to _____; 1/2 cycle is from 0 m to _____.

Amplitude (A) = _____ Total cycles: _____;

It is a sound wave; find frequency:

Is this frequency audible to humans (can we hear it)?

A wave's velocity is 90 m/sec with a frequency of 6 Hz. What is it's wavelength?

A sound wave has a wavelength of 20 m. Find its frequency.

If a sound wave's frequency is 100 Hz. What is its period?

What is the above wave's wavelength?

A railroad crew is repairing a rail. You hear the hammer 0.5 seconds after it is swung. How far away is the crew?

You hear a plane 4 seconds after you see it. Find the distance to the plane.

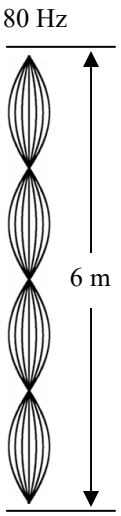
Why is space silent?

If I increase the energy I give a sound wave what changes:

If a wave's fourth harmonic has a frequency of 40 Hz, what is its natural frequency and what is the frequency of $H_6$?

If a wave's fundamental is 6 Hz, what harmonic has a frequency of 48 Hz?

Find its period:




What harmonic is this?
Could a human hear this frequency?
Mark the nodes and anti-nodes.
How many wavelengths is it?

What is its wavelength?

Find the fundamental frequency:

5th harmonic frequency:

Speed of the wave on this string:

If a sound is 40 dB loud. Answer how many dB these would be:

1) A sound twice as loud:

2) A sound half as loud:

Compared to a 50 dB sound, you would hear a 60 dB as: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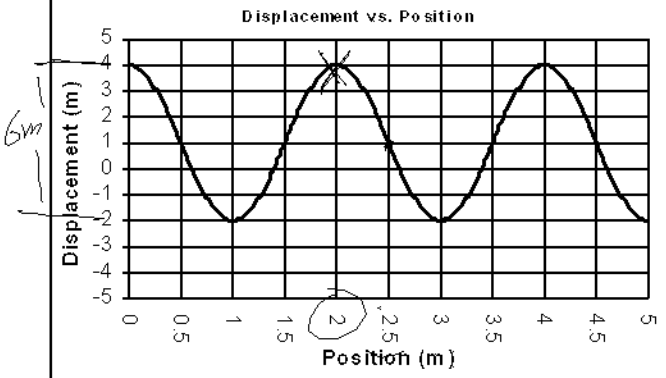
Name: _____

Period: _____

Ch 13:1

| | |
|---|---|
| 1. Sound B | A. Faster than the speed of sound. |
| 2. Sonic boom D | B. A wave caused by alternating high and low pressure. |
| 3. Supersonic A | C. The organ that detects sound waves. |
| 4. Ultrasonic E | D. A pressure wave caused by an object going faster than sound. |
| 5. Cochlea C | E. A sound higher than humans can hear. |

| | |
|---|---|
| 1. Pitch B | A. Where there is no sound because of its vacuum. |
| 2. dB D | B. How we hear changes of frequency of sound. |
| 3. Space A | C. 340 m/s in air. |
| 4. Loudness E | D. How we measure loudness. |
| 5. $v_s$ C | E. The amplitude or strength of a sound. |




Use the graph to answer these questions: $\lambda$ = 2 m

1 cycle is from 1 m to 3m; 1/2 cycle is from 0 m to 1m.

Amplitude (A) = 3m Total cycles: 2.5;

It is a sound wave; find frequency:

$v = 340 m/s = f\lambda$ $340 = f(2)$ $f = 170$ Hz

Is this frequency audible to humans (can we hear it)?

yes between 20 – 20,000 Hz

A wave's velocity is 90 m/sec with a frequency of 6 Hz. What is it's wavelength?

$v = f\lambda$ $\lambda = 15$ m

$90 = 6(\lambda)$

A sound wave has a wavelength of 20 m. Find its frequency.

$v = 340 = f\lambda$ $f = 17$ Hz

$340 = f(20)$

If a sound wave's frequency is 100 Hz. What is its period?

$v = 340$ $T = \frac{1}{f} = \frac{1}{100} = .01$ sec

What is the above wave's wavelength?

$v = f\lambda$ $\lambda = 3.4$ m

$340 = 100\lambda$

A railroad crew is repairing a rail. You hear the hammer 0.5 seconds after it is swung. How far away is the crew?

$v = 340$ m/s $v = \frac{D}{T}$ $D = vT = 340(.5) = 170$ m

$t = .5$

You hear a plane 4 seconds after you see it. Find the distance to the plane.

$340 = \frac{D}{4}$ $1360$ m $= D$

If a sound is 40 dB loud. Answer how many dB these would be:

1) A sound twice as loud: 50 dB
2) A sound half as loud: 30 dB

Compared to a 50 dB sound, you would hear a 60 dB as:

twice as loud

Why is space silent?

no medium (vacuum)

If I increase the energy I give a sound wave what changes:

ampl. = loudness

If a wave's fourth harmonic has a frequency of 40 Hz, what is its natural frequency and what is the frequency of $H_6$?

$\frac{40}{4} = 10$ Hz $H_6 = 6(10) = 60$ Hz

$H_1$

If a wave's fundamental is 6 Hz, what harmonic has a frequency of 48 Hz?

$\frac{48}{6} = 8$ th harm.

Find its period: $T = 1/80 = .0125$ sec

What harmonic is this? 4

Could a human hear this frequency? yes

Mark the nodes and anti-nodes.

