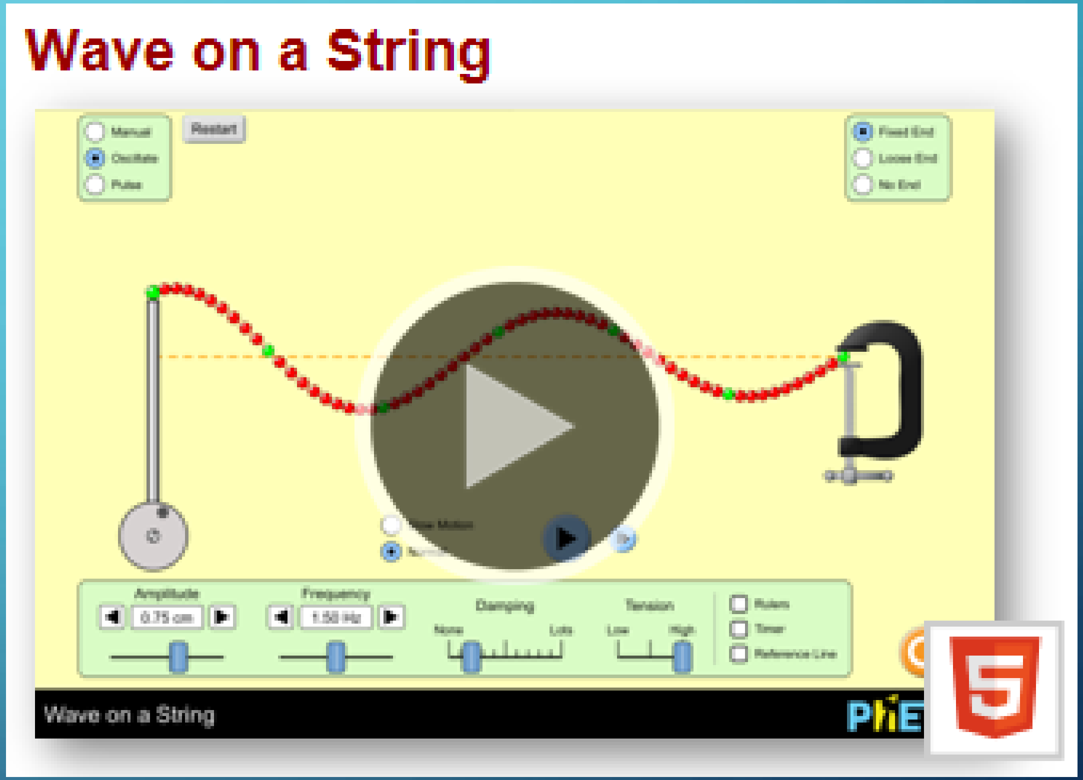
UNIT 1: LIGHT

LLT1 – WAVES

DESCRIBE THE PROPERTIES OF TRANSVERSE AND LONGITUDINAL WAVES, APPLY THE WAVE EQUATION AND DESCRIBE WAVE INTERFERENCE.

WAVES – A VISUAL

- Terms
  - Frequency
  - Period
  - Wavelength
  - Amplitude
  - Equilibrium Position
  - Speed
  - Tension



