NOTES
THE CHARACTERISTICS OF WAVES

WHAT ARE WAVES?

A WAVE IS A DISTURBANCE THAT TRANSFERS **ENERGY** FROM PLACE TO PLACE.

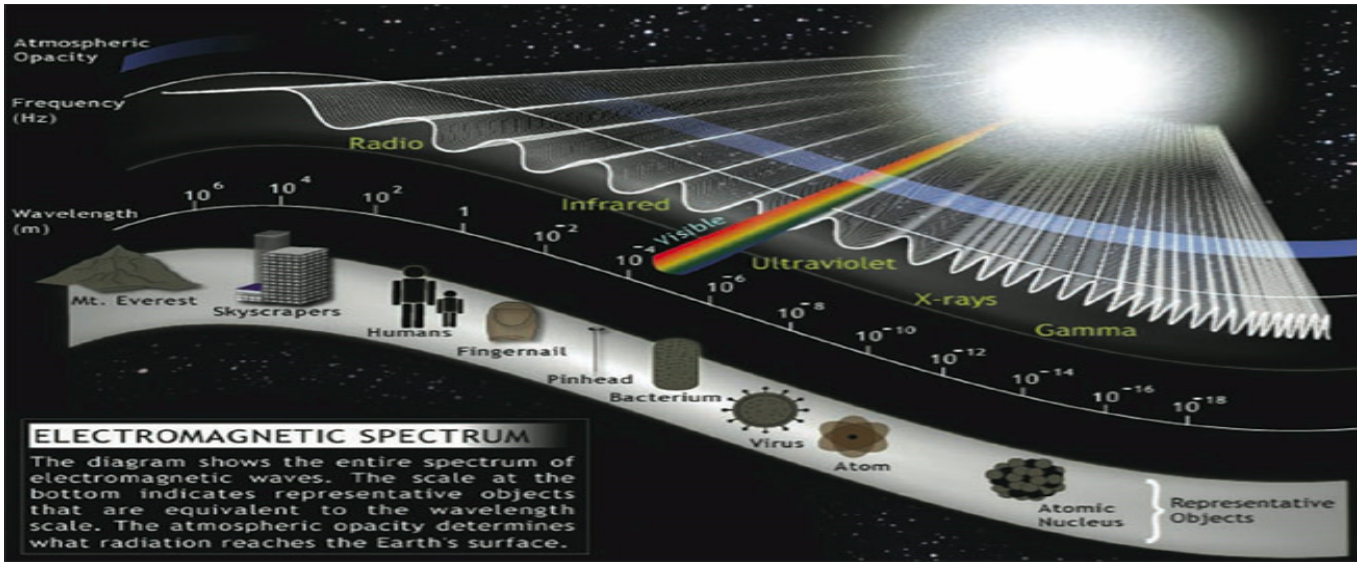
ENERGY IS THE ABILITY TO DO WORK.

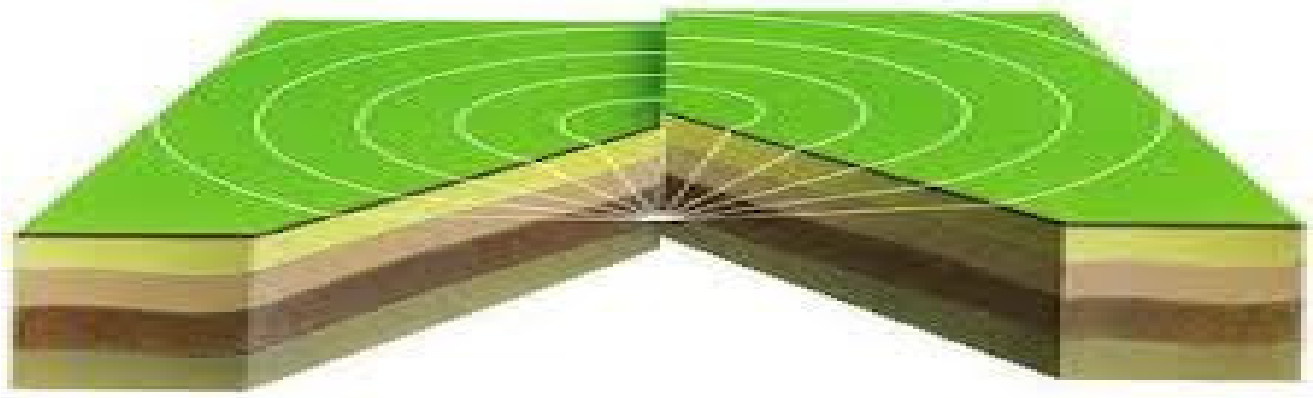
https://www.youtube.com/watch?v=RVyHkV3wIyk
https://www.youtube.com/watch?v=eNwNgmtD67o
https://www.youtube.com/watch?v=TfYCnOvNnFU

WAVES ARE EVERYWHERE IN NATURE

- *Sound waves,*
- *visible light waves,*
- *radio waves,*
- *microwaves,*
- *water waves,*
- *sine waves,* ***(mathematical curve that describes a smooth repetitive oscillation.)***
- *telephone cord waves,*
- *stadium waves,*
- *earthquake waves,*
- *waves on a string,*
- *slinky waves*

https://www.youtube.com/watch?v=lwfJPc-rSXw


Atmospheric Opacity
Frequency (Hz)
Radio
Infrared
Visible
Ultraviolet
X-rays
Gamma
Wavelength (m)
10^{6}
10^{4}
10^{2}
1
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
10^{-16}
10^{-18}
Mt. Everest
Skyscrapers
Humans
Fingernail
Pinhead
Bacterium
Virus
Atom
Atomic Nucleus
Representative Objects
ELECTROMAGNETIC SPECTRUM
The diagram shows the entire spectrum of electromagnetic waves. The scale at the bottom indicates representative objects that are equivalent to the wavelength scale. The atmospheric opacity determines what radiation reaches the Earth's surface.



MANY WAVES REQUIRE SOMETHING TO TRAVEL THROUGH.

THE MATERIAL THROUGH WHICH A WAVE TRAVELS IS CALLED A **MEDIUM**.

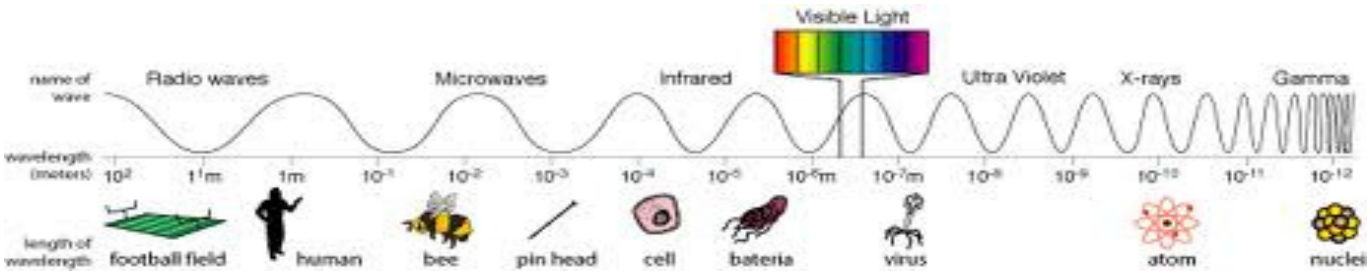
WATER WAVES TRAVEL ALONG THE **SURFACE OF THE WATER**, AND SOUND WAVES TRAVEL THROUGH **AIR**.

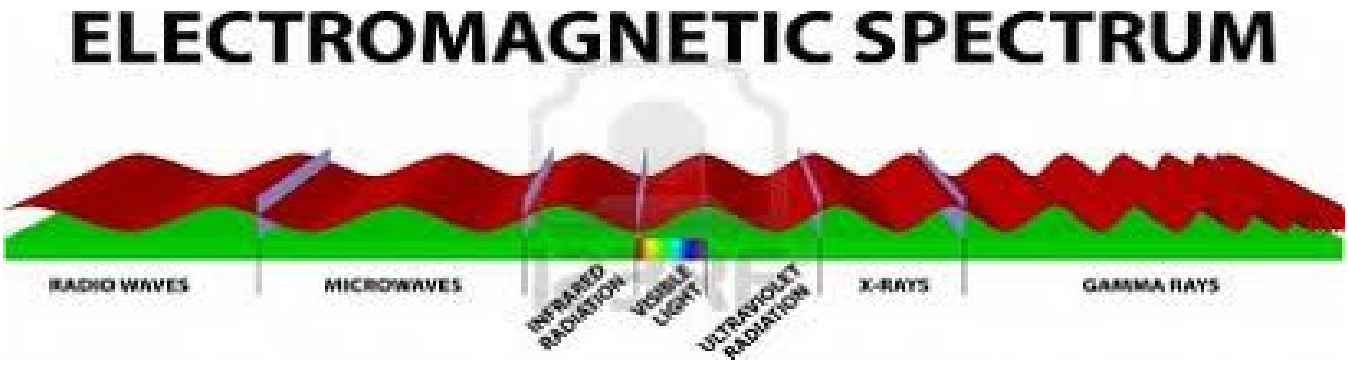
GASES, LIQUIDS, AND SOLIDS ACT AS MEDIUMS.

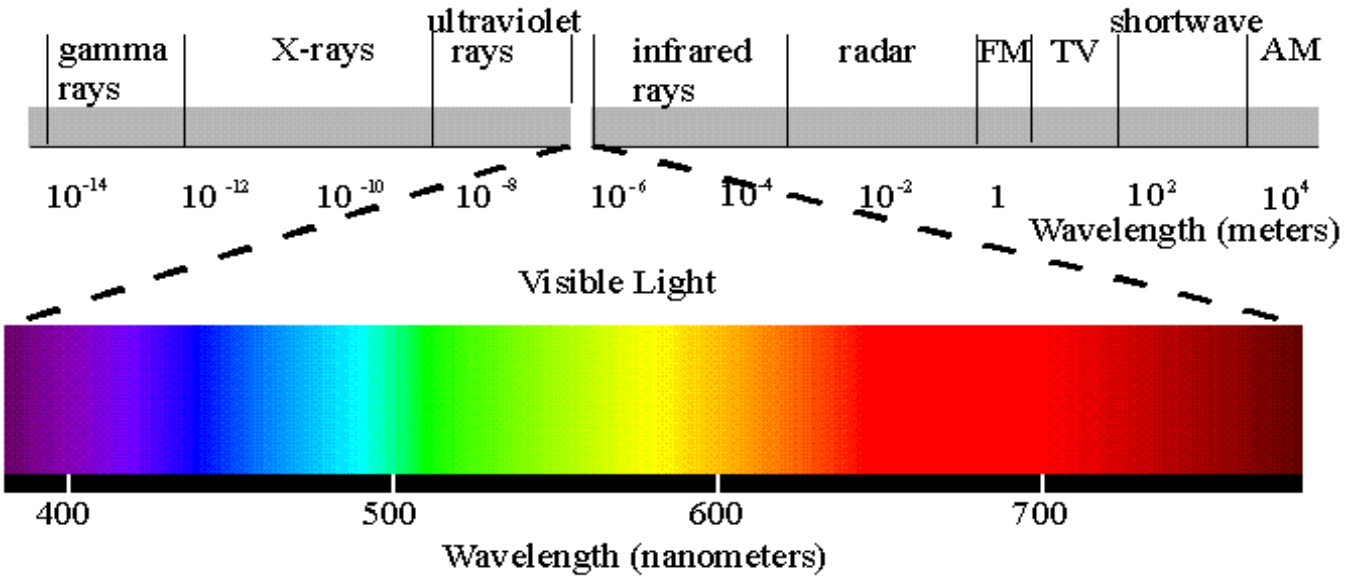
WAVES THAT REQUIRE A MEDIUM THROUGH WHICH TO TRAVEL ARE CALLED **MECHANICAL WAVES.**

THE WAVES DO NOT CARRY THE MEDIUM WITH THEM AS THEY TRAVEL THROUGH IT.