How many wavelengths is it? $2\lambda = 6$m

What is its wavelength? $\lambda = 3$m

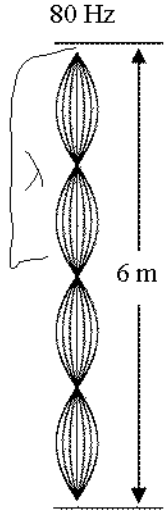
Find the fundamental frequency:

$\frac{80}{4} = 20$ Hz

5th harmonic frequency: $20(5) = 100$ Hz

Speed of the wave on this string:

$v = f\lambda = 80(3) = 240$ m/s



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Name: _____

Period: _____

Unit 10:6

# Light

## Light is a Wave

Light is refracted in lenses and reflected by mirror. Also, two fingers close together causes lines of darkness in between: destructive interference. ***So, light must be a wave!***

## Light is a Particle

Light can travel thru the vacuum of space, but a wave can't travel in a vacuum. So ***light must be a particle!***

## Light is Both

This contradiction perplexed scientists for many, many years, but the evidence must be believed: **light is both a wave and a particle.**

***A light packet is called a <u>photon</u>.***

## Speed of Light = c = 3 x $10^8$ m/s

**Sound is fast**: 340 m/sec, in air, but **light is faster:** 3 x $10^8$ m/s! That's 3 with 8 zeroes or 300,000,000 m/sec. Light can circle the earth 7.5 times in one second!

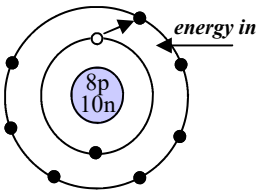
**Speed Limit**

**C**

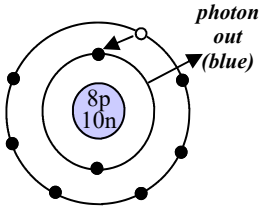
The speed of light is the ultimate speed limit. **Nothing can go faster than light**.

## Where Does Light Come From?

***Photons (light) come from electrons falling from high electron orbits to low orbits.***
These orbits are also called ***energy levels***.




*Energy can raise an electron to a higher energy level.*



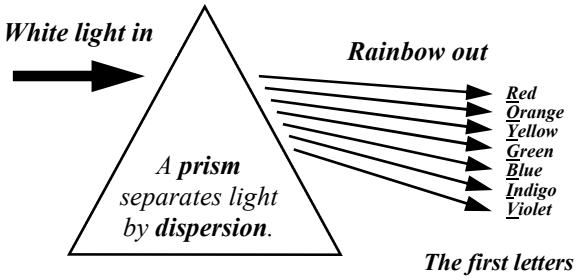

*When the electron falls back, a photon is given off: light!*

Because each element has a different number of protons, **each element** has slightly different electron energy levels and **gives off different colors.**

This fact allows us to tell the chemical makeup of stars. Just by looking at the light it gives off (its spectrum) scientist know the elements in the star.

## Visible Light

White light is actually made up of many different colors, each with a different wavelength and frequency.




***Different wavelengths (colors) refract (bend) differently when passing into glass. A prism's double refraction makes this more obvious.***

***The first letters spell: ROY – G – BIV***

## Colors have Different Energies

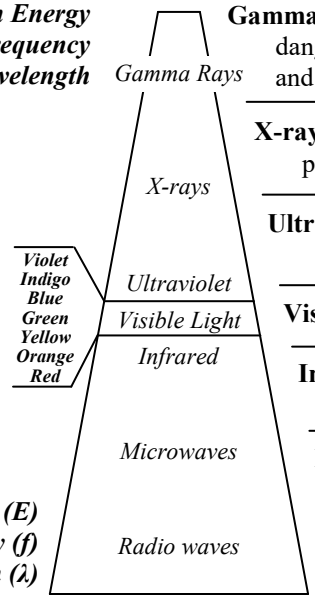
You know that different color flames give off different amounts of heat. Red flames are the coolest and blue flames are the hottest. ***As you move from Red to Blue, light GAINS energy.***

***White light is made up of all colors. That is why a white flame is the hottest!***

## Electromagnetic (EM) Spectrum

"Light" waves are electromagnetic radiation and includes ALL light: visible and invisible.

***High Energy***
***High Frequency***
***Short Wavelength***




***Low Energy (E)***
***Low Frequency (f)***
***Long Wavelength (λ)***

**All electro-magnetic radiation trav-els at the speed of light: 3×$10^8$ m/s.**

**Gamma rays** (λ = less than .01 nm [a billionth of a meter]) – the most powerful and dangerous form of radiation. Emitted by nuclear reactions, they can break chemical and nuclear bonds and cause mutations.

**X-rays** (λ = .01 nm to 10 nm) – Used in medicine and industry because they can penetrate materials and tissues. Too much can cause mutations or tissue damage.

**Ultraviolet light** (λ = 10 to 400 nm) – just above visible light; causes sunburns and skin cancer. The ozone layer protects us from most of the sun's ultraviolet light.

**Visible light** (λ = 400 to 700 nm) – The smallest part of the EM spectrum.

**Infrared** (λ = 1mm to 700 nm)– invisible red light radiation: what most people think of as heat. Can be seen by infrared cameras and goggles.

**Microwaves** (λ = 1mm to 30cm)– used to cook food and for cell phones.

**Radio waves** (λ = less than a cm to hundreds of meters) – very long, low energy waves used to transmit radio and television signals. Radio towers have to be so tall so they can long radio waves.

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Name: _____ Unit 10:6

Period: _____

| | |
|---|---|
| 1. Photon | A. the speed of light and the fastest speed in the universe. |
| 2. $3 \times 10^8$ m/sec | B. Also known as an electron orbit. To move from low to high requires energy. |
| 3. Prism | C. All light: visible and invisible. |
| 4. Light | D. Uses dispersion to separate white light into its colors. |
| 5. EM Spectrum | E. A single particle or packet of light. |
| 6. Energy Level | F. A wave that can travel through a vacuum. |

| | |
|---|---|
| 1. Radio waves | A. Electromagnetic waves we feel as heat. |
| 2. Infrared | B. Dangerous EM waves that have very high energy and come from nuclear reactions. |
| 3. Ultraviolet | C. EM waves that have very low energy and long wavelengths. |
| 4. X-rays | D. EM waves that can pass through skin and have short wavelengths. |
| 5. Gamma rays | E. EM waves with more energy than visible light and can cause sunburns. |
| 6. Microwaves | F. Long wavelengths; used in cell phones. |

Is light a wave or a particle? Prove your answer:

Where does light come from?

Find the period of a 10 Hz wave.

A wave has these characteristics: 25 Hz and 8 m. Find speed.