WAVES – SO MANY TYPES

- Water
- Sound
- Slinky (?!)
- Rope (?!)
- Pressure
- Electromagnetic
- Gravity

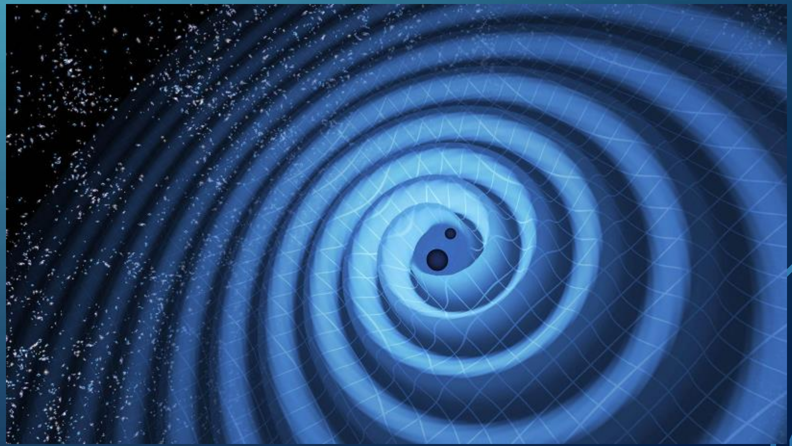
Mechanical Waves

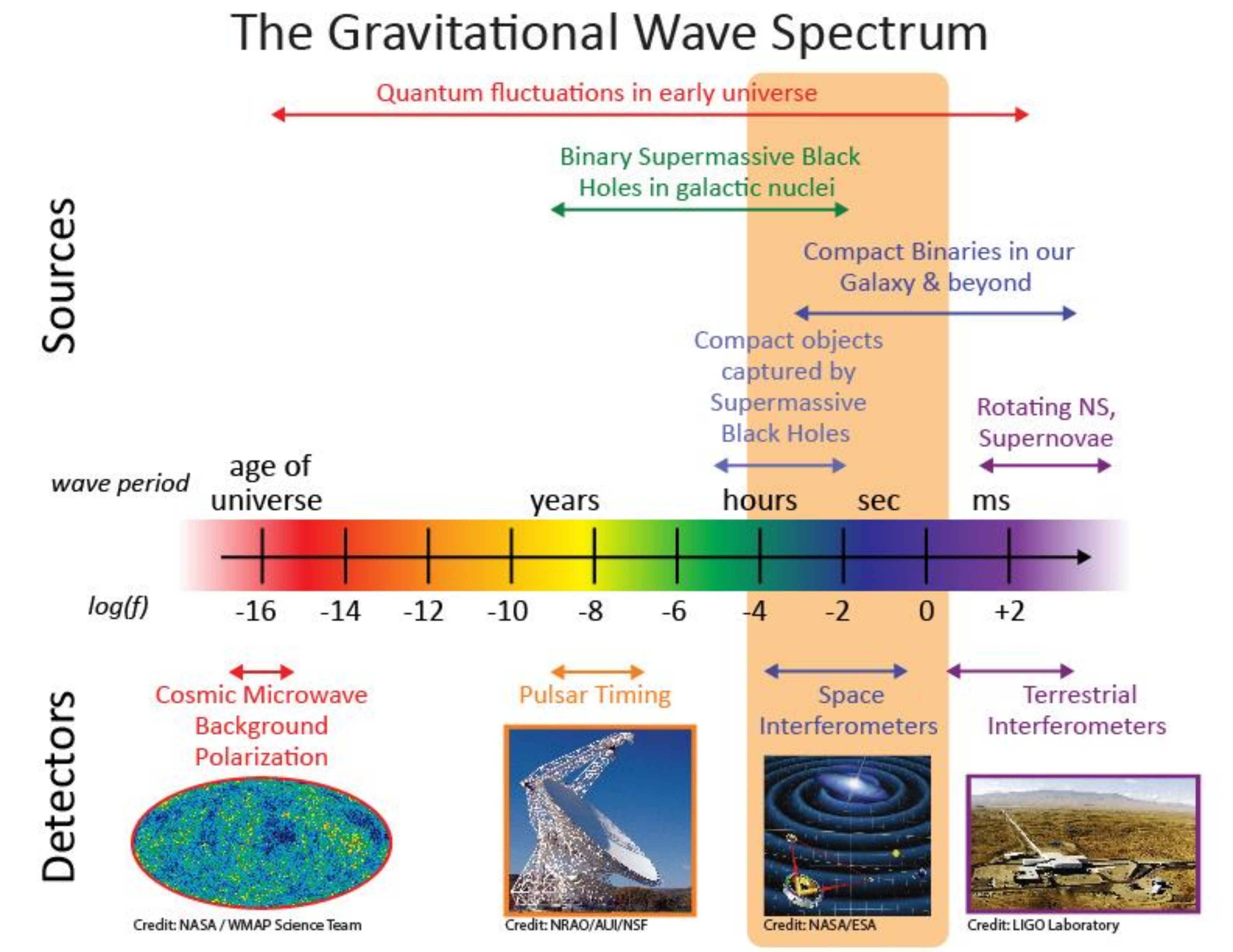
Travel through matter

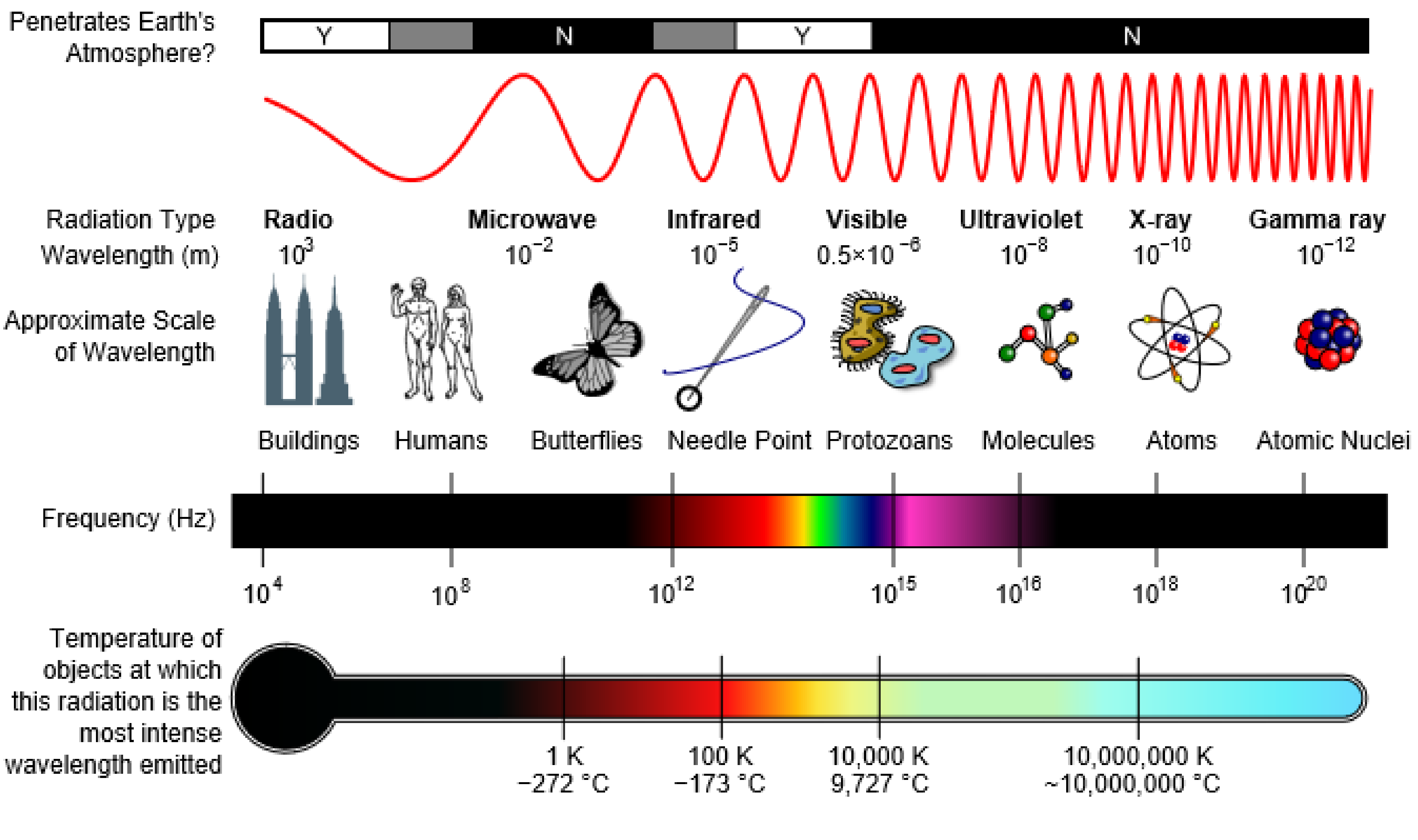
Travel through empty space

Wave:

A disturbance that transfers energy through a medium.