LIGHT WAVES **DO NOT** REQUIRE A MEDIUM. LIGHT IS AN EXAMPLE OF AN **ELECTRO-MAGNETIC WAVE**.







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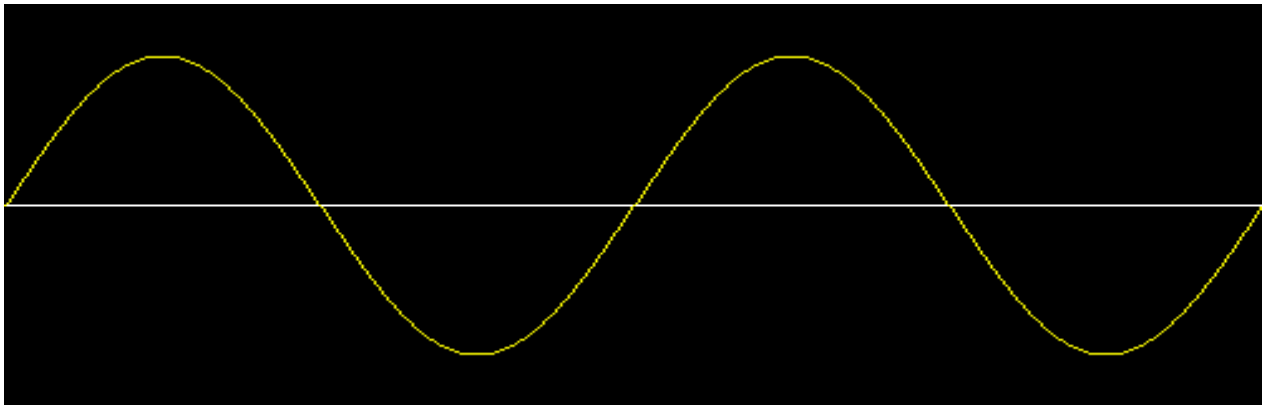
WHAT CAUSES WAVES?

WAVES ARE CREATED WHEN A SOURCE OF ENERGY CAUSES A MEDIUM TO **VIBRATE**.

A VIBRATION IS A REPEATED BACK-AND-FORTH OR UP-AND-DOWN MOTION. **THIS MOTION IS THE WAVE.**

A MOVING OBJECT HAS ENERGY. IT CAN TRANSFER ENERGY TO A NEARBY MEDIUM, CREATING A WAVE.



https://www.youtube.com/watch?v=cfXzwh3KadE

Radio Waves

https://www.youtube.com/watch?v=sRX2EY5Ubto

https://www.youtube.com/watch?v=bht9AJ1eNYc

https://www.youtube.com/watch?v=Io-HXZTepH4

Heart
https://www.youtube.com/watch?v=RYZ4daFwMa8

https://www.youtube.com/watch?v=FThXJUFWUrw

TYPES OF WAVES

WAVES ARE CLASSIFIED ACCORDING TO HOW THEY MOVE.

THE **THREE** TYPES OF WAVES ARE:

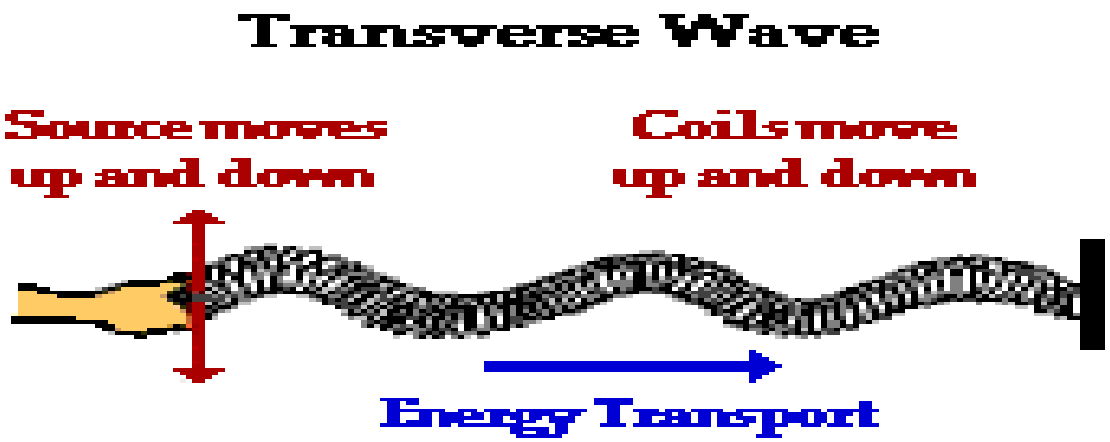
1. **TRANSVERSE**
2. **LONGITUDINAL**
3. **SURFACE**

TRANSVERSE WAVES

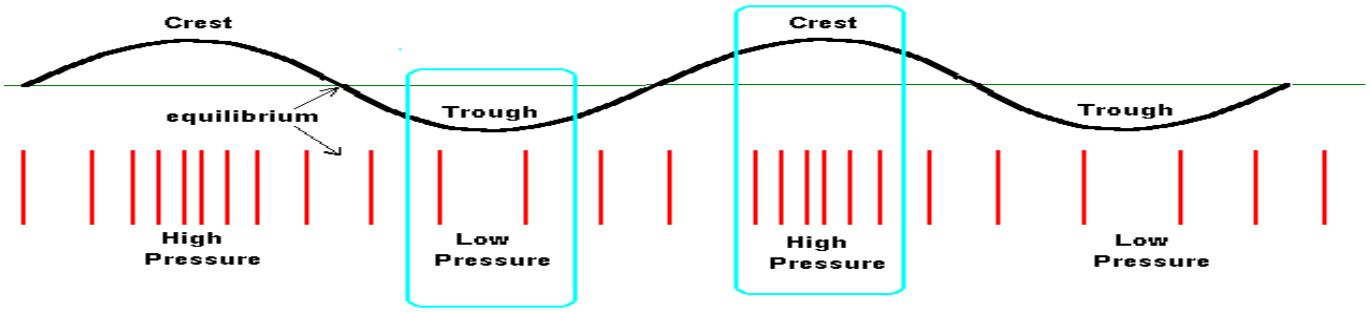
TRANSVERSE MEANS **MOVING ACROSS**.

THE PARTICLES MOVE ACROSS, OR PERPENDICULAR TO, THE DIRECTION THAT THE WAVE IS TRAVELING. EX. **A WAVE MOVING ON A ROPE.**

WAVES THAT MOVE THE MEDIUM AT **RIGHT ANGLES** TO THE DIRECTION IN WHICH THE WAVES ARE TRAVELING ARE CALLED **TRANSVERSE WAVES**.



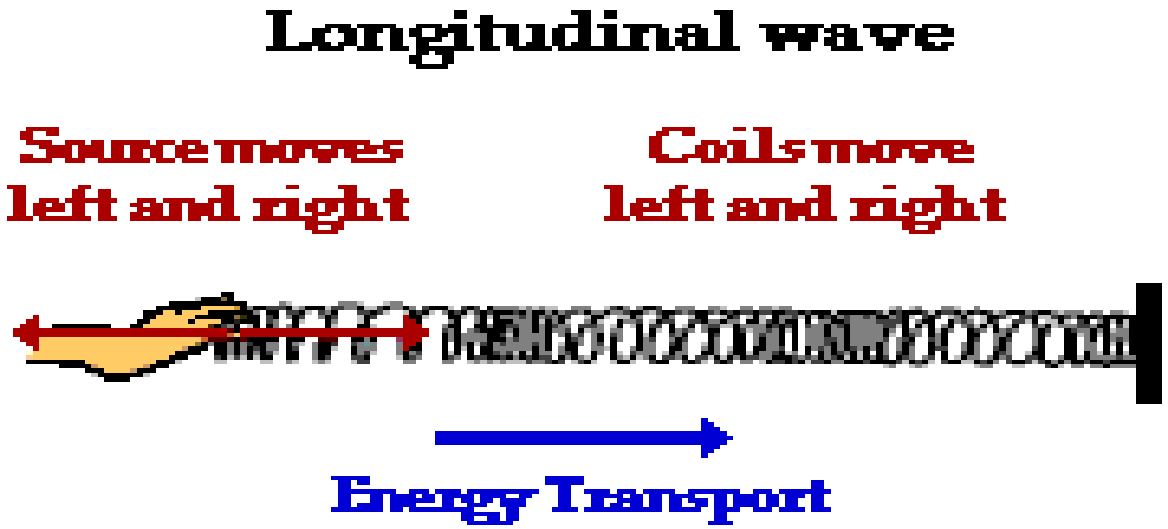
THE HIGHEST PARTS OF THE WAVE ARE CALLED THE **CREST**, AND THE LOWEST PARTS ARE CALLED **TROUGHS.**



Rest Position

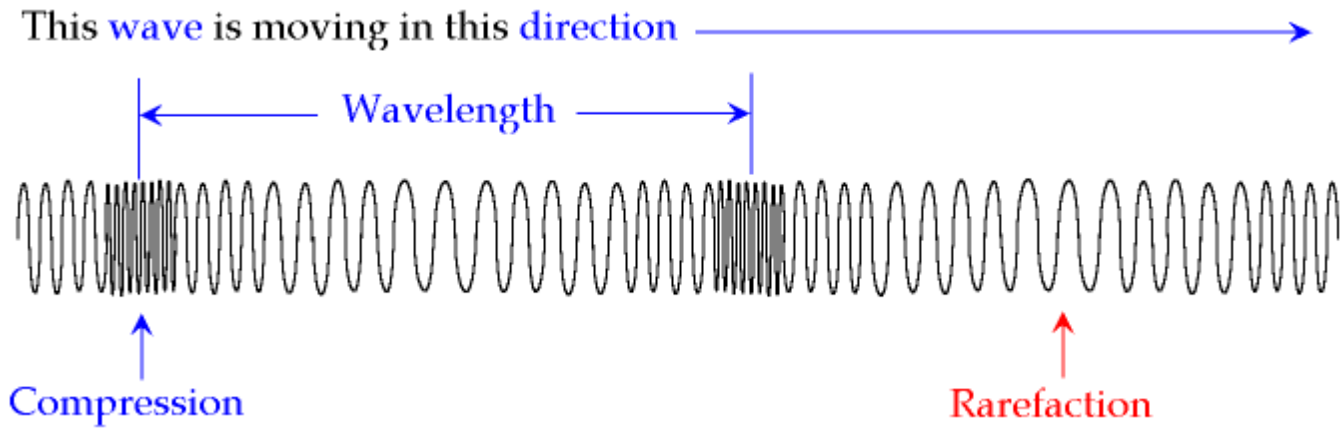
LONGITUDINAL WAVES

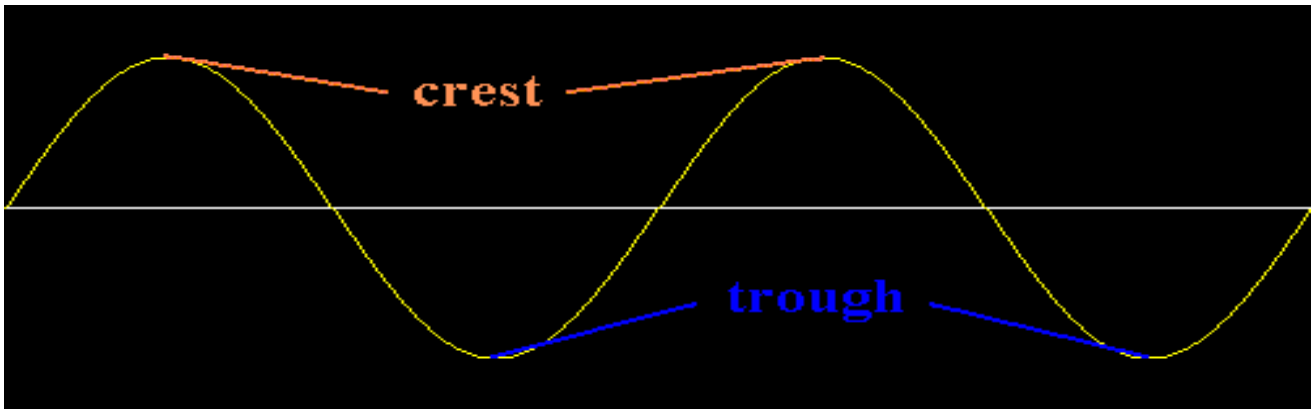
LONGITUDINAL WAVES MOVE THE PARTICLES OF THE MEDIUM **PARALLEL** TO THE DIRECTION IN WHICH THE WAVES ARE TRAVELING.