A sound changes from 25 dB to 5 dB. How much louder does the 25 dB seem to us?

You hear a thunder 3 seconds after you see the lightening. How far away is the storm?

You are in a concert hall and yell up to the ceiling. It takes 1 second for the echo to come back to you.
A) 1 second—is that the time for the sound to go to the ceiling or for the sound to go to the ceiling and back?
B) If you want to know how high the ceiling is, how long does it take for the sound to get to the ceiling?
C) Find the how high the ceiling is.

Put these three in order from slowest to fastest:

Light waves; sound waves; water waves.

_____

Put these from shortest to longest wavelengths

Radio waves Ultraviolet X-rays Visible Microwaves

_____

Put these from least energy to most energy.

Radio waves Ultraviolet X-rays Visible Microwaves

_____

Why do we see lightening and hear the thunder a few seconds later?

Find its period: _____

What harmonic is this? _____

Mark the nodes and anti-nodes.

Mark one wavelength on the harmonic.

Can humans hear this frequency?_____

Find the fundamental frequency:

_____

3rd harmonic frequency:

_____

40 Hz

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Name: _____

Period: _____



| | | | |
|---|---|---|---|
| 1. Photon E | A. the speed of light and the fastest speed in the universe. | 1. Radio waves C | A. Electromagnetic waves we feel as heat. |
| 2. $3 \times 10^8$ m/sec A | B. Also known as an electron orbit. To move from low to high requires energy. | 2. Infrared A | B. Dangerous EM waves that have very high energy and come from nuclear reactions. |
| 3. Prism D | C. All light: visible and invisible. | 3. Ultraviolet E | C. EM waves that have very low energy and long wavelengths. |
| 4. Light F | D. Used to separate white light into its colors. | 4. X-rays D | D. EM waves that can pass through skin and have short wavelengths. |
| 5. EM Spectrum C | E. A single particle or packet of light. | 5. Gamma rays B | E. EM waves with more energy than visible light and can cause sunburns. |
| 6. Energy Level B | F. A wave that can travel through a vacuum. | 6. Microwaves F | F. Long wavelengths; used in cell phones. |

Is light a wave or a particle? Prove your answer:

Both ~ waves: can interfere

particle: can go thru vacuum

Put these three in order from slowest to fastest:

Light waves; sound waves; water waves.

water / sound / light

Where does light come from?

electrons falling from high orbits to low orbits

Put these from shortest to longest wavelengths

| Radio waves | Ultraviolet | X-rays | Visible | Microwaves |
|---|---|---|---|---|
| 5 | 2 | 1 (shortest) | 3 | 4 |

longest

Find the period of a 10 Hz wave.

$f = 10$ Hz $\quad T = \frac{1}{f} = \frac{1}{10} = .1$ sec

$T =$ ___

A wave has these characteristics: 25 Hz and 8 m. Find speed.

$f = 25$ Hz $\quad v = f\lambda$

$\lambda = 8$ m $\quad = 25(8) = 200$ m/s

$v =$ ___

A sound changes from 25 dB to 5 dB. How much louder does the 25 dB seem to us?

four times as loud.

You hear a thunder 3 seconds after you see the lightening. How far away is the storm?

$t = 3$ sec $\quad v = \frac{D}{t} \quad D = vt$

$v = 340$ m/s $\quad = 340(3) =$

$D =$ ___ $\quad 1020$ m

You are in a concert hall and yell up to the ceiling. It takes 1 second for the echo to come back to you.

A) 1 second—is that the time for the sound to go to the ceiling or for the sound to go to the ceiling and back?

B) If you want to know how high the ceiling is, how long does it take for the sound to get to the ceiling? .5 sec.

C) Find the how high the ceiling is.

$D = vt$

$= 340(.5) = 170$ m

Put these from least energy to most energy.

| Radio waves | Ultraviolet | X-rays | Visible | Microwaves |
|---|---|---|---|---|
| 1 | 4 | 5 | 3 | 2 |

least $\quad$ most E

Why do we see lightening and hear the thunder a few seconds later?

light travels faster than sound.

Find its period: $T = \frac{1}{f} = \frac{1}{40} = .025$ sec

What harmonic is this? 5th

Mark the nodes and anti-nodes.

Mark one wavelength on the harmonic. (2AN)

Can humans hear this frequency? yes

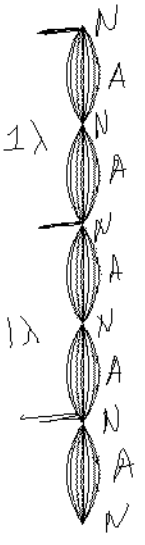
(above 20 Hz + below 20,000 Hz)

Find the fundamental frequency:

$5X = 40$ Hz $\quad X = 8$ Hz

3rd harmonic frequency:

$X = 8$ Hz $\quad 3X = 24$ Hz




40 Hz



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Name: _____

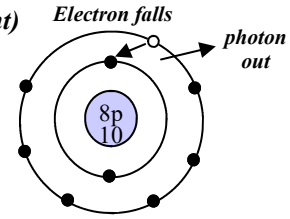
Period: _____

Unit 10:7

# Color

## Light Comes from the Atom

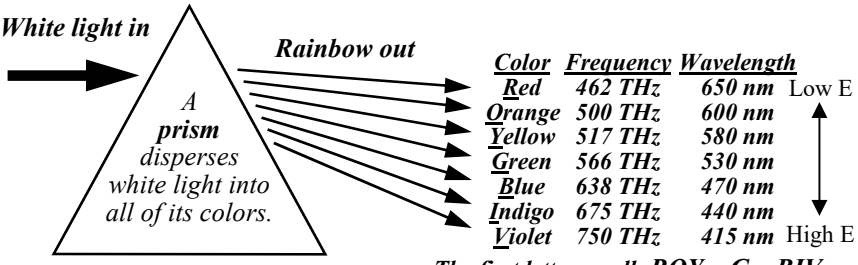
***Photons (light) come from electrons falling from high electron orbits to low orbits.***




When the electron falls back, a photon is given off: light!