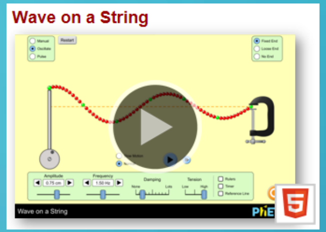



The Gravitational Wave Spectrum
Sources
Quantum fluctuations in early universe
Binary Supermassive Black Holes in galactic nuclei
Compact Binaries in our Galaxy & beyond
Compact objects captured by Supermassive Black Holes
Rotating NS, Supernovae
wave period
age of universe
years
hours
sec
ms
log(f)
-16
-14
-12
-10
-8
-6
-4
-2
0
+2
Detectors
Cosmic Microwave Background Polarization
Pulsar Timing
Space Interferometers
Terrestrial Interferometers
Credit: NASA / WMAP Science Team
Credit: NRAO/AUI/NSF
Credit: NASA/ESA
Credit: LIGO Laboratory



Penetrates Earth's Atmosphere?
Y
N
Y
N
Radiation Type
Wavelength (m)
Radio
10^3
Microwave
10^{-2}
Infrared
10^{-5}
Visible
0.5×10^{-6}
Ultraviolet
10^{-8}
X-ray
10^{-10}
Gamma ray
10^{-12}
Approximate Scale of Wavelength
Buildings
Humans
Butterflies
Needle Point
Protozoans
Molecules
Atoms
Atomic Nuclei
Frequency (Hz)
10^4
10^8
10^{12}
10^{15}
10^{16}
10^{18}
10^{20}
Temperature of objects at which this radiation is the most intense wavelength emitted
1 K −272 °C
100 K −173 °C
10,000 K 9,727 °C
10,000,000 K ~10,000,000 °C

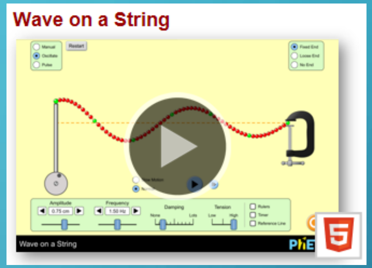
MECHANICAL WAVES – WAVE SPEED



- Wave speed is constant in a particular medium.
  - Independent of the size or amount of energy in a wave.
  - Does not change speed as it travels.
  - Wave speed within a medium is a physical characteristic of that medium; much like density or boiling point.
  - Wave speed is determined by the forces between and the mass of the medium particles.
  - For example, if everyone in the class talks then every single sound wave will have the same speed through the air. No matter the pitch or volume.

MECHANICAL WAVES – WAVE SPEED

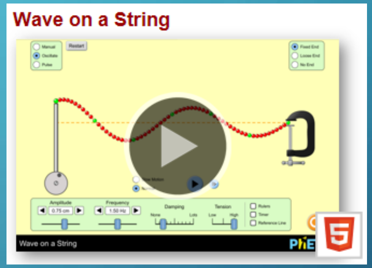
- The greater the force between particles, the more rapidly the particles return to equilibrium position.
  - Results in a faster wave speed.



- The greater the mass of the particles, the more slowly they return to equilibrium position because of their inertia.
  - Results in a slower wave speed.
- Friction: acts to dampen or reduce the amplitude of the wave, but has no effect on wave speed (unlike sliding something on a table).

MECHANICAL WAVES – FREQUENCY & PERIOD

- Frequency, *f*: The number of waves that are created per unit time.
  - If time is in seconds, the unit for frequency is measured in Hertz, Hz.
- Period, *T*: The time to create one wave.
- They are reciprocal functions: $T = \frac{1}{f}$ and $f = \frac{1}{T}$



- The mathematical relationship you use depends on the information given in the problem.

$T = \frac{\Delta t}{\#waves}$	$f = \frac{\#waves}{\Delta t}$	$T = \frac{1}{f}$	$f = \frac{1}{T}$

FREQUENCY & PERIOD PROBLEMS

- Example 1: Watching water waves, an observer notes that 25 waves pass by him in 175 seconds. Calculate the period and frequency of these waves.

FREQUENCY & PERIOD PROBLEMS

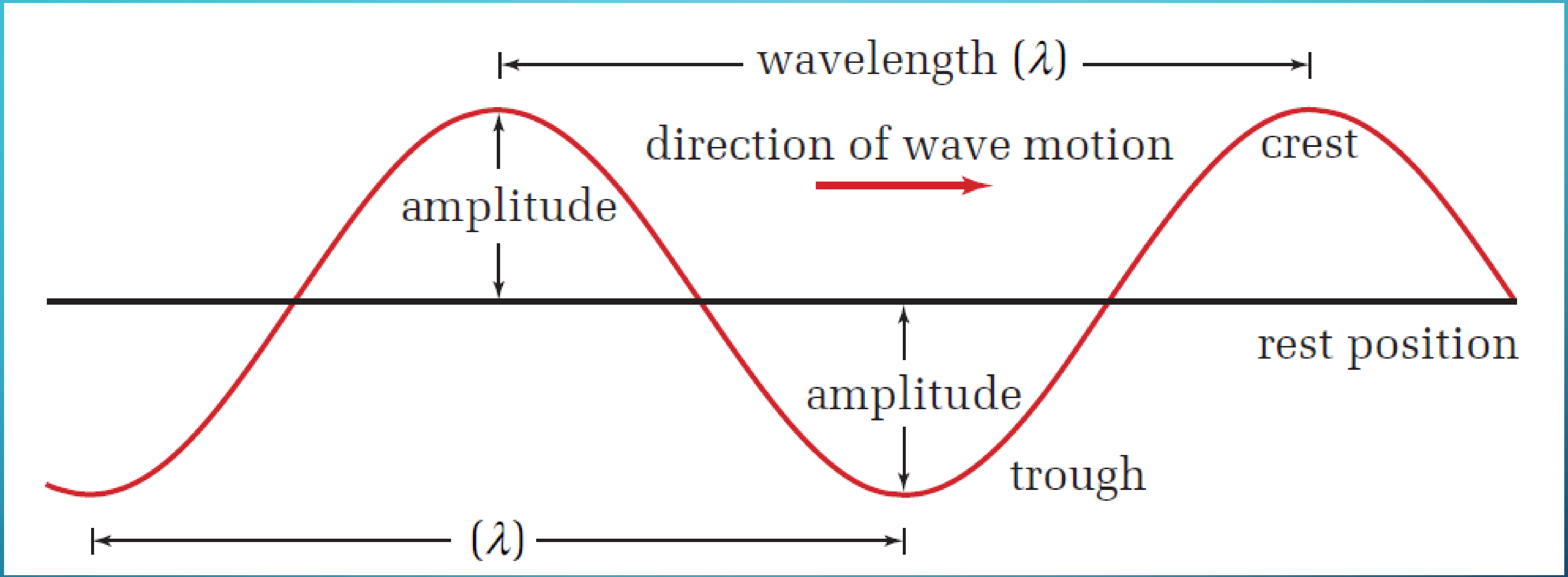
- Example 2: A basketball shoots 33 balls in 120 seconds. Calculate the frequency and period of the shots.