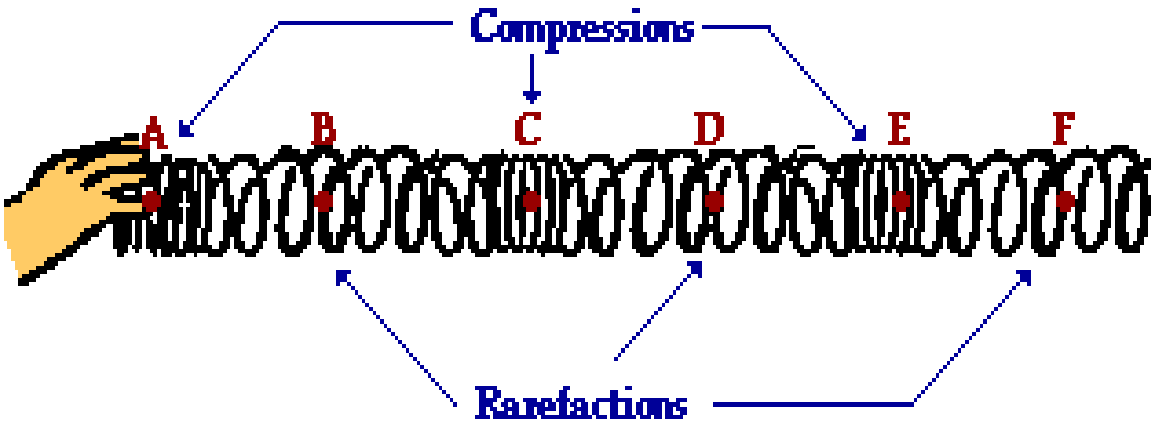
NOTICE THAT IN SOME PARTS OF THE SPRING THE COILS ARE CLOSE TOGETHER. IN OTHER PARTS, THE COILS ARE SPREAD OUT.

THE PARTS WHERE THE COILS ARE CLOSE TOGETHER ARE CALLED **COMPRESSIONS**.





THE PARTS WHERE THE COILS ARE SPREAD OUT, OR RAREFIED, ARE CALLED **RAREFACTION**.



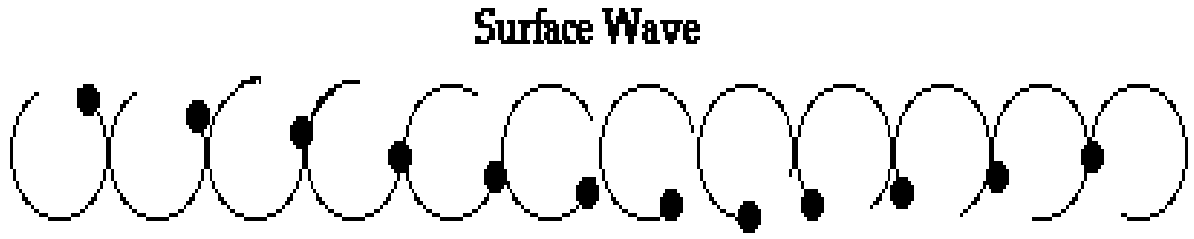
AS COMPRESSIONS AND RAREFACTIONS TRAVEL ALONG THE SPRING EACH COIL MOVES SLIGHTLY FORWARD AND THEN BACK.

THE ENERGY TRAVELS FROM ONE END OF THE SPRING TO THE OTHER, CREATING A WAVE.

SURFACE WAVES

SURFACE WAVES ARE COMBINATIONS OF **TRANSVERSE** AND **LONGITUDINAL** WAVES.

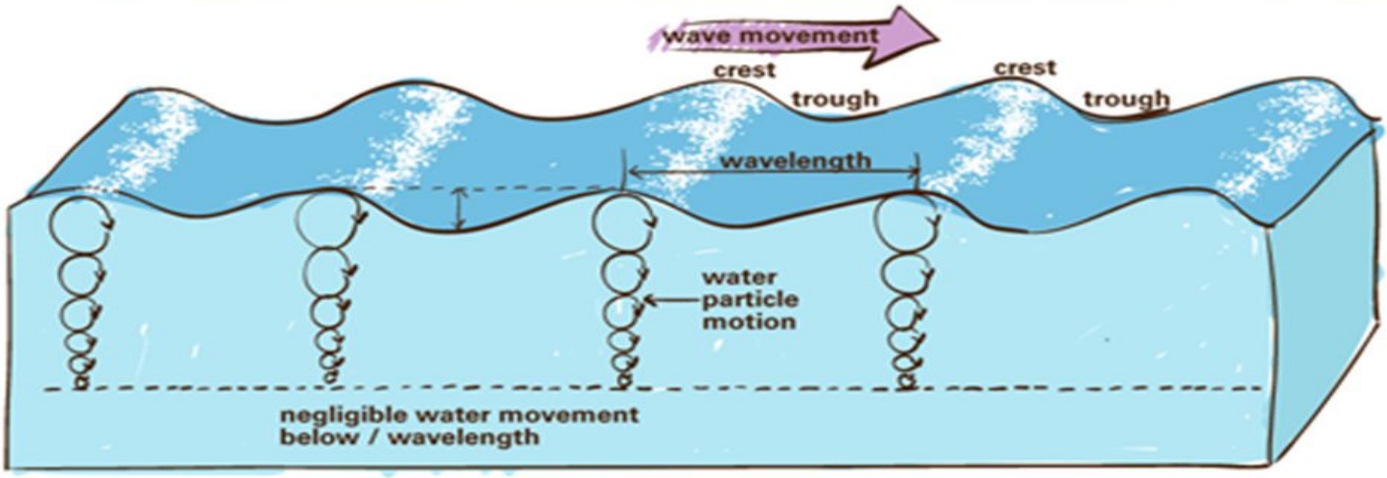
A SURFACE WAVE IS A WAVE IN WHICH THE PARTICLES OF THE MEDIUM UNDERGO A **CIRCULAR MOTION**.



IN A SURFACE WAVE, IT IS ONLY THE PARTICLES AT THE SURFACE OF THE MEDIUM WHICH UNDERGO THE CIRCULAR MOTION.

Water Motion

- As a wave passes, water particles moves in circular motion.
- Deeper water particles moves in a smaller circles than those near the surface.
- The wind affects the water at the surface than it affects the deep water.
- Below a certain depth, the water does not move at all as the wave passes.

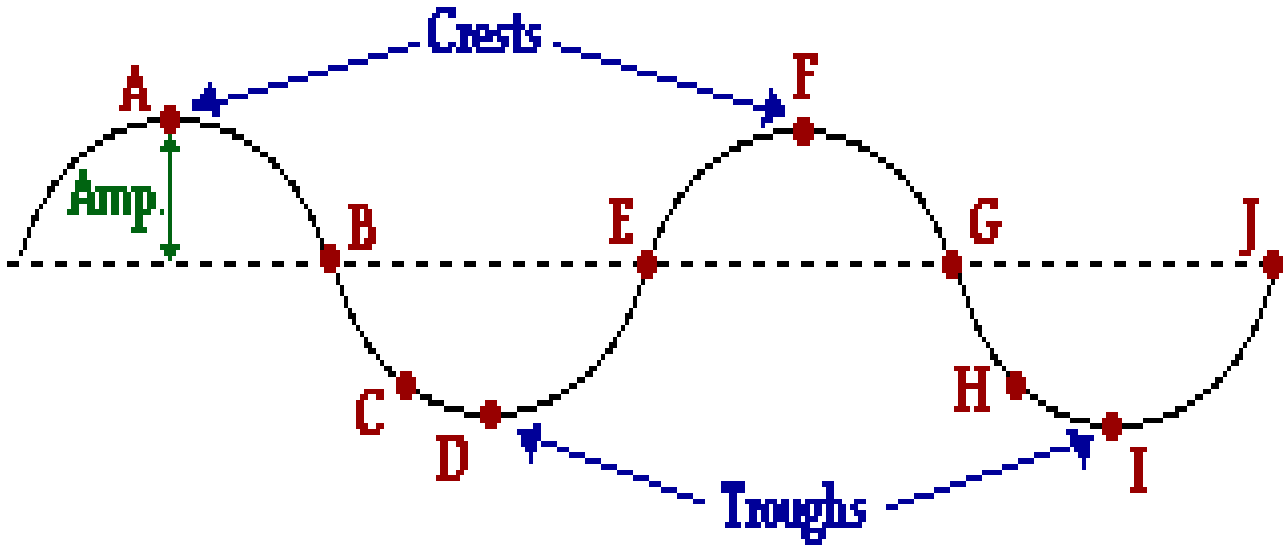


THE MOTION OF THE PARTICLES TENDS TO DECREASE AS ONE PRECEDES FURTHER FROM THE SURFACE.

PROPERTIES OF WAVES

THE **BASIC PROPERTIES** OF WAVES ARE:

A] AMPLITUDE
B] WAVELENGTH
C] FREQUENCY
D] SPEED/VELOCITY



AMPLITUDE

AMPLITUDE IS THE MAXIMUM DISTANCE THE PARTICLES OF THE MEDIUM CARRYING THE WAVE MOVE AWAY FROM THEIR **REST POSITIONS**.

THE AMPLITUDE IS A MEASURE OF HOW MUCH A PARTICLE IN THE MEDIUM MOVES WHEN DISTURBED BY THE WAVE.

THE FURTHER THE MEDIUM MOVES AS IT VIBRATES, THE LARGER THE AMPLITUDE OF THE RESULTING WAVES.

THE AMPLITUDE OF A WAVE IS A DIRECT MEASURE OF ITS ENERGY.

A WAVE WITH A LARGER AMPLITUDE CARRIES MORE **ENERGY** THAN A WAVE WITH A SMALL AMPLITUDE.

THE LARGER THE AMPLITUDE IS, THE TALLER THE WAVE IS.