## Different Colors

Different colors come from white (sun) light. Each of these colors has its own frequency, wavelength, and energy.




| Color | Frequency | Wavelength | |
|---|---|---|---|
| Red | 462 THz | 650 nm | Low E |
| Orange | 500 THz | 600 nm | |
| Yellow | 517 THz | 580 nm | |
| Green | 566 THz | 530 nm | |
| Blue | 638 THz | 470 nm | |
| Indigo | 675 THz | 440 nm | |
| Violet | 750 THz | 415 nm | High E |

***The first letters spell: ROY – G – BIV***

## Lights—Additive Color
### *RGB Model*

*Lights add color to a black background. The three primary lights colors are Red, Green, and Blue (RGB)*

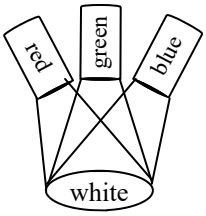
Before you turn on any lights, a room is black. By turning on lights you add colors. The three primary light colors are red, green, and blue. By adding different amounts of each color we can make any color. This method of additive color is known as RGB.

**Adding Light Colors:**

***Red and Blue lights make Magenta*** (*purple*).

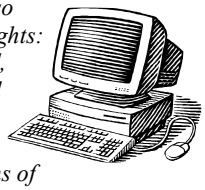
***Red and Green lights make Yellow***.

***Green and Blue lights make Cyan*** (***sea green***).

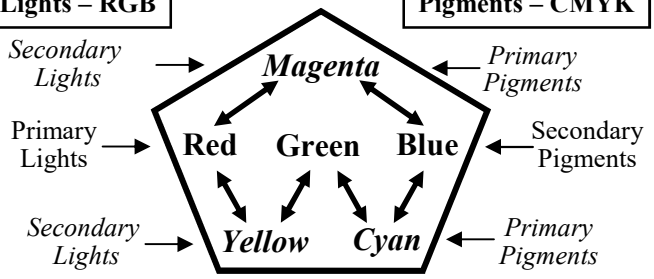



*Red, green, and blue light interfere constructively to make white light.*

*Computers and TVs are black when off, so they use lights: RGB. Red, green, and blue lights make all the millions of colors on your screen.*



**Lights – RGB** | **Pigments – CMYK**




***Using the Color Chart:***

***Lights (RGB)***: Follow the arrows from the lights to the color you are making. Red and Blue make *Magenta*.

***Pigments (CMYK)***: Follow the arrows from the pigments to the color you are making. *Yellow* and *Cyan* make Green.

## Pigments—Subtractive Color
### *CMYK Model*

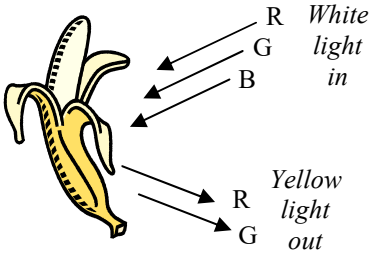
*Pigments reflect color and have a white background. The three primary colors of pigments are Cyan, Magenta, and Yellow. Each one absorbs a different color.*

***Pigments*** are ***dyes*** that color paints, inks, and even food. Pigments produce color by ***reflection***. What you see is what is reflected.

***You can tell that printers uses CMYK, because the paper is white.***

**BLACK** Pigments that absorb all light look black.

**WHITE** Pigments that reflect all light look white.




Yellow reflects red and green light, so **blue was absorbed**.

***CMYK***—As you know from your color printer at home, color pigments are very expensive. To make black by mixing three pigments (CMY) doesn't make sense. So printers add black (K) to make four colors: CMYK. (***K stands for black*** *because B stands for blue.)*

When you buy paint, pigments (dyes) are mixed into white paint. Yet because the store has more room than your printer, they can use more than just three dyes.

Green light is reflected off a leaf, so the leaf absorbs red and blue. To make green with CMYK you would use yellow (*absorbs blue*) and cyan (*absorbs red*). (*Or remember that both yellow and cyan have green in them.)*

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Name: _____

Period: _____



| | |
|---|---|
| 1. Pigment | A. A color model that uses pigments on a white background. |
| 2. Magenta | B. A color made from red and green. |
| 3. Cyan | C. Dyes and paints are a type of this. |
| 4. Yellow | D. A color made from blue and red. |
| 5. RGB | E. A color model that uses lights on a black background. |
| 6. CMYK | F. A color made from green and blue. |

Magenta reflects what two colors?
So what color does Magenta absorb?

Yellow reflects what two colors?
So what color does Yellow absorb?

Make the following additive colors using RGB.

Cyan _____ White _____ Yellow _____

Red _____ Magenta _____ Black _____

Make the following subtractive colors using CMYK.

Blue _____ White _____ Green _____

Red _____ Magenta _____ Black _____


What color is a stop sign?

Is this additive or subtractive color?

What two colors would a printer use to make this color?

Find the frequency of a wave with a period of 0.5 seconds.

A 40 Hz wave is 3 m from crest to crest. Find the speed of the wave.

You hear a thunder 4 seconds after you see the lightening.
A) What is the speed of sound?
B) How far away is the storm?

You are in a canyon and yell across. It takes 4 seconds for the echo to come back to you. How wide is the canyon?

Decide if the following use RGB or CMYK and why.

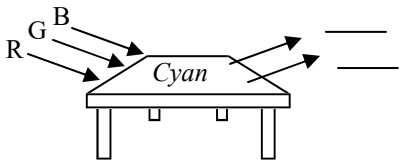
Television: _____ Why? _____

Paint on a wall: _____ Why? _____

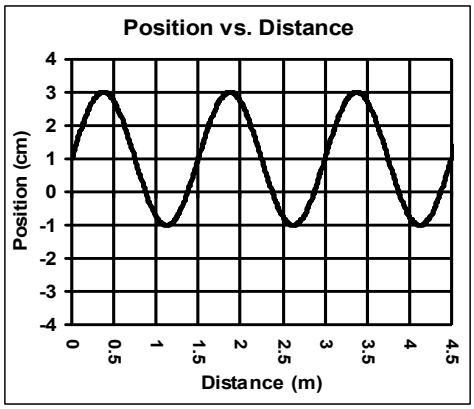
Movie Theater: _____ Why? _____

Color Printer: _____ Why? _____

*Light shines on a cyan table.*




What color light is shining on the table?
To be Cyan what colors of light are reflecting off of the table?
What color is being absorbed by the table?