FREQUENCY & PERIOD PROBLEMS

- Example 3: The frequency of a sound wave is 252 Hz. Calculate the period of the wave.

MHR Practice Sheet

DESCRIBING WAVES

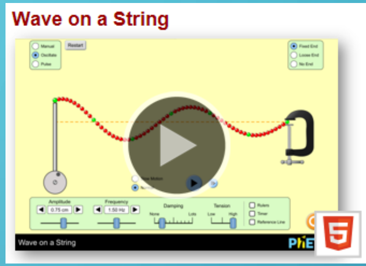


Wavelength, λ: The distance from a point on the wave to a corresponding point such that it includes one complete crest and trough.

- λ is the lowercase Greek letter, lambda.

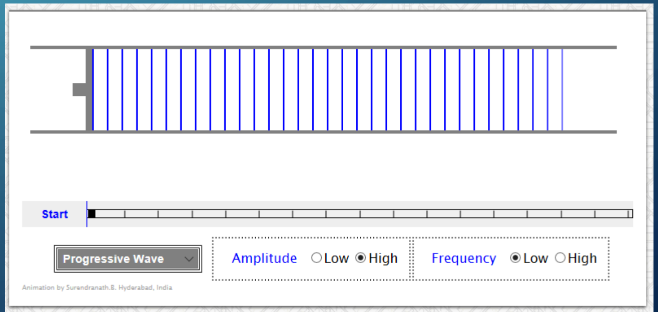
TRANSVERSE WAVES

- Particles of the medium vibrate perpendicular to the direction the wave is traveling.
  - Making waves in a rope/string.



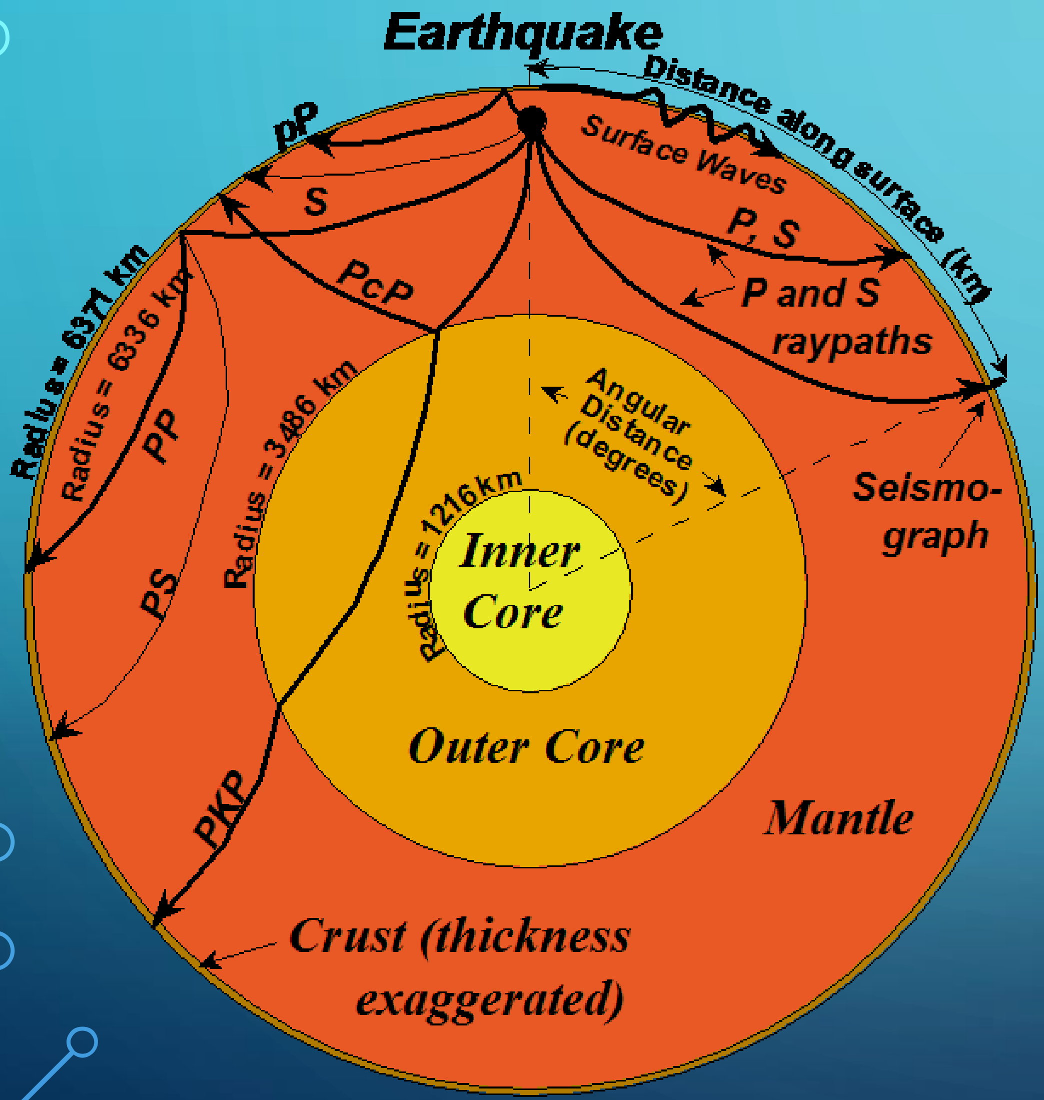
LONGITUDINAL WAVES

- Particles of the medium vibrate parallel to the direction the wave is traveling.
  - Sound/Pressure waves.