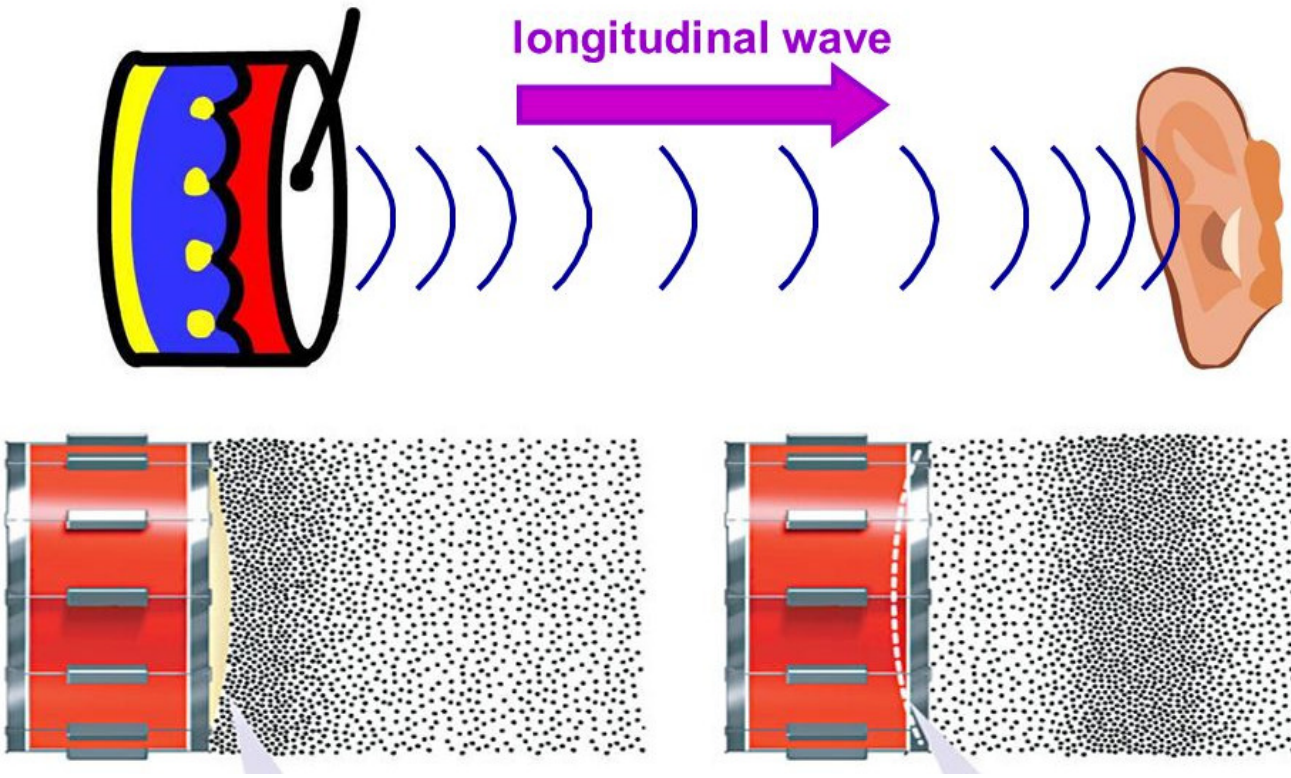
THE **AMPLITUDE OF A TRANSVERSE WAVE** IS THE MAXIMUM DISTANCE THE MEDIUM MOVES UP OR DOWN FROM ITS REST POSITION.

YOU CAN FIND THE **AMPLITUDE** OF A TRANSVERSE WAVE BY MEASURING THE DISTANCE FROM THE **REST POSITION** TO A **CREST** OR TO A **TROUGH**.

THE **AMPLITUDE OF A LONGITUDINAL WAVE** IS A MEASURE OF HOW COMPRESSED OR RAREFIED THE MEDIUM BECOMES.

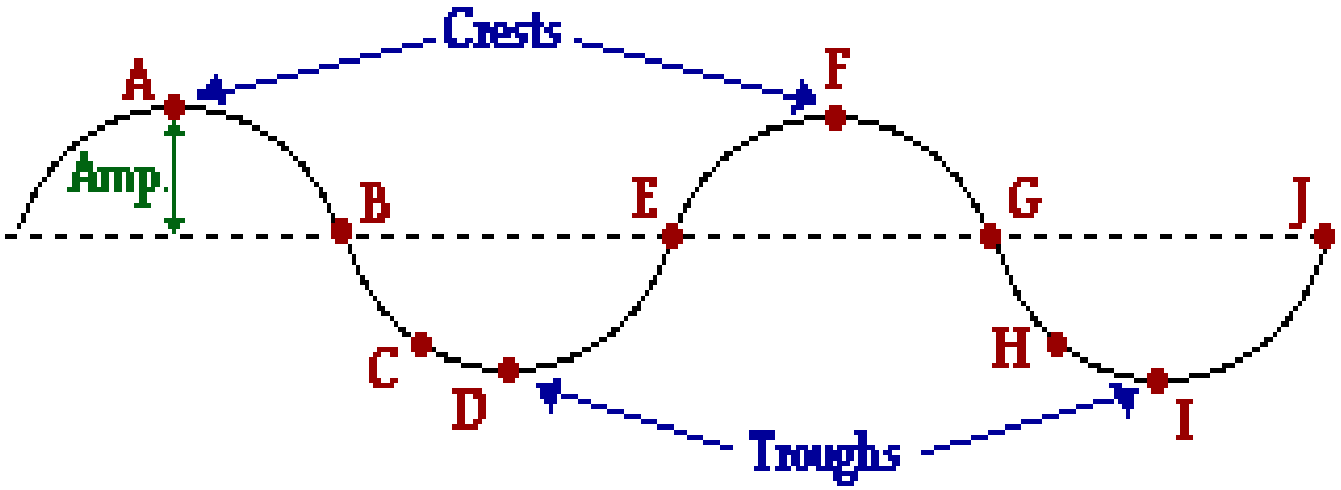
HIGH-ENERGY VIBRATIONS CAUSE THE COMPRESSIONS TO BE VERY CROWDED. THIS MAKES THE RAREFACTION QUITE LOOSE.

CROWDED COMPRESSIONS AND UNCROWDED RAREFACTIONS ARE LIKE HIGH CRESTS AND LOW TROUGHS.



-WAVELENGTH (λ)

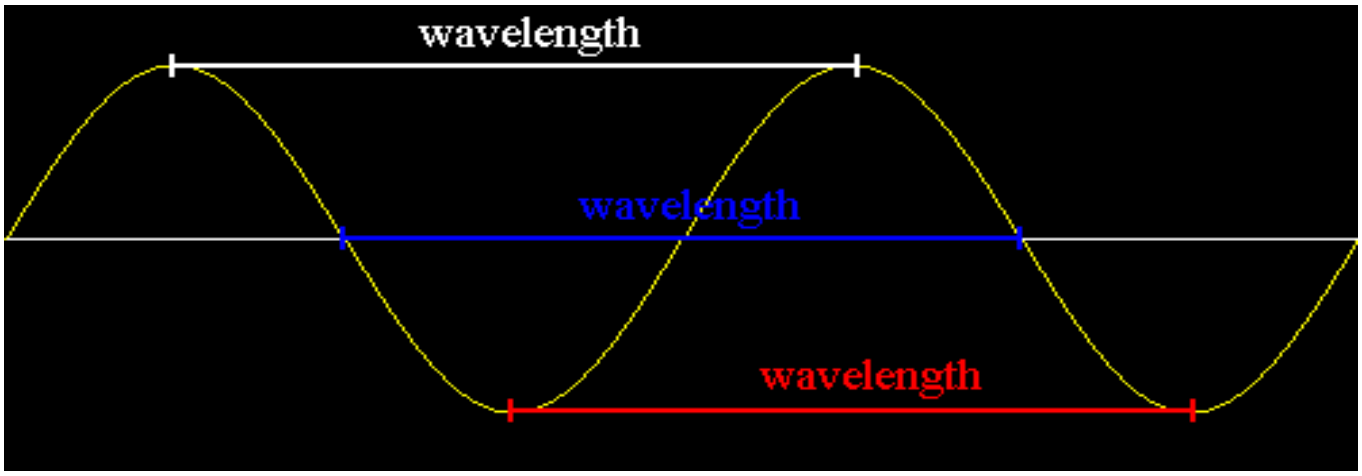
THE **WAVELENGTH** (λ = LAMBDA) OF A WAVE IS SIMPLY THE LENGTH OF ONE COMPLETE WAVE CYCLE OR THE DISTANCE BETWEEN TWO CORRESPONDING PARTS OF A WAVE.



Α α	alpha	Ν ν	nu
Β β	beta	Ξ ξ	ksi
Γ γ	gamma	Ο ο	omicron
Δ δ	delta	Π π	pi
Ε ε	epsilon	Ρ ρ	rho
Ζ ζ	zeta	Σ σς	sigma
Η η	eta	Τ τ	tau
Θ θ	theta	Υ υ	upsilon
Ι ι	iota	Φ φ	phi
Κ κ	kappa	Χ χ	chi
Λ λ	lambda	Ψ ψ	psi
Μ μ	mu	Ω ω	omega

YOU CAN FIND THE WAVELENGTH OF A TRANSVERSE WAVE BY MEASURING THE DISTANCE FROM **CREST TO CREST** OR FROM **TROUGH TO TROUGH**.

YOU CAN FIND THE WAVELENGTH OF A LONGITUDINAL WAVE BY MEASURING THE DISTANCE **FROM ONE COMPRESSION TO THE NEXT**.



FREQUENCY

WAVE **FREQUENCY** IS THE NUMBER OF COMPLETE WAVES THAT PASS A GIVEN POINT IN A CERTAIN AMOUNT OF TIME.

THE FREQUENCY OF A WAVE IS MEASURED IN UNITS CALLED **HERTZ** (Hz).

A WAVE OR VIBRATION THAT OCCURS EVERY SECOND HAS A FREQUENCY OF 1 Hz.

SPEED/VELOCITY

THE SPEED OF A WAVE IS HOW FAR A WAVE TRAVELS IN ONE UNIT OF TIME OR **DISTANCE DIVIDED BY TIME**.

S = DISTANCE/TIME

EX. **IF A WAVE TRAVELS 6 m IN 2 s, WHAT IS ITS SPEED?**

S = D/T
S= 6 m/2s
S = 3 m/s
OR

V = WAVELENGTH X FREQUENCY

EX. **A WAVE ON A LAKE HAS A WAVELENGTH OF 0.5 m AND A FREQUENCY OF 2 Hz (2 Hz = 2 PER SECOND, OR 2/s).**

TO FIND THE SPEED OF THE WAVE YOU USE THIS FORMULA:

S = WAVELENGTH X FREQUENCY

OR

V = SPEED
λ = WAVELENGTH
f = FREQUENCY

V = λ X f
λ = V/f
f = V/λ

S = 0.5 m X 2 Hz
S = 0.5 m X 2 /s
S = 1 m/s

http://www.slideshare.net/kkosten/wave-interactions
https://www.youtube.com/watch?v=VPWHFeN9hOQ
https://www.youtube.com/watch?v=AwMwY7DVRw4

INTERACTION OF WAVES

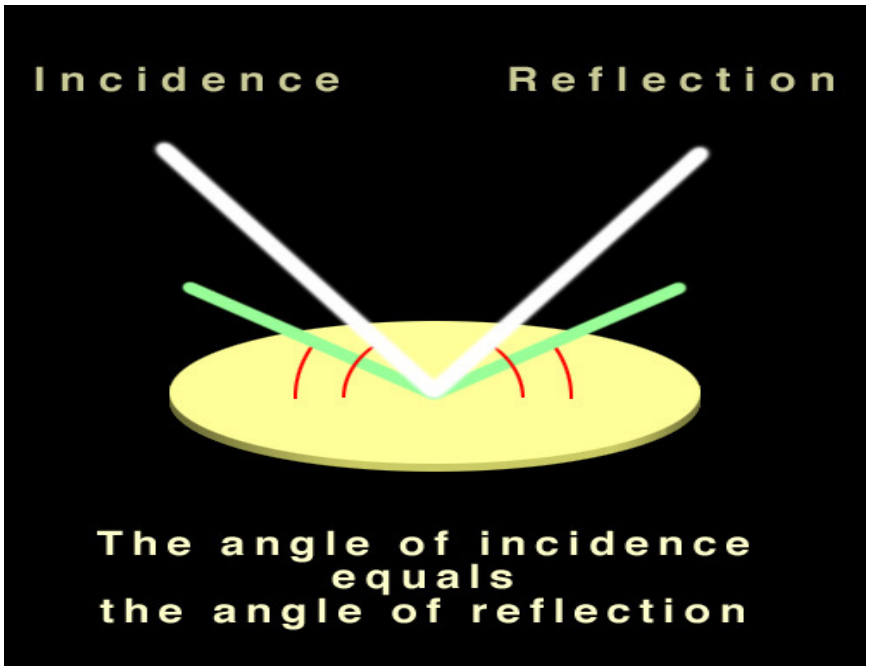
REFLECTION

WHEN AN OBJECT OR WAVE HITS A SURFACE THROUGH WHICH IT CANNOT PASS, IT BOUNCES BACK. THIS ACTION IS CALLED **REFLECTION**.

THE **ANGLE OF INCIDENCE** IS THE ANGLE BETWEEN THE INCOMING WAVE AND AN IMAGINARY PERPENDICULAR LINE CALLED **NORMAL**.

THE ANGLE OF **REFLECTION** IS THE ANGLE BETWEEN THE REFLECTED WAVE AND THE IMAGINARY LINE.