# of cycles:

Mark the second crest.

Mark 1 cycle.

Amplitude:

Wavelength:

If the above wave has a frequency of 10 Hz, find its speed.

Find its period:

300 Hz

How many nodes?
How many antinodes?
What harmonic is this?
How many wavelengths is it?

Can humans hear this frequency?

Find the fundamental (natural) frequency:

Fifth harmonic frequency:

How would it change if it had less amplitude?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Name: _____ Unit 10:7

Period: _____

| | |
|---|---|
| 1. Pigment C | A. A color model that uses pigments on a white background. |
| 2. Magenta D | B. A color made from red and green. |
| 3. Cyan F | C. Dyes and paints are a type of this. |
| 4. Yellow B | D. A color made from blue and red. |
| 5. RGB E | E. A color model that uses lights on a black background. |
| 6. CMYK A | F. A color made from green and blue. |

Magenta reflects what two colors? R and B
So what color does Magenta absorb? G

Yellow reflects what two colors? R and G
So what color does Yellow absorb? B

Make the following additive colors using RGB.

Cyan BG White all Yellow RG

Red R Magenta RB Black none

Make the following subtractive colors using CMYK.

Blue CM White none Green CY

Red YM Magenta M Black K


What color is a stop sign? Red
Is this additive or subtractive color?
What two colors would a printer use to make this color? Yellow and Magenta

Find the frequency of a wave with a period of 0.5 seconds.

T = .5 sec $f = \frac{1}{T} = \frac{1}{.5} = 2$ Hz

f = ____

A 40 Hz wave is 3 m from crest to crest. Find the speed of the wave.

f = 40 Hz $v = f\lambda = 40(3) = 120$ m/s

λ = 3 m

You hear a thunder 4 seconds after you see the lightening.
A) What is the speed of sound? 340 m/s
B) How far away is the storm?

v = 340 m/s $v = \frac{D}{T}$

t = 4 sec $D = VT = 340(4) =$

D = ____

You are in a canyon and yell across. It takes 4 seconds for the echo to come back to you. How wide is the canyon?

v = 340 m/s $V = \frac{2D}{T}$ D = 340(2)/2 = 340 m

t = 2 sec

D = ____

Decide if the following use RGB or CMYK and why.

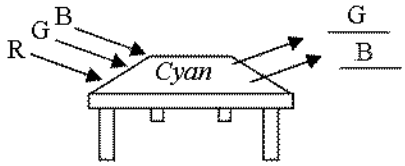
Television: RGB Why? black when off

Paint on a wall: CMYK Why? paints (white wall)

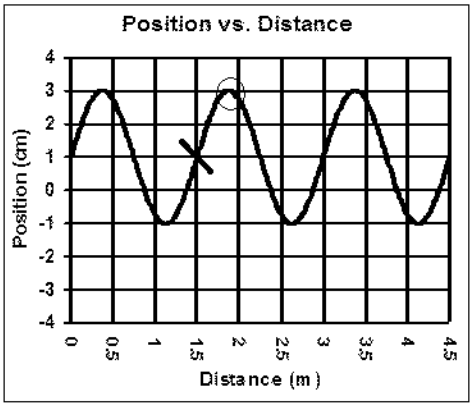
Movie Theater: RGB Why? Black background

Color Printer: CMYK Why? white paper

*Light shines on a cyan table.*




What color light is shining on the table? White
What colors of light are reflecting off of the table? G, B
What color is being absorbed by the table? R




# of cycles: 3

Mark the second crest.

Mark 1 cycle.

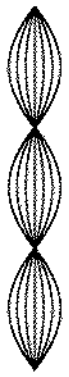
Amplitude: 2 cm

Wavelength: 1.5 m

If the above wave has a frequency of 10 Hz, find its speed.
10(1.5) = 15 m/s

Find its period: T = 1/300 = .0033 sec

300 Hz



How many nodes? 4
How many antinodes? 3
What harmonic is this? 3rd
How many wavelengths is it? 1.5

Can humans hear this frequency? yes

Find the fundamental (natural) frequency:
300/3 = 100 Hz

Fifth harmonic frequency: 100(5) = 500 Hz

How would it change if it had less amplitude?
skinnier (not as wide)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Name: _____

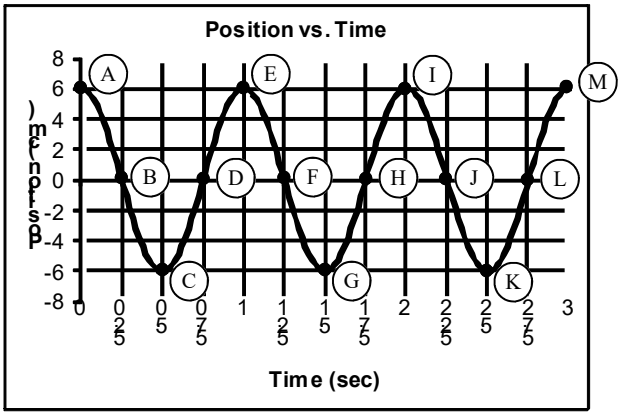
Period: _____

# Harmonic Motion and Waves Review

Unit 10:8

## λ, v, f, T, D, A, or dB?

A) ___ Amplitude
B) ___ Distance
C) ___ Decibels
D) ___ Velocity
E) ___ Frequency
F) ___ Period
G) ____ Wavelength
H) ____ Measured in m/s
I) ____ Measured in Hz
J) ____ Measured in m
K) ____ Measured in sec
L) ____ Measure in cm, m, or °.
M) ___ Tells you how loud a sound is.
N) ___ Measures distance from one wave crest to another.
O) ___ How many times a wave repeats each second.
P) ___ How much energy harmonic motion has.
Q) ___ Increases as a pendulum swings back-and-forth farther.
R) ___ How fast a wave moves.
S) ___ How far a wave travels in a certain amount of time.
T) ___ How long it takes for one cycle to repeat.
U) ___ How far a wave swings from the center to one side.