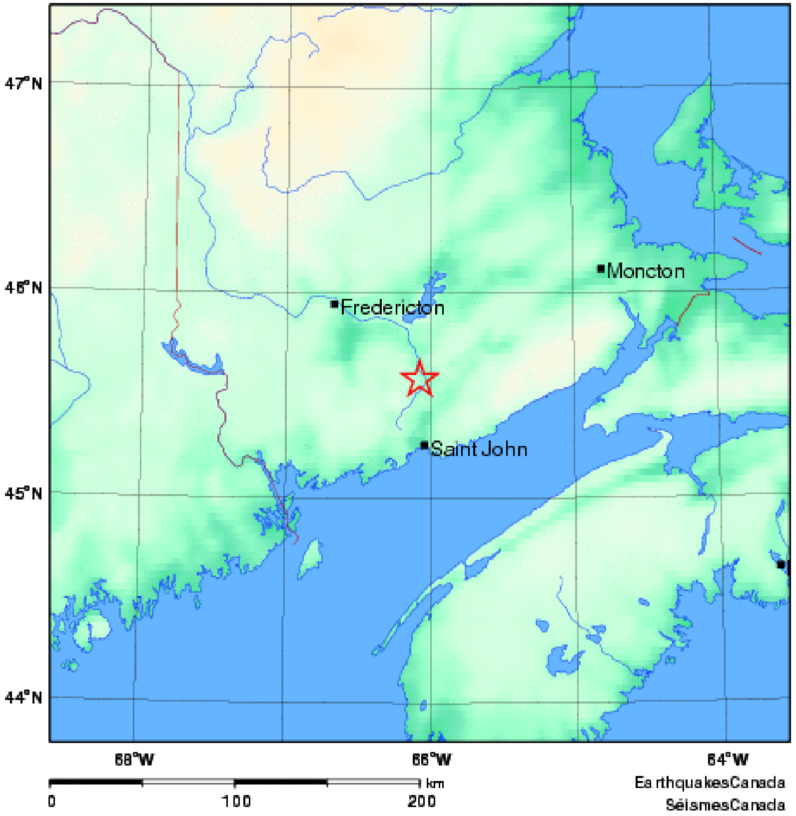


APPLICATION OF WAVES: SEISMOLOGY & ASTEROSEISMOLOGY

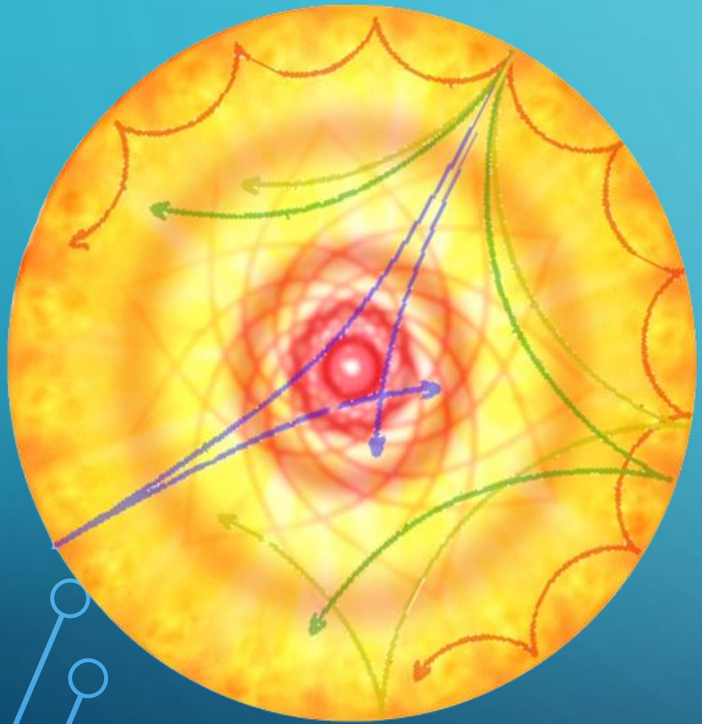
Local Time:	09:49:00 AST
Magnitude:	3.8 MN
Latitude:	45.36 North
Longitude:	66.24 West
Depth:	2 km
UT Date and Time:	2019/01/10 13:49:00 UT

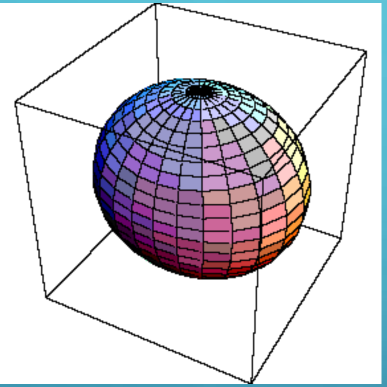


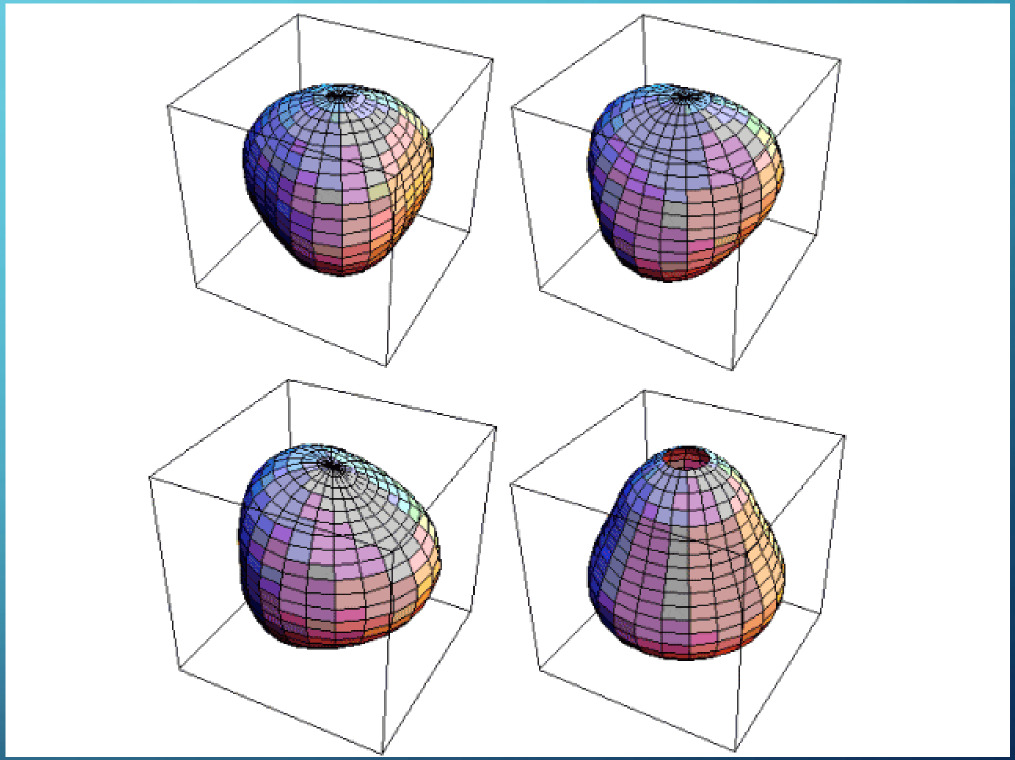
Approximate Location of Earthquake: Strongly felt in Saint John, Grand Bay-Westfield, Rothesay.