Show This
https://www.youtube.com/watch?v=iywSzxsG568



THE LAW OF REFLECTION STATES THAT THE ANGLE OF REFLECTION EQUALS THE ANGLE OF INCIDENCE.

(By René Descartes)

ALL WAVES OBEY THE LAW OF REFLECTION.

EX. A BALL HITS A WALL BOUNCES BACK, OR IS REFLECTED.

> USING A MIRROR

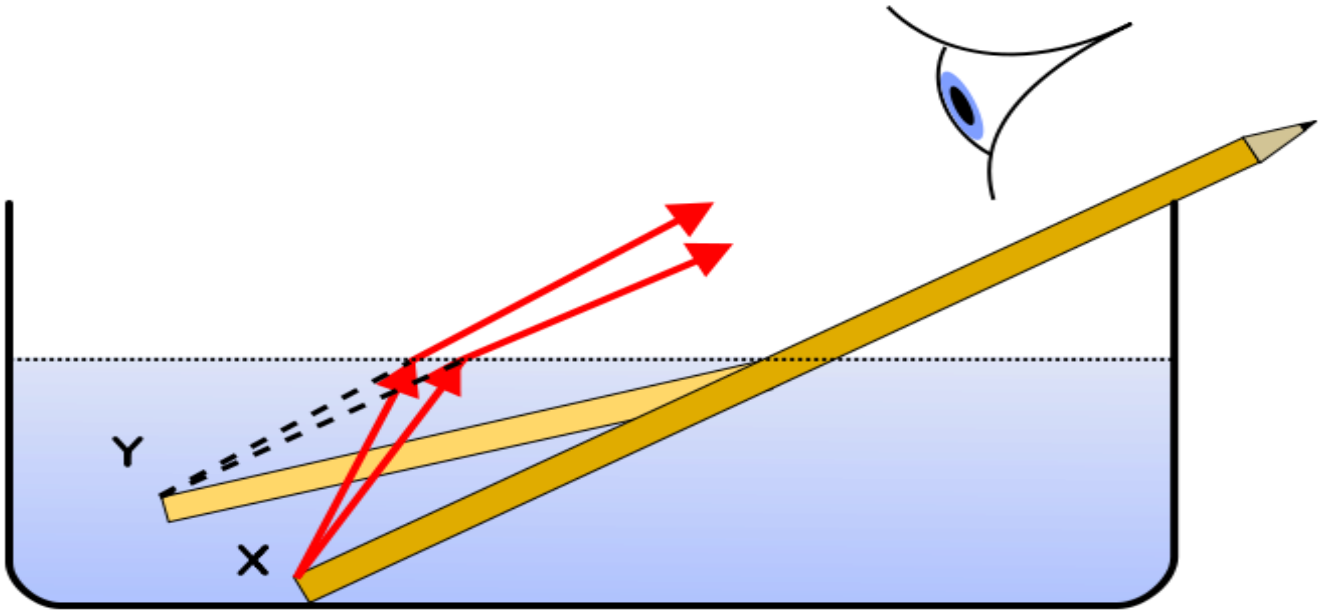
> AN ECHO IS REFLECTED SOUND

REFRACTION

WHEN A WAVE MOVES FROM ONE **MEDIUM** INTO ANOTHER MEDIUM AT AN ANGLE, IT CHANGES SPEED AS IT ENTERS THE SECOND MEDIUM, WHICH CAUSES IT TO **BEND.**

Show This
https://www.youtube.com/watch?v=DJY75LMdi-U

THE BENDING OF WAVES DUE TO A CHANGE IN SPEED IS CALLED **REFRACTION**.



REFRACTION CAN BE SEEN WHEN LOOKING INTO A BOWL OF WATER.

IF A PERSON LOOKS AT A STRAIGHT OBJECT, SUCH AS A PENCIL OR STRAW, WHICH IS PLACED AT A SLANT, PARTIALLY IN THE WATER, THE OBJECT APPEARS TO BEND AT THE WATER'S SURFACE.

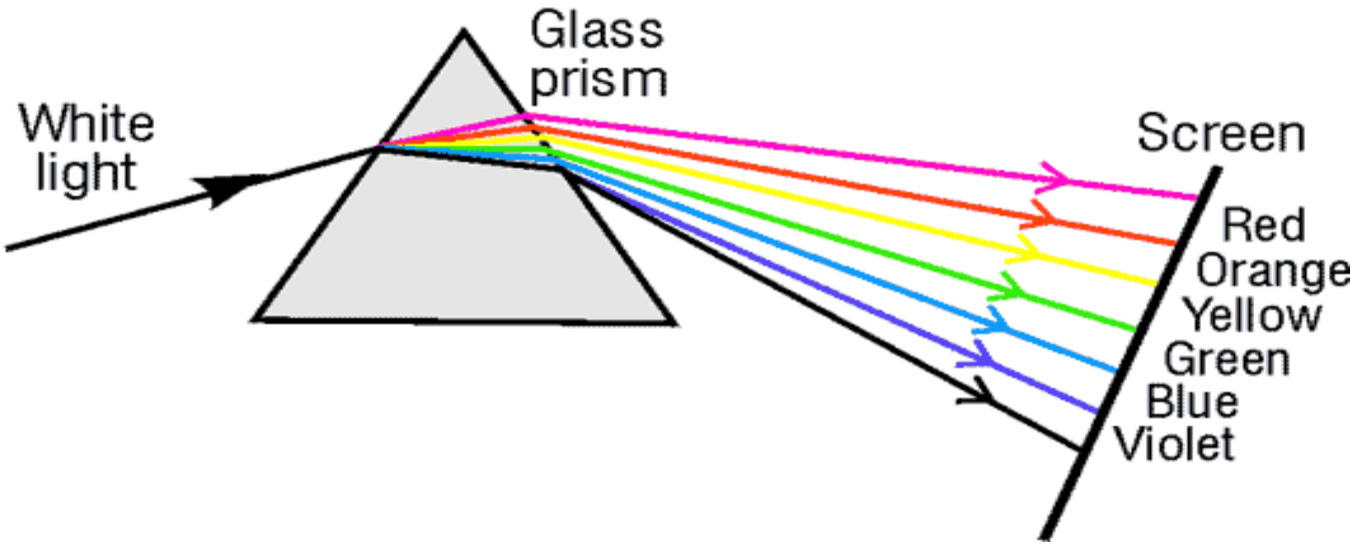
THIS IS DUE TO THE BENDING OF LIGHT RAYS AS THEY MOVE FROM THE WATER TO THE AIR.

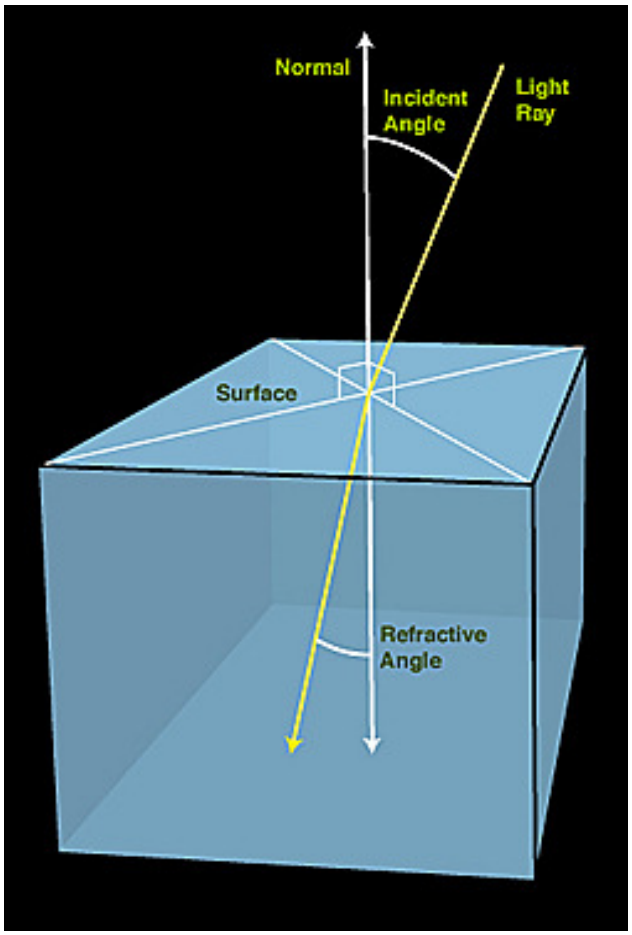
ONCE THE RAYS REACH THE EYE, THE EYE TRACES THEM BACK AS STRAIGHT LINES (LINES OF SIGHT). THE LINES OF SIGHT (SHOWN AS DASHED LINES) INTERSECT AT A HIGHER POSITION THAN WHERE THE ACTUAL RAYS ORIGINATED. THIS CAUSES THE PENCIL TO APPEAR HIGHER AND THE WATER TO APPEAR SHALLOWER THAN IT REALLY IS.

THE DEPTH THAT THE WATER APPEARS TO BE WHEN VIEWED FROM ABOVE IS KNOWN AS THE ***APPARENT DEPTH***.

THIS IS AN IMPORTANT CONSIDERATION FOR SPEARFISHING FROM THE SURFACE BECAUSE IT WILL MAKE THE TARGET FISH APPEAR TO BE IN A DIFFERENT PLACE, AND THE

FISHER MUST AIM LOWER TO CATCH THE FISH.




Normal
Incident Angle
Light Ray
Surface
Refractive Angle

DIFFRACTION

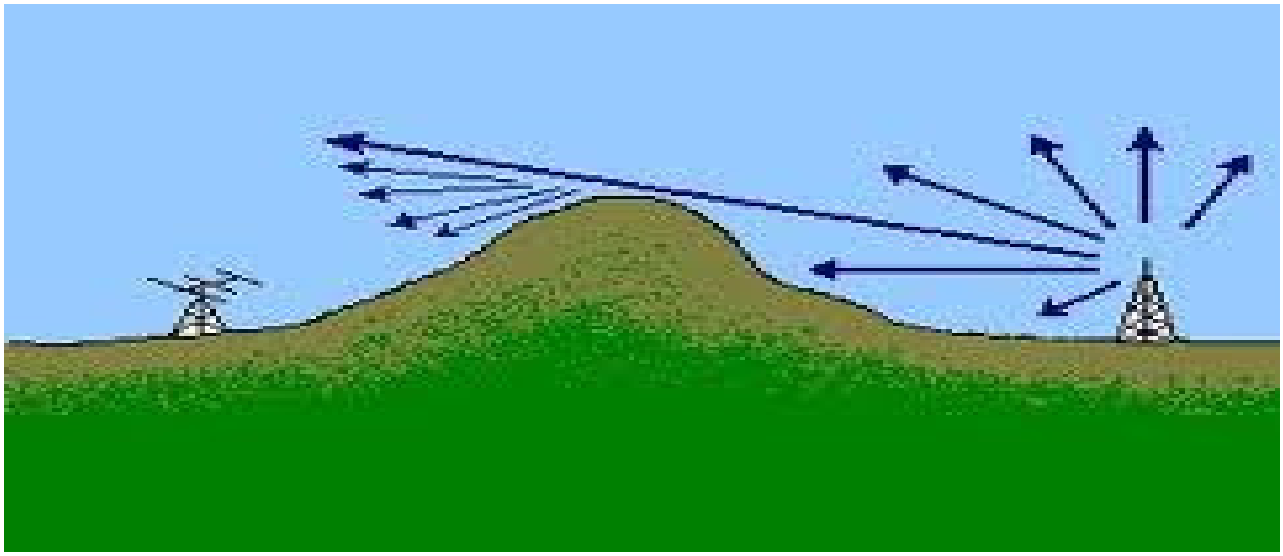
WHEN A WAVE PASSES A BARRIER OR MOVES THROUGH A HOLE IN A BARRIER, IT BENDS AND SPREADS OUT.