1 cycle after B is ____; 2 cycles after C is ____.
1/2 cycle before H is ____; 1/4 cycle before K is ____.
# of complete cycles shown is ____.
# of troughs: _____; # of crests: _____.
Period (T) = Frequency (f) =
Equilibrium position = Amplitude (A) =

A.

B.

___ A transverse wave.
___ A longitudinal wave.
___ Like sound.
___ Like light.
___ Like a water wave.
___ Like earthquakes.
___ Amplitude affects speed.

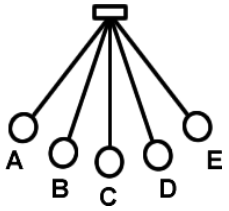
A wave is moving 20 m/s. If it vibrates at 5 Hz, find its wavelength.

Find the above wave's period.

## Harmonic Motion: Yes or No?

A stick pulled to one side and then released?
Why or why not?

A ball that bounces on the floor?
Why or why not?



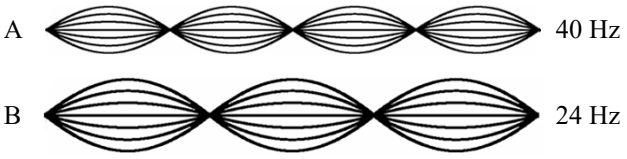

Where is the equilibrium position for this pendulum?

If the pendulum starts at C going to the right, where does 1 cycle end?

From letter ____ to letter ____ would be the amplitude.

If the pendulum starts at A, how many times does it pass point C in 1 cycle?

If it is 80° from A to E, what is the amplitude of the pendulum?




Which has the greatest amplitude?
Do they have the same fundamental frequency?
How many antinodes does B have?
How many nodes does A have?
How many wavelengths is B?
Find the fundamental frequency of A:

## Reflection, Refraction, Absorption, Diffraction, Interference

A. _____When a wave dies out in a soft boundary.
B. _____When two waves interact with each other.
C. _____When a wave hits a hard boundary.
D. _____When a wave bends around a corner.
E. _____When a wave bends as it goes from one material to another of a different speed.
F. _____Can make two waves cancel each other out.
G. _____Allows you to hear someone around a corner.
H. _____When light hits a mirror.
I. _____When light hits a black piece of paper.

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Name: _____ Unit 10:8

Period: _____

Can we hear 50 Hz?
Can we hear 10 Hz?
Can we hear 21,000 Hz?
Can we hear 19,000 Hz?

Which speaks at higher pitch: a bird or an elephant?

Twice as loud as 30 dB is _____ dB.

A spaceship explodes in space. If you are in a ship nearby will the sound of the explosion be higher or lower pitch than if it occurred on the earth?

What is the speed of sound?

What is the speed of light?

A person is hammering a spike from across a field.
A) Will you hear the sound at the same time the spike is struck or will there be a delay?
B) Why?

A sound's frequency is 170 Hz. Find its wavelength.

While standing at the top of a canyon you wonder how deep it is. You drop a large rock and after it hits the bottom of the canyon you time 2 seconds until the sound of the rock's impact gets back to you. How deep is the canyon?

You also want to know how wide the canyon is. You clap your hands as loud as you can and it takes 6 seconds for the echo to get back to you. How wide is the canyon?

How did we make the wave move faster on the slinky?

Is the speed of sound faster in dense or loose materials?

Is the speed of sound faster when its hot or cold outside?

Is the speed of sound faster at sea level or high in the mountains?

Where does light come from?

Is light a particle or a wave?

What do scientists call all light?

Which has more energy: radio waves or x-rays?
Which is faster: infrared radiation or gamma rays?
Which has a longer wavelength: x-rays or microwaves?
Which has a higher frequency: ultraviolet light or red light?

Why can waves go thru things?

A red ball is sitting in a pool of water. A blue ball is pushed into the water, making waves. After the waves get to the red ball both balls are bobbing at the same speed.
A) The two balls have the same: _____.

B) What transferred between the two balls to allow them to be moving up and down together?

How can you separate out the different colors that are in white light?

This process is called d_____.

What type of color does a computer monitor use:
RGB or CMYK?

How do you know?

*Using RGB:*
What color is the background?
Make the following colors:
Red: _____; Blue: _____; Cyan: _____;
White: _____; Magenta: _____; Black: _____;

*Using CMYK:*
What color is the background?
Make the following colors:
Red: _____; Blue: _____; Cyan: _____;
White: _____; Magenta: _____; Black: _____;

What color does Yellow absorb?

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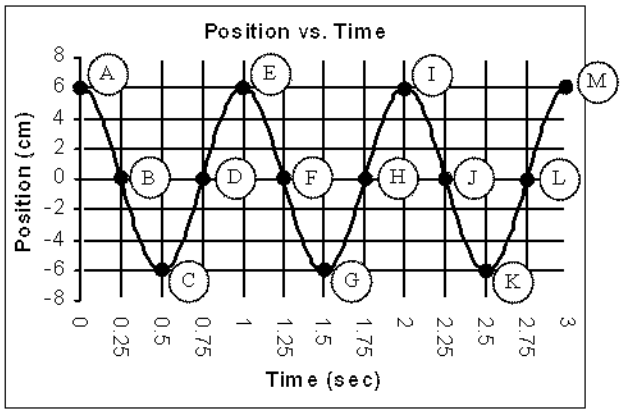
Name: _____ Unit 10:8

Period: _____

# Harmonic Motion and Waves Review

## λ, v, f, T, D, A, or dB?

A) A Amplitude
B) D Distance
C) dB Decibels
D) V Velocity
E) F Frequency
F) T Period
G) λ Wavelength
H) V Measured in m/s
I) F Measured in Hz
J) λ Measured in m
K) T Measured in sec
L) A Measure in cm or m.
M) dB Tells you how loud a sound is.
N) λ Measures distance from one wave crest to another.
O) F How many times a wave repeats each second.
P) A How much energy harmonic motion has.
Q) A Increases as a pendulum swings back-and-forth farther.
R) V How fast a wave moves.
S) D How far a wave travels in a certain amount of time.
T) T How long it takes for one cycle to repeat.
U) A How far a wave swings from the center to one side.