APPLICATION OF WAVES: SEISMOLOGY & ASTEROSEISMOLOGY







THE WAVE EQUATION

- $V = f\lambda$
- V = Speed (m/s)
- f = frequency (Hz)
- λ = wavelength (m)
- In a particular medium, all waves will travel the same speed.
- If a wave travels from one medium to another, it's speed will likely change, but its frequency will not.

WAVE EQUATION PRACTICE #1

- A sound wave has a frequency of 325 Hz and a wavelength of 1.20 m. Calculate the wave speed.

(v = 390 m/s)

WAVE EQUATION PRACTICE #2

- A radio wave travels 3.00×10^8 m/s through the air. Calculate the wavelength of radio waves that have a frequency of 99.3 MHz.

(λ = 3.02 m)

WAVE EQUATION PRACTICE #3

- A sound wave has a wavelength of 0.34 m and a speed of 350 m/s in air.
  - Calculate the frequency. (f = 1029 Hz)
- If that sound wave enters sea water, where its speed is 1531 m/s. Calculate its new wavelength. (λ = 1.49 m)

WAVE EQUATION PRACTICE #4

- Waves are created in a 15 m long rope that have a wavelength of 0.42 m. It takes the waves 8.8 seconds to travel the length of the rope. Calculate the frequency and period of the waves.

(f = 4.05 Hz), T = 0.25 s

PRACTICE PROBLEM

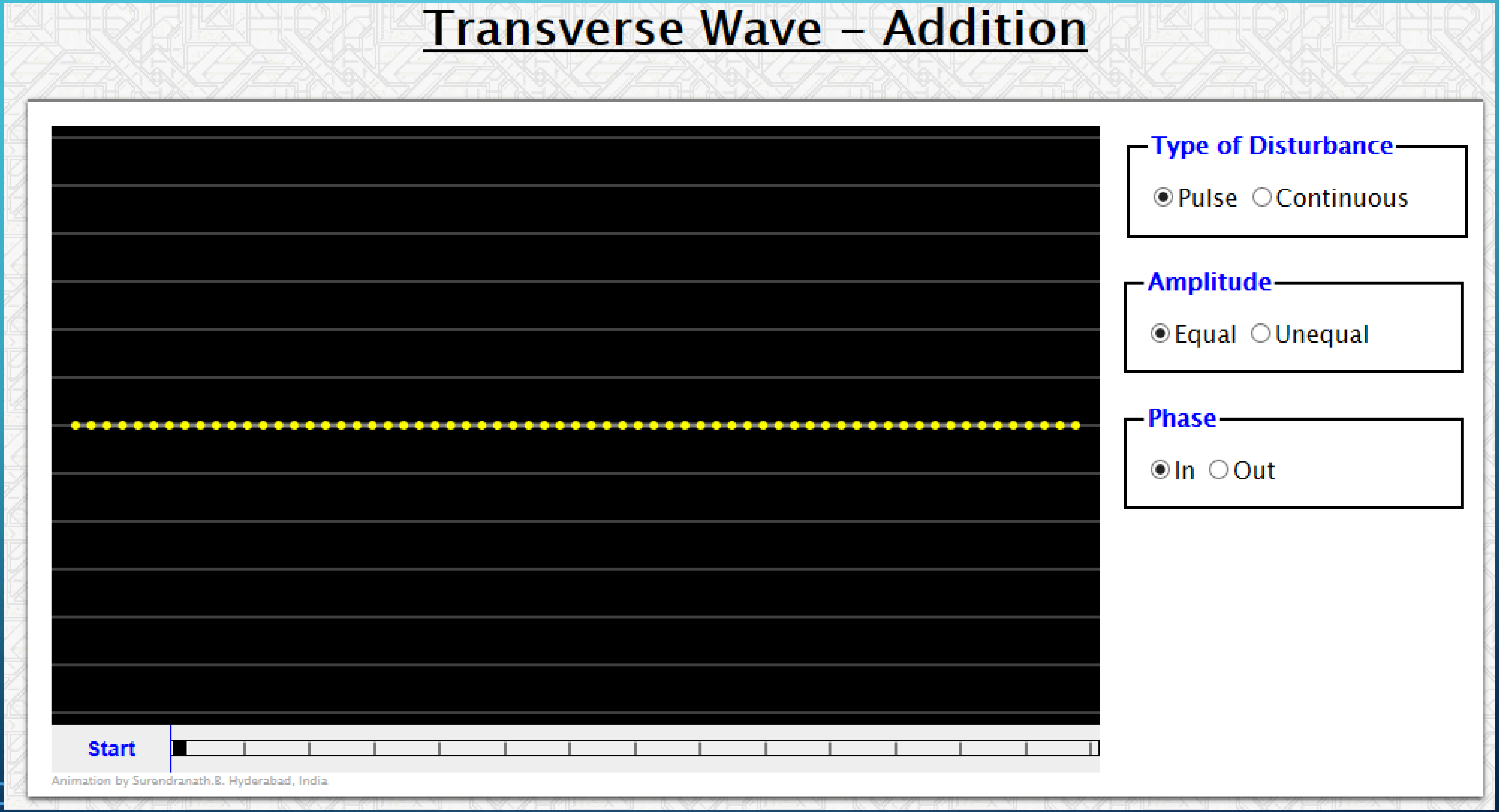
- Two boats are 90 m apart. When one boat is on a crest and the other is in a trough there are two crests between them. A boat goes up-and-down and up again 15 times in 60 seconds. Calculate the speed of the waves.

YOUR TURN

- Two boats are 115 m apart. When each boat is on a crest and there are 4 crests between them. A boat goes up-and-down and up again 20 times in 75 seconds. Calculate the speed of the waves.