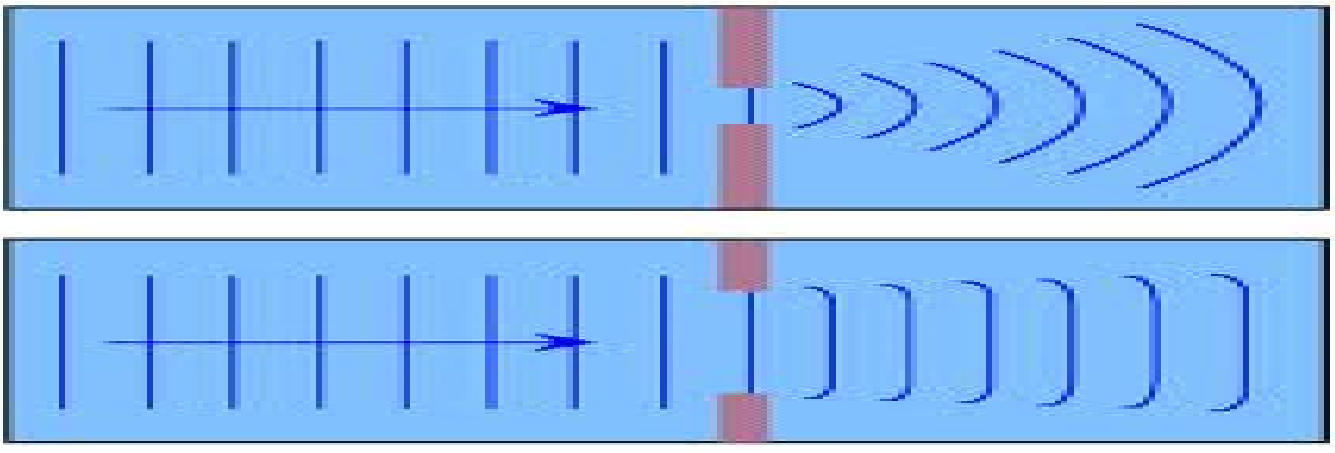
Show These

https://www.youtube.com/watch?v=NazBRcMDOOo

https://www.youtube.com/watch?v=aYkd_xSvaxE

THE BENDING OF WAVES AROUND THE EDGE OF A BARRIER IS KNOWN AS **DIFFRACTION**.





INTERFERENCE

WHEN TWO OR MORE WAVES MEET, THEY HAVE AN EFFECT ON EACH OTHER. THIS INTERACTION IS CALLED **INTERFERENCE**.

THERE TWO TYPES OF INTERFERENCE:

A] CONSTRUCTIVE
B] DESTRUCTIVE

https://www.youtube.com/watch?v=oTjTXS40pqs

CONSTRUCTIVE INTERFERENCE OCCURS WHENEVER TWO WAVES COMBINE TO MAKE A WAVE WITH A **LARGER AMPLITUDE.**

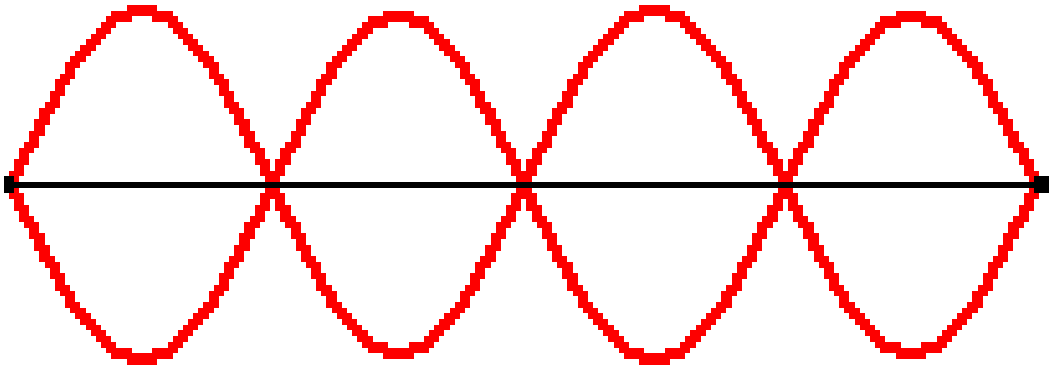
DESTRUCTIVE INTERFERENCE OCCURS WHEN THE AMPLITUDE OF TWO WAVES COMBINE WITH EACH OTHER, PRODUCING A **SMALLER AMPLITUDE**.

Interference of Waves
https://www.youtube.com/watch?v=CAe3lkYNKt8

STANDING WAVES

A STANDING WAVE IS A WAVE THAT APPEARS TO STAND IN ONE PLACE, EVEN THOUGH IT IS REALLY **TWO WAVES** INTERFERING AS THEY PASS THROUGH EACH OTHER.

Typical Diagram of a Standing Wave

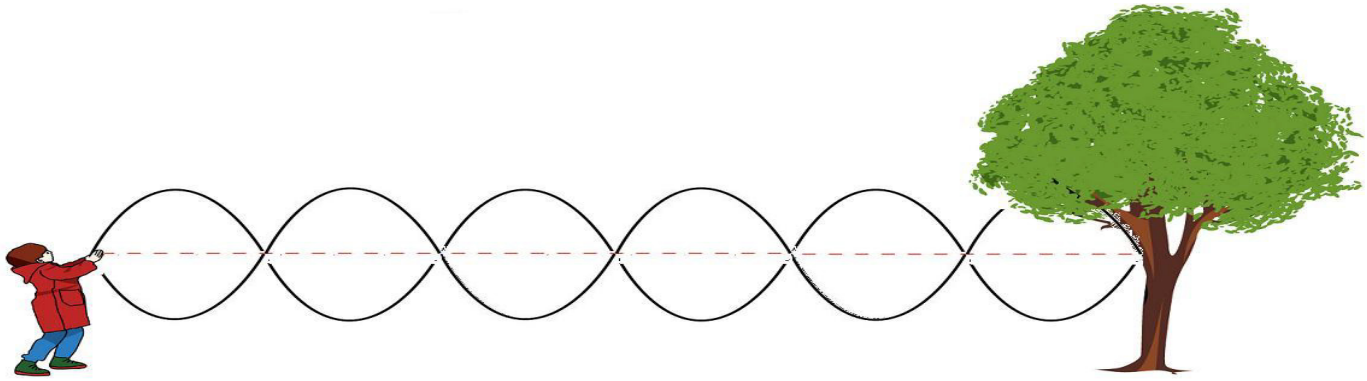


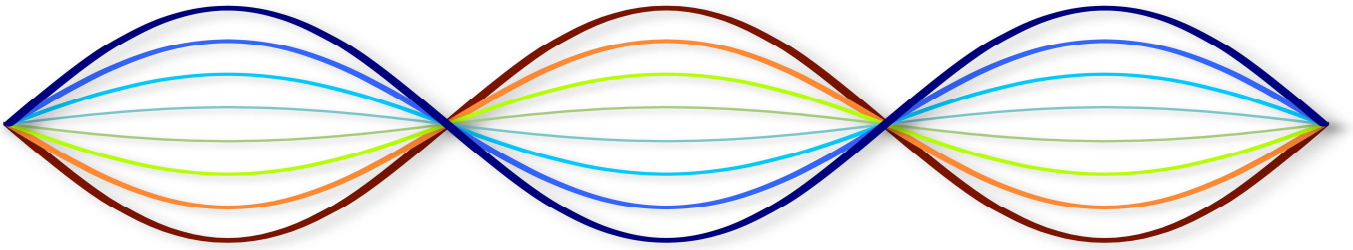
NODES & ANTINODES

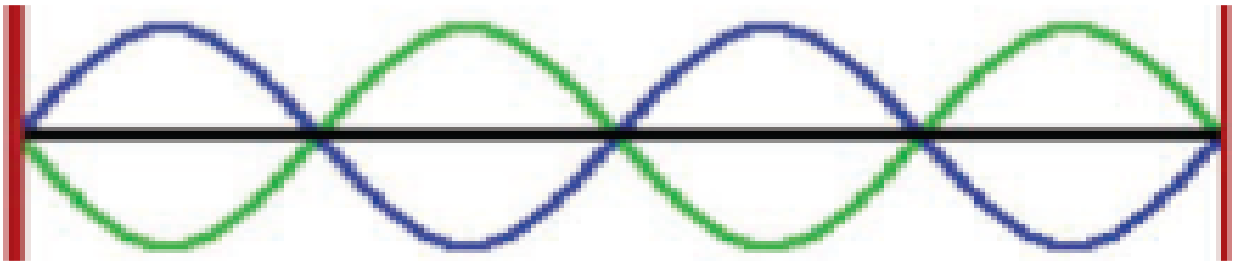
A **NODE** IS A POINT OF **ZERO AMPLITUDE** ON A STANDING WAVE WHERE THE WAVE HAS MINIMAL AMPLITUDE.

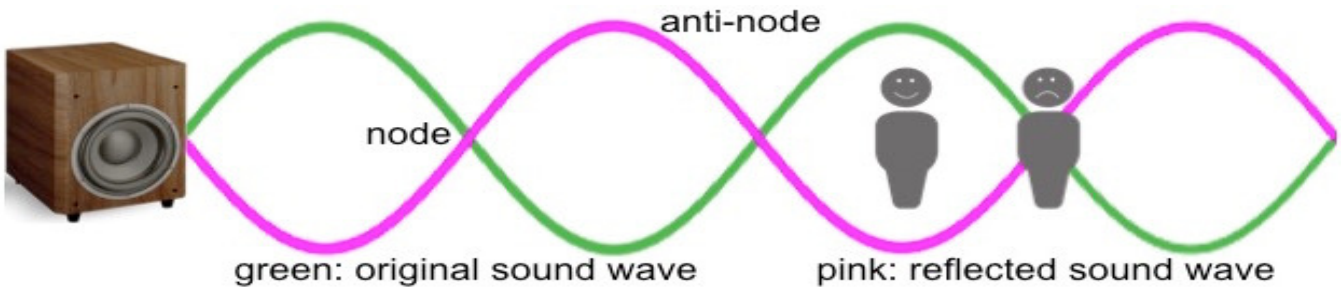
AN **ANTI-NODE** IS A POINT OF **MAXIMUM AMPLITUDE** ON A STANDING WAVE.