1 cycle after B is F; 2 cycles after C is K.
1/2 cycle before H is F; 1/4 cycle before K is J.
# of complete cycles shown is 3.
# of troughs: 3; # of crests: 4.
Period (T) = 1 sec Frequency (f) = 1 Hz
Equilibrium position = 0 cm Amplitude (A) = 6 cm

A.

B.

B A transverse wave.
A A longitudinal wave.
A Like sound.
B Like light.
B Like a water wave.
both Like earthquakes.
none Amplitude affects speed.
amplitude

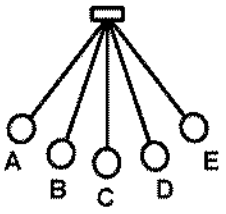
A wave is moving 20 m/s. If it vibrates at 5 Hz, find its wavelength.
v = 20 m/s
f = 5 Hz
λ = ____
v = fλ
20 = 5λ
λ = 4 meters

Find the above wave's period.
T = ____
$T = \frac{1}{f} = \frac{1}{5} = .2$ sec

## Harmonic Motion: Yes or No?

A stick pulled to one side and then released? yes
Why or why not? it stops in the middle

A ball that bounces on the floor? NO
Why or why not? stops at the bottom



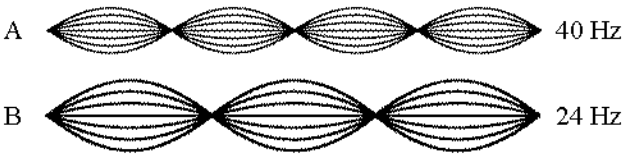

Where is the equilibrium position for this pendulum? C (where stops)

If the pendulum starts at C going to the right, where does 1 cycle end?
C going right

From letter C to letter E would be the amplitude. or A to C

If the pendulum starts at A, how many times does it pass point C in 1 cycle? 2

If it is 80° from A to E, what is the amplitude of the pendulum?
40°




Which has the greatest amplitude? B
Do they have the same fundamental frequency? NO
How many antinodes does B have? 3
How many nodes does A have? 5
How many wavelengths is B? 1.5 λ
Find the fundamental frequency of A:
40 = 4x x = 10 Hz

## Reflection, Refraction, Absorption, Diffraction, Interference

A. abs. When a wave dies out in a soft boundary.
B. interf. When two waves interact with each other.
C. reflec When a wave hits a hard boundary.
D. Diff. When a wave bends around a corner.
E. Refr. When a wave bends as it goes from one material to another of a different speed.
F. inter When can make two waves cancel each other out.
G. diff Allows you to hear someone around a corner.
H. refl When light hits a mirror.
I. abs When light hits a black piece of paper.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Name: _____ Unit 10:8

Period: _____

Can we hear 50 Hz? yes
Can we hear 10 Hz? NO
Can we hear 21,000 Hz? NO
Can we hear 19,000 Hz? yes

Which speaks at higher pitch: a bird or an elephant?

Twice as loud as 30 dB is 40 dB.

A spaceship explodes in space. If you are in a ship nearby will the sound of the explosion be higher or lower pitch than if it occurred on the earth?

doesn't matter - no sound in space

What is the speed of sound? $340\ m/s$

What is the speed of light? $3 \times 10^8\ m/s$

A person is hammering a spike from across a field.

A) Will you hear the sound at the same time the spike is struck or will there be a delay? delay

B) Why? light goes faster than sound

A sound's frequency is 170 Hz. Find its wavelength.

$v = 340\ m/s$

While standing at the top of a canyon you wonder how deep it is. You drop a large rock and after it hits the bottom of the canyon you time 2 seconds until the sound of the rock's impact gets back to you. How deep is the canyon?

$v = 340\ m/s$
$t = 2\ sec$
$D =$ ____

$v = \frac{D}{T}$ $D = VT$
$= 340(2)$
$= 680\ m$

You also want to know how wide the canyon is. You clap your hands as loud as you can and it takes 6 seconds for the echo to get back to you. How wide is the canyon?

$v = 340\ m/s$
$t = 3\ sec$ (half)
$D =$

$D = VT$ (see above)
$= 340(3) = 1020\ m$

How did we make the wave move faster on the slinky?

pull it tighter

Is the speed of sound faster in dense or loose materials?

denser = tighter

Is the speed of sound faster when its hot or cold outside?

cold air is denser.

Is the speed of sound faster at sea level or high in the mountains?

more air = denser

Where does light come from?

e's falling from high to low orbits.

Is light a particle or a wave? both

What do scientists call all light?

electro magnetic spectrum (EM)

Which has more energy: radio waves or x-rays?
Which is faster: infrared radiation or gamma rays? same
Which has a longer wavelength: x-rays or microwaves?
Which has a higher frequency: ultraviolet light or red light?

Why can waves go thru things?

waves are just energy

A red ball is sitting in a pool of water. A blue ball is pushed into the water, making waves. After the waves get to the red ball both balls are bobbing at the same speed.

A) The two balls have the same: freq.

B) What transferred between the two balls to allow them to be moving up and down together?

energy

How can you separate out the different colors that are in white light? prism

This process is called dispersion

White type of color does a computer monitor use: RGB or CMYK?

How do you know? black when off

*Using RGB:*
What color is the background? black
Make the following colors:
Red: R; Blue: B; Cyan: BG;
White: all; Magenta: RB; Black: none;

*Using CMYK:*
What color is the background? white
Make the following colors:
Red: YM; Blue: MC; Cyan: C;
White: none; Magenta: M; Black: K;

What color does Yellow absorb? Blue
(because it reflects R + G)



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Name: _____

Period: _____



# Lab: Period of a Pendulum

**Purpose** –
To be able to demonstrate how various factors influence the period of a pendulum including amplitude, mass, and length.

**Background** –
Students should already understand the concepts of cycle, amplitude, period, and frequency as they pertain to harmonic motion and a pendulum.