V = 6.88 m/s

WAVE INTERFERENCE

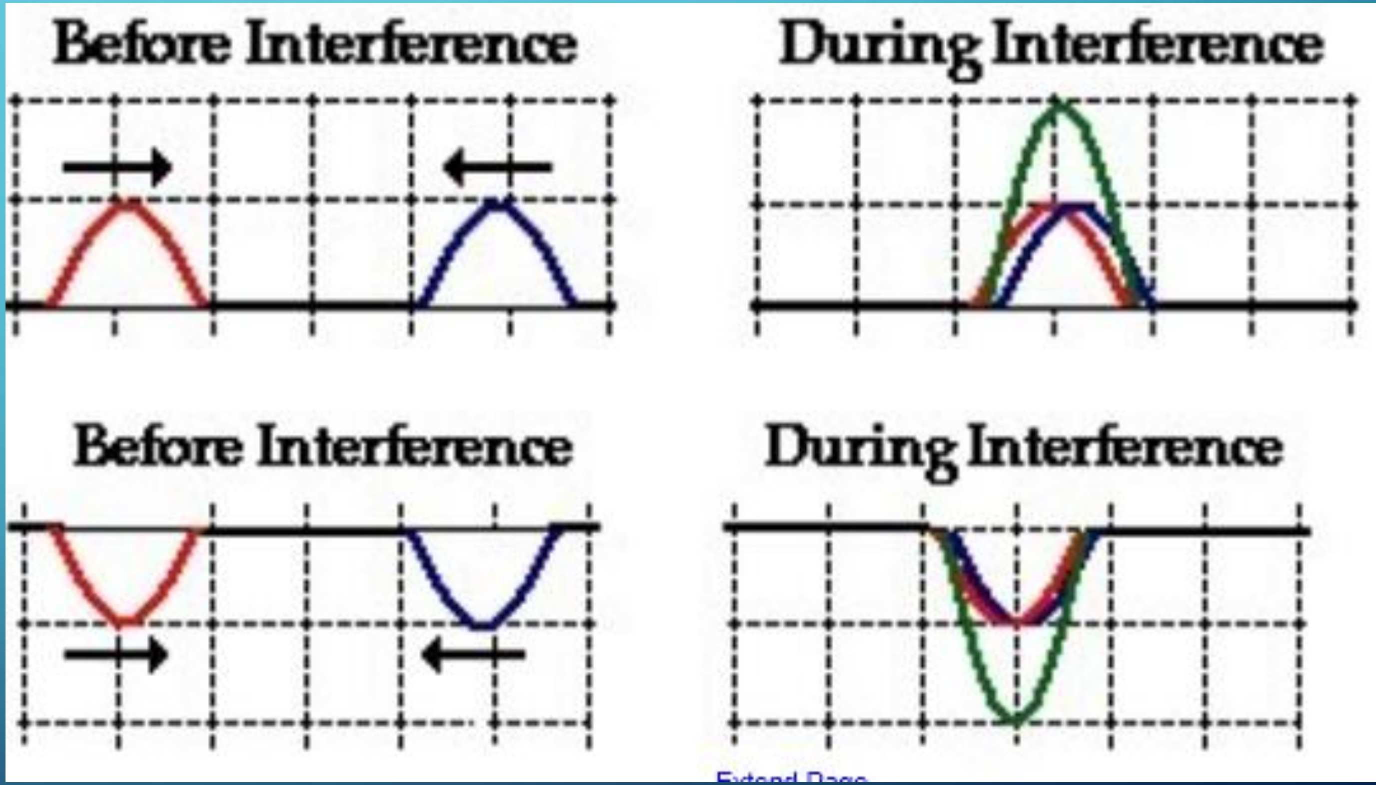


WAVE INTERFERENCE

- When two or more waves act simultaneously on the same particles of a medium.
- Principle of Superposition: The resultant displacement of a given particle is equal to the sum of the displacements that would have been produced by each wave acting independently.