http://upload.wikimedia.org/wikipedia/commons/8/8c/Standing_wave.gif








anti-node
node
green: original sound wave
pink: reflected sound wave

http://www.aplusphysics.com/courses/regents/waves/images/stwave.gif

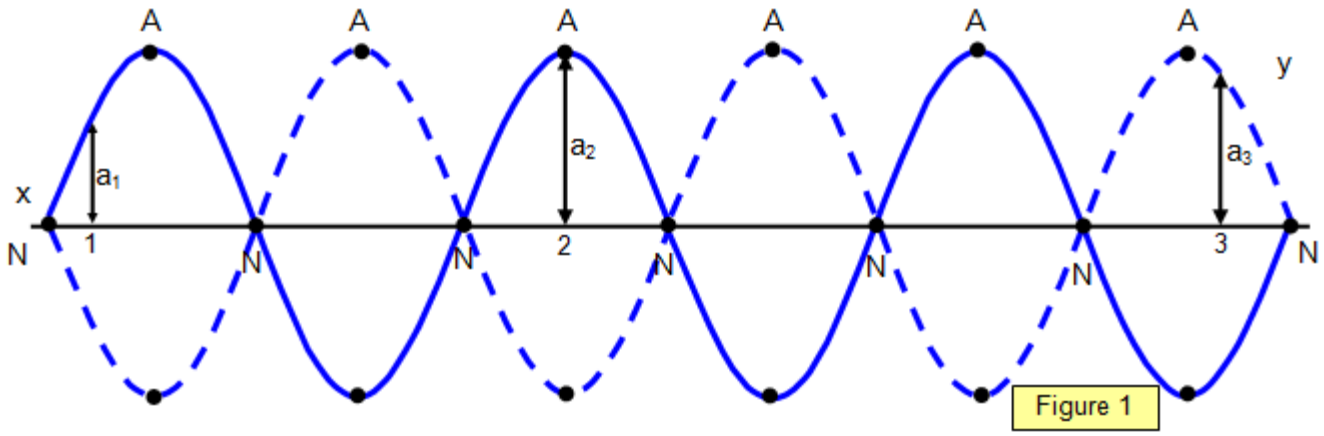
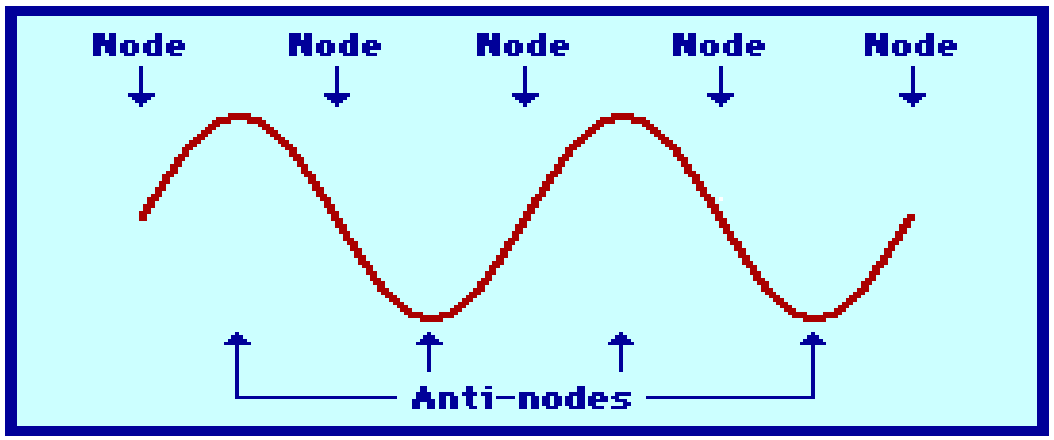
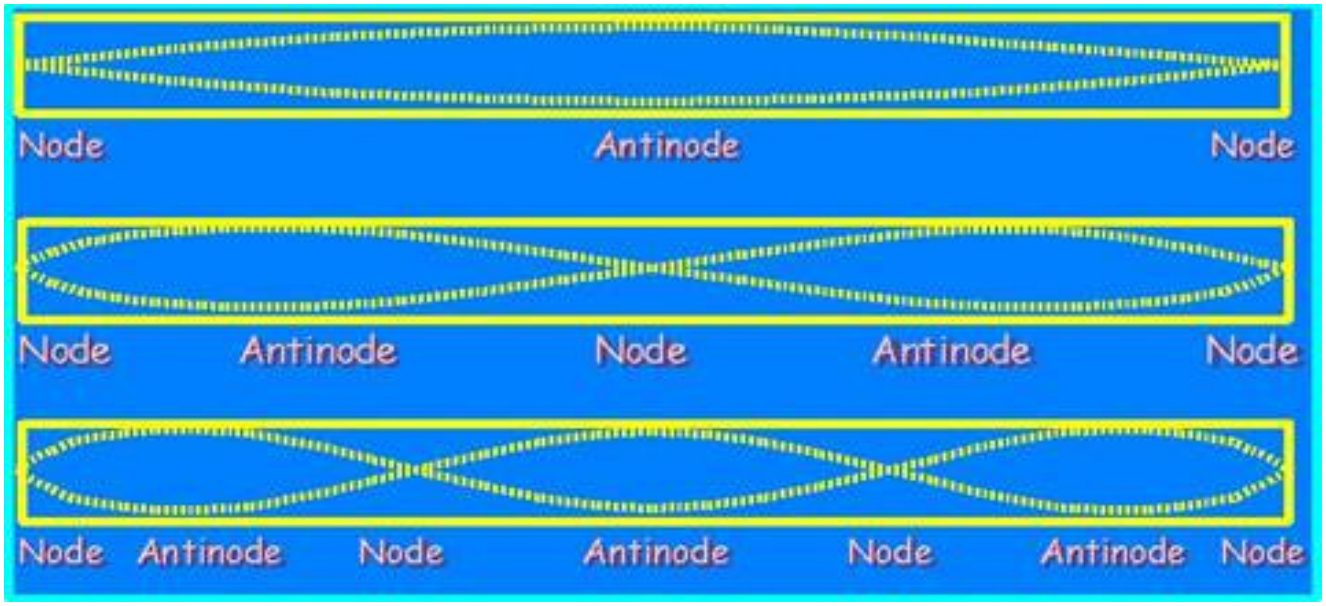


Figure 1



AN **ANTI-NODE** IS A POINT OF **MAXIMUM AMPLITUDE** ON A STANDING WAVE.



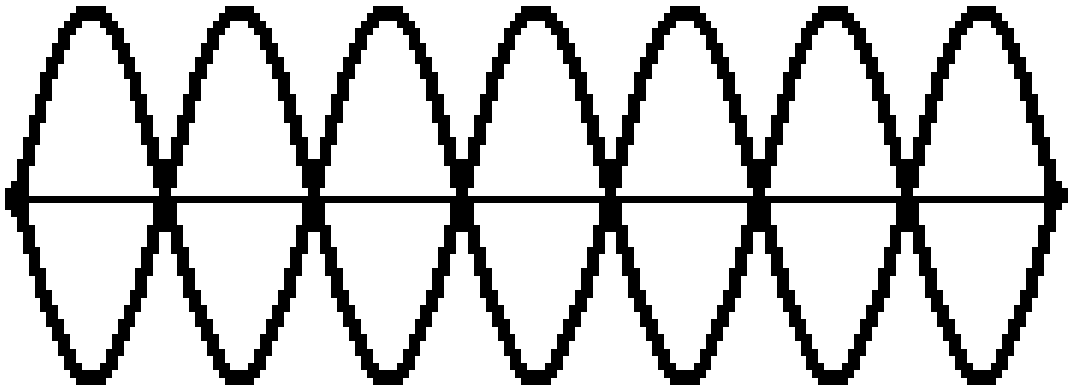
NODES ARE POINTS OF COMPLETE DESTRUCTIVE INTERFERENCE AND,

ANTI-NODES ARE POINTS OF MAXIMUM CONSTRUCTIVE INTERFERENCE.

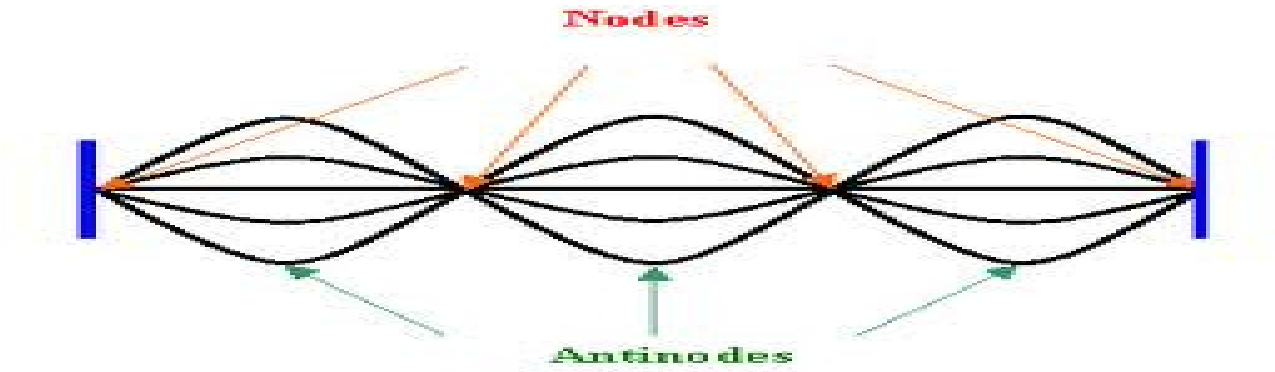
NODES AND ANTINODES ARE AT FIXED POINTS ON THE STRING.

THE NUMBER OF NODES IN THE STANDING WAVE SHOWN IN THE DIAGRAM BELOW IS _____8.

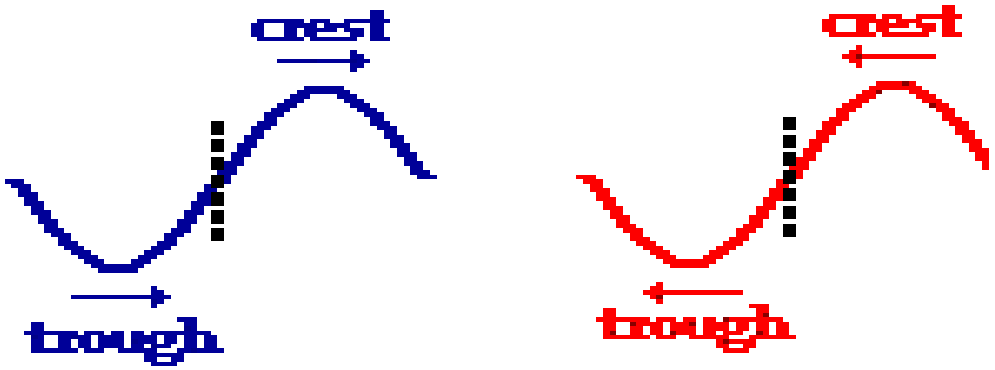
THE NUMBER OF ANTINODES IN THE SAME STANDING WAVE IS _____7.



A STANDING WAVE ALWAYS CONSISTS OF AN ALTERNATING PATTERN OF **NODES** AND **ANTINODES**.



NODES FORM AT THE LOCATIONS WHERE A CREST OF ONE WAVE MEETS A TROUGH OF A SECOND WAVE;



OR A HALF-CREST OF ONE WAVE MEETS A HALF-TROUGH OF A SECOND WAVE;

OR A QUARTER-CREST OF ONE WAVE MEETS A QUARTER-TROUGH OF A SECOND WAVE.

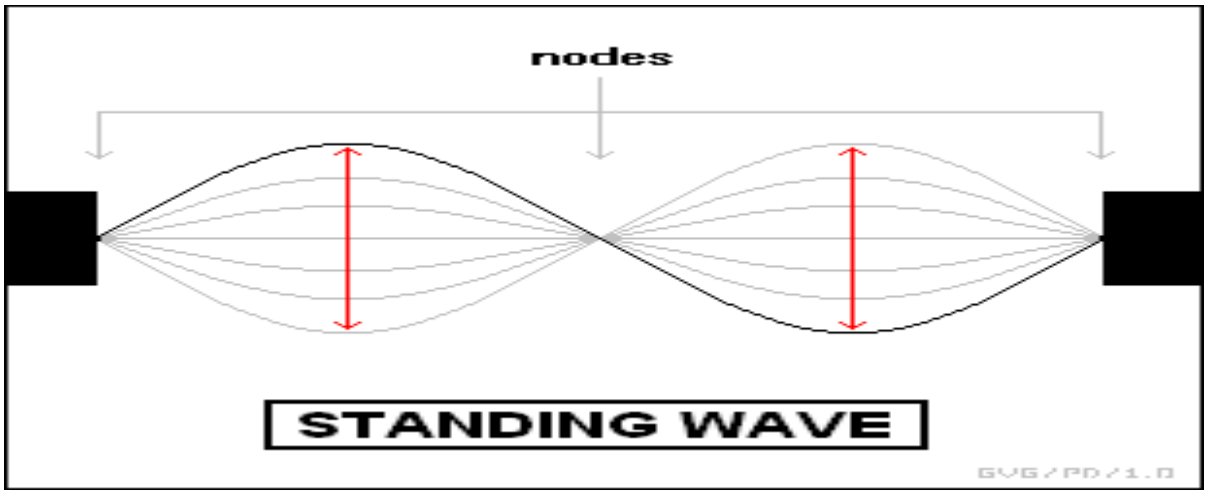
ANTINODES ARE FORMED AT LOCATIONS WHERE CONSTRUCTIVE INTERFERENCE OCCURS.

http://upload.wikimedia.org/wikipedia/commons/8/8c/Standing_wave.gif

THE RED DOTS ARE THE WAVE NODES.

http://www.aplusphysics.com/courses/regents/waves/images/stwave.gif

A NODE IS A POINT ALONG A STANDING WAVE WHERE THE WAVE HAS MINIMAL AMPLITUDE.