**Preparation and Materials** –
Pendulum – could be made of string hung from the ceiling.
Timers to record period.
Hooked Masses to vary the mass of the pendulum bob: 100 g, 100g; 500 g.

**Data Tables**

How does Mass Affect Period?

| Length of Pendulum | Mass of Pendulum Bob | Amplitude | Time for 20 cycles | Period (for 1 cycle) |
|---|---|---|---|---|
| medium | 100 g | medium | | |
| medium | 200 g | medium | | |
| medium | 500 g | medium | | |

How does Amplitude Affect Period?

| Length of Pendulum | Mass of Pendulum Bob | Amplitude | Time for 20 cycles | Period (for 1 cycle) |
|---|---|---|---|---|
| medium | 200 g | small | | |
| medium | 200 g | medium | | |
| medium | 200 g | wide | | |

How does Length Affect Period?

| Length of Pendulum | Mass of Pendulum Bob | Amplitude | Time for 20 cycles | Period (for 1 cycle) |
|---|---|---|---|---|
| short | 200 g | medium | | |
| medium | 200 g | medium | | |
| long | 200 g | medium | | |

**Student Outcome** –
Write a scientific explanation of what factors affect the period of a pendulum.

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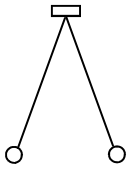
**What affects the period of a pendulum?** Remember: Period (T) is the time for 1 cycle. Name: _____

| | Different Amplitudes (same mass and length) | | Different Masses (same length and amplitude) | | Different Length (same amplitude and mass) | |
|---|---|---|---|---|---|---|
| *Hint: Take 10 periods and divide by 10 to reduce error.* | Big amplitude  | Small amplitude  | Heavy mass  | Light mass  | Short length  | Long length  |
| Period (T): (in sec) | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = |

1. What affects the period of a pendulum?
2. To increase the period, you would:
3. To decrease the period (make it faster) you would:
4. To increase the frequency you would: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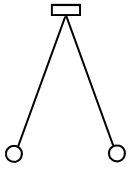
**What affects the period of a pendulum?** Remember: Period (T) is the time for 1 cycle. Name: _____

| | Different Amplitudes (same mass and length) | | Different Masses (same length and amplitude) | | Different Length (same amplitude and mass) | |
|---|---|---|---|---|---|---|
| *Hint: Take 10 periods and divide by 10 to reduce error.* | Big amplitude  | Small amplitude  | Heavy mass  | Light mass  | Short length  | Long length  |
| Period (T): (in sec) | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = |

1. What affects the period of a pendulum?
2. To increase the period, you would:
3. To decrease the period (make it faster) you would:
4. To increase the frequency you would:

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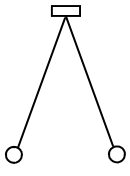
**What affects the period of a pendulum?** Remember: Period (T) is the time for 1 cycle. Name: _____

| | Different Amplitudes (same mass and length) | | Different Masses (same length and amplitude) | | Different Length (same amplitude and mass) | |
|---|---|---|---|---|---|---|
| *Hint: Take 10 periods and divide by 10 to reduce error.* | Big amplitude  | Small amplitude  | Heavy mass  | Light mass  | Short length  | Long length  |
| Period (T): (in sec) | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = | 10 T =<br>1 T = |

1. What affects the period of a pendulum?
2. To increase the period, you would:
3. To decrease the period (make it faster) you would:
4. To increase the frequency you would:

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Name: _____ Unit 10:

Period: _____

Curriculum Notes—

Disclaimer: On the "Waves" notes I say that "*water waves are transverse waves*". This is not perfectly true, since water waves are really circular waves. Any object sitting on water will follow a circular path, back to where it starts. I use this example because it is close to a transverse wave and certainly one example most familiar to students. Light is actually a transverse, but unfamiliar.

Beginning with the "Waves" worksheet, I emphasize that wave speed only changes if the medium changes. (See *demo below.)* I reemphasize this on standing waves (*see standing wave lab note below*). Before, I only emphasized this during sound, when it becomes essential to solve word problems. By emphasizing this for most of the chapter, not only does it teach students an important concept, but it also makes the teaching of sound easier.

Standing Waves Lab: We have the CPO wave generators. I let the students do this lab twice (yes, twice). The first day they figured out the sequence of the harmonics, how to find wavelength, and that the wave speed stayed the same. The second day, they did it much faster and locked down the information. Sound was pretty easy this year (2010).

Slinky Demo – For use with "Waves". If you don't have super long slinky, a normal one will suffice, as long as it is metal. A super slinky costs about $30.00 from any science supply company.

Show transverse (move slinky left and right) and longitudinal waves (move hand forward and backward).

Show amplitude, reflection (see how the pulse will invert at the end), and dampening (dying out due to friction with the floor).

Show that two waves can move thru each other. Have the student holding the other side produce a transverse wave as you produce a longitudinal wave. The two pulses will pass thru each other proving that waves are a movement of energy. Remind students that this is should seem logical, since two pairs of students can have conversations at the same time. The sound waves go thru each other.

Show the wave speed does not change unless the medium changes. Using a timer, show that a greater amplitude will not cause the speed to change. If the time is slightly different it is due to the person timing. Show this by making to close pulses (second one larger). The larger pulse will not catch the first pulse, thus proving the speed is constant. Also, a longitudinal wave has the same speed. Then pull the slinky tighter and the pulse will move obviously faster.

Students as a Wave Demo—Have 5 or 6 students standing side by side as particles in a medium

Density Affects Wave Speed—The closeness of the students represents the density of a substance. If you push on one of the students, they will bump into the next students and the next, etc, which is the wave propagating in the medium. The closer the students stand, the faster the wave moves.

Transverse Waves only Move Thru Solids—Have the students lock arms to represent a solid. Then you can push on the first student to show a longitudinal wave or move them side to side as a transverse wave.

Only Longitudinal Waves Move Thru Fluids—If their arms are not locked they represent a fluid (gas or liquid). You cannot produce a transverse wave, only a longitudinal wave.

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