IN A VIBRATING GUITAR STRING, THE ENDS OF THE STRING ARE **NODES**. BY CHANGING THE POSITION OF THE END NODE THROUGH FRETS, THE GUITARIST CHANGES THE EFFECTIVE LENGTH OF THE VIBRATING STRING AND THEREBY THE NOTE PLAYED.

THE OPPOSITE OF A NODE IS AN **ANTI-NODE**, A POINT WHERE THE AMPLITUDE OF THE STANDING WAVE IS A MAXIMUM. THESE OCCUR MIDWAY BETWEEN THE NODES.

RESONANCE

RESONANCE IS THE INCREASE IN THE AMPLITUDE OF VIBRATION THAT OCCURS WHEN EXTERNAL VIBRATIONS MATCH THE OBJECT'S NATURAL FREQUENCY.

http://www.physicsclassroom.com/class/sound/u11l4a.cfm

http://video.mit.edu/watch/breaking-glass-with-sound-3947/

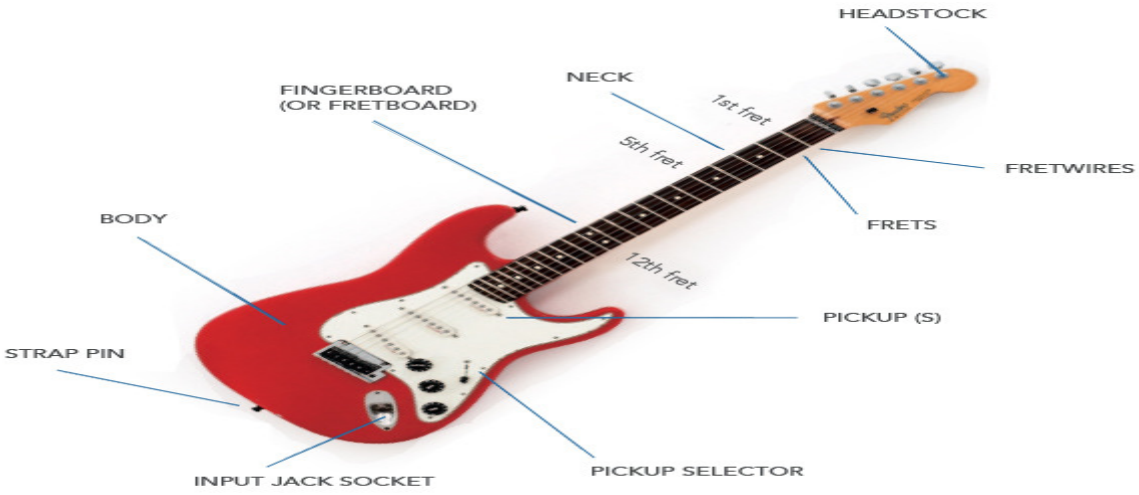
https://www.youtube.com/watch?v=Ude8pPjawKI

https://www.youtube.com/watch?v=nEaDk77HW-Y

BOUNDARY CONDITIONS OF WAVES

FIXED BOUNDARIES

- **THE ATTACHMENT POINTS OF GUITAR STRINGS.**



THE PERIPHERY OF A DRUMHEAD

FREE BOUNDARIES

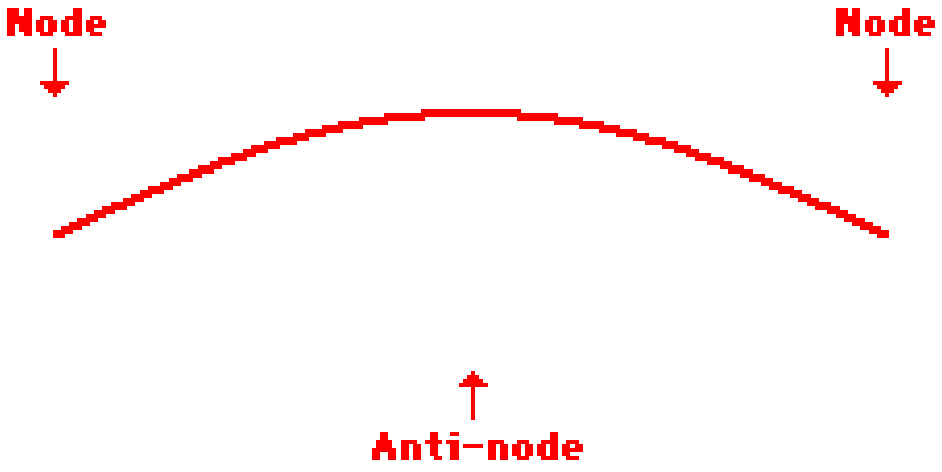
- **TUNING FORK**
- **THE ENDS OF AN ANTENNA**
- **THE END OF THE VIBRATING RESONATOR BAR IN A XYLOPHONE**

HARMONICS

IS A WAVE SIGNAL OR WAVE WHOSE FREQUENCY IS A COMPONENT OF A FUNDAMENTAL FREQUENCY IN A WAVE.

THE SIMPLEST STANDING WAVE PATTERN THAT COULD BE PRODUCED WITHIN A SNAKEY IS ONE THAT HAS POINTS OF NO DISPLACEMENT (NODES) AT THE TWO ENDS OF THE SNAKEY AND ONE POINT OF MAXIMUM DISPLACEMENT (ANTINODE) IN THE MIDDLE.

First Harmonic Standing Wave Pattern



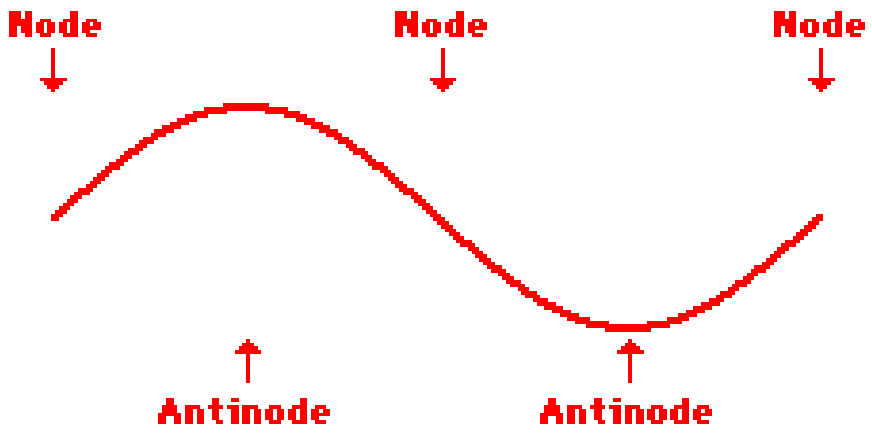
THE ABOVE STANDING WAVE PATTERN IS KNOWN AS THE **FIRST HARMONIC**. IT IS THE SIMPLEST WAVE PATTERN PRODUCED WITHIN THE SNAKEY AND IS OBTAINED BY VIBRATING INTO THE END OF THE MEDIUM AT LOW FREQUENCIES.

OTHER WAVE PATTERNS CAN BE OBSERVED WHEN IT IS VIBRATED AT GREATER FREQUENCIES.

THIS STANDING WAVE PATTERN IS CHARACTERIZED BY NODES ON THE TWO ENDS OF THE SNAKEY AND AN ADDITIONAL NODE IN THE EXACT CENTER OF THE SNAKEY.

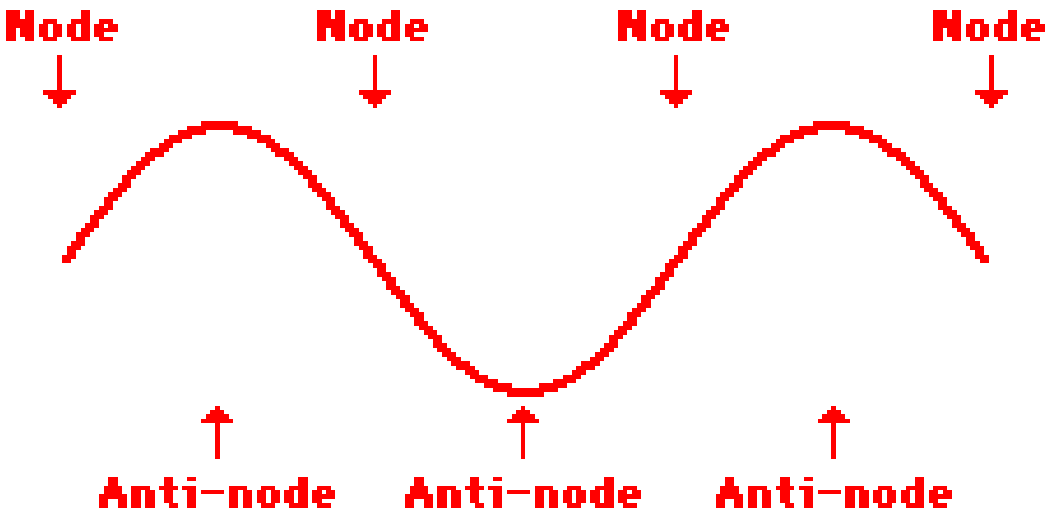
AS IN ALL STANDING WAVE PATTERNS, EVERY NODE IS SEPARATED BY AN ANTINODE. THIS PATTERN WITH THREE NODES AND TWO ANTINODES IS REFERRED TO AS THE **SECOND HARMONIC** AND IS DEPICTED BELOW.

Second Harmonic Standing Wave Pattern



IF THE FREQUENCY INCREASES EVEN MORE, THEN THE THIRD HARMONIC WAVE PATTERN CAN BE PRODUCED WITHIN THE SNAKEY. THE STANDING WAVE PATTERN FOR THE THIRD HARMONIC HAS AN ADDITIONAL NODE AND ANTINODE BETWEEN THE ENDS OF THE SNAKEY.

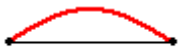
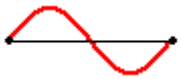
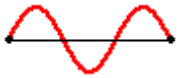
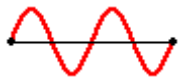
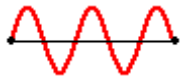
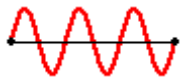
Third Harmonic Standing Wave Pattern



OBSERVE THAT EACH CONSECUTIVE HARMONIC IS CHARACTERIZED BY HAVING ONE ADDITIONAL NODE AND ANTINODE COMPARED TO THE PREVIOUS ONE.

THE TABLE BELOW SUMMARIZES THE FEATURES OF THE STANDING WAVE

PATTERNS FOR THE FIRST SEVERAL HARMONICS.

Harmonic	# of Nodes	# of Antinodes	Pattern
1st	2	1	
2nd	3	2	
3rd	4	3	
4th	5	4	
5th	6	5	
6th	7	6	
nth	n + 1	n	--

http://www.physicsclassroom.com/Class/waves/U10L4d.cfm VISIT THIS SITE FOR ABOVE

http://www.physicsclassroom.com/Class/waves/u10l4e.cfm NOT REQUIRED

SEISMIC WAVES

THE WAVES PRODUCED BY EARTHQUAKES ARE KNOW AS **SEISMIC WAVES**.

THERE ARE THREE MAIN TYPES OF SEISMIC WAVES:

PRIMARY WAVES

PRIMARY OR P-WAVES ARE LONGITUDINAL WAVES. THEY ARE MADE UP OF COMPRESSIONS & RAREFACTIONS.

SECONDARY WAVES

SECONDARY OR S-WAVES ARE TRANSVERSE WAVES. THEY **DO NOT** TRAVEL THROUGH LIQUIDS.

SURFACE WAVES

WHEN P-WAVES & S-WAVES REACH EARTH'S SURFACE, SOME OF THEM ARE TRANSFORMED INTO SURFACE WAVES SIMILAR TO WAVES ON THE SURFACE OF WATER.

TSUNAMIS ARE HUGE SURFACE WAVES PRODUCED BY UNDERWATER EARTHQUAKES.