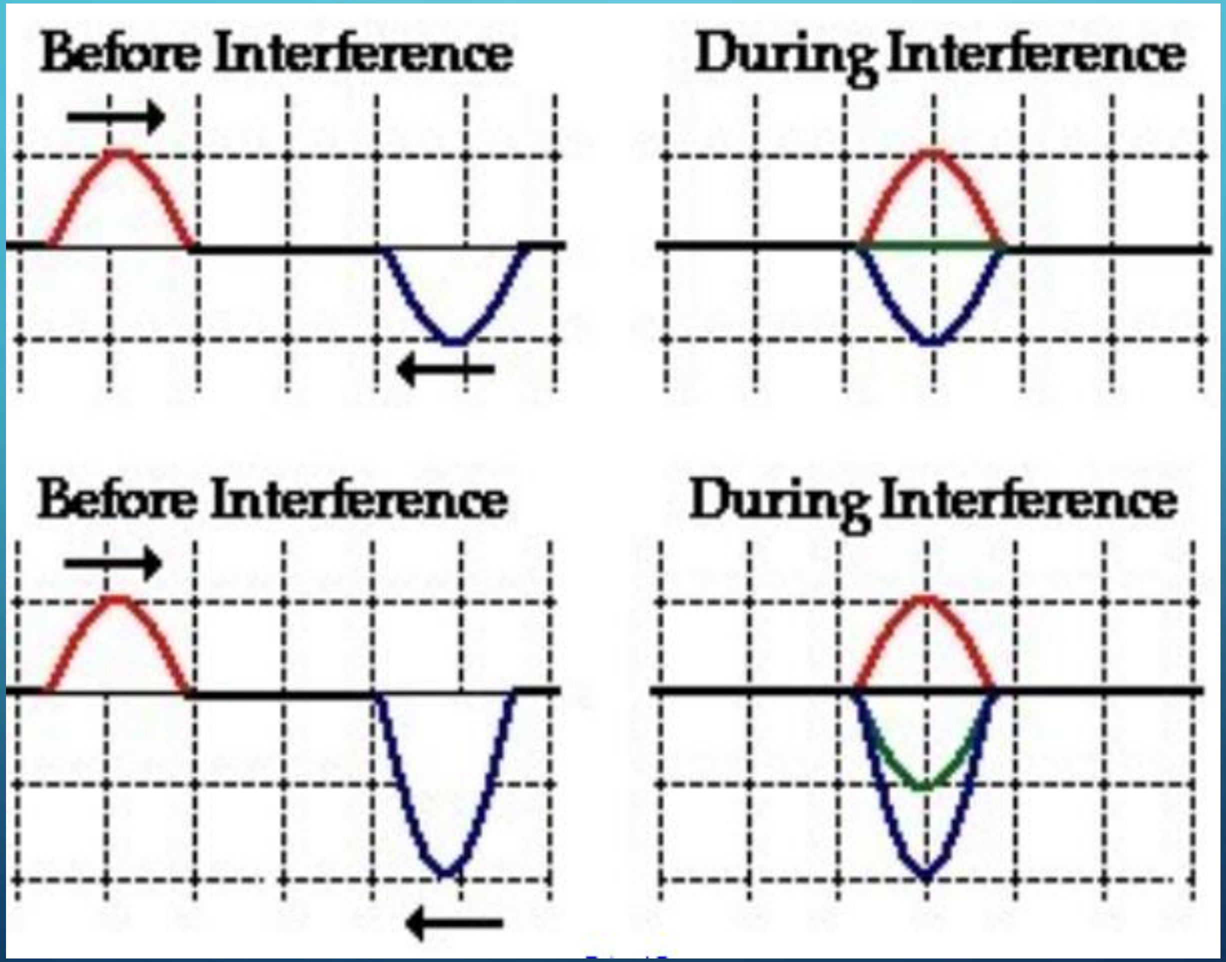
CONSTRUCTIVE INTERFERENCE

- Results when who or more waves interfere to produce a resultant displacement greater than the displacement caused by either wave itself.



DESTRUCTIVE INTERFERENCE

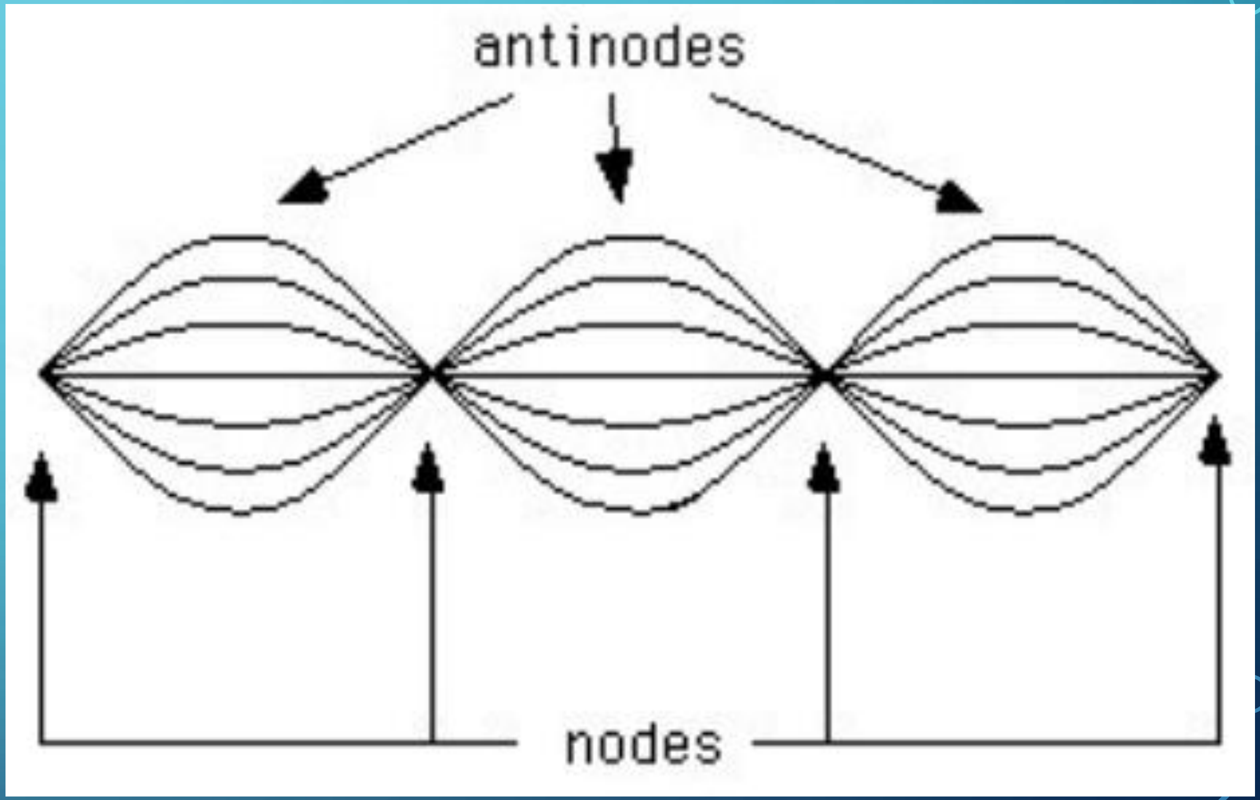
- When the resultant displacement is smaller than the displacement that would be caused by one wave by itself.



STANDING WAVES

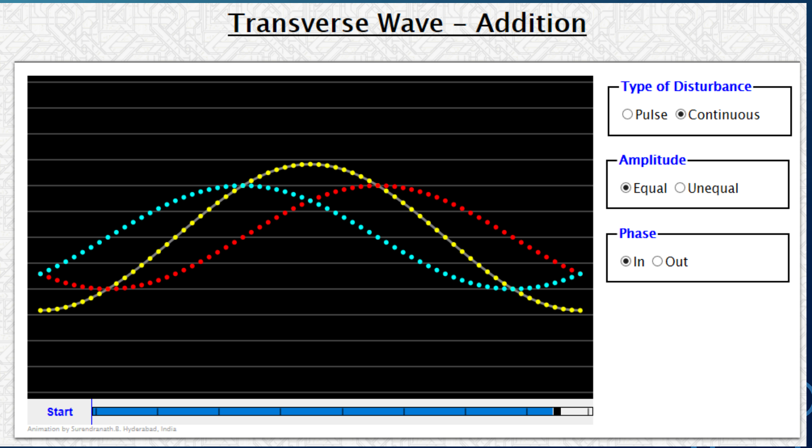
- An interference pattern that occurs if interfering waves have the same amplitude, wavelength, frequency and are traveling in different directions.
- Creates special points or lines called ***nodes*** and ***antinodes***.
  - Nodal points or nodal lines are places of continuous total destructive interference.
  - The particles experience no displacement.

NODES AND ANTINODES



1-D STANDING WAVES

- Along a rope, string, rod or wire (etc.).
- When plucked or struck, a wire will vibrate at its natural frequency (like a guitar or piano wire).
- Changing the tension in the wire (tuning) changes the natural frequency of the wire because that changes the waves' speed. The wavelength is the length of the wire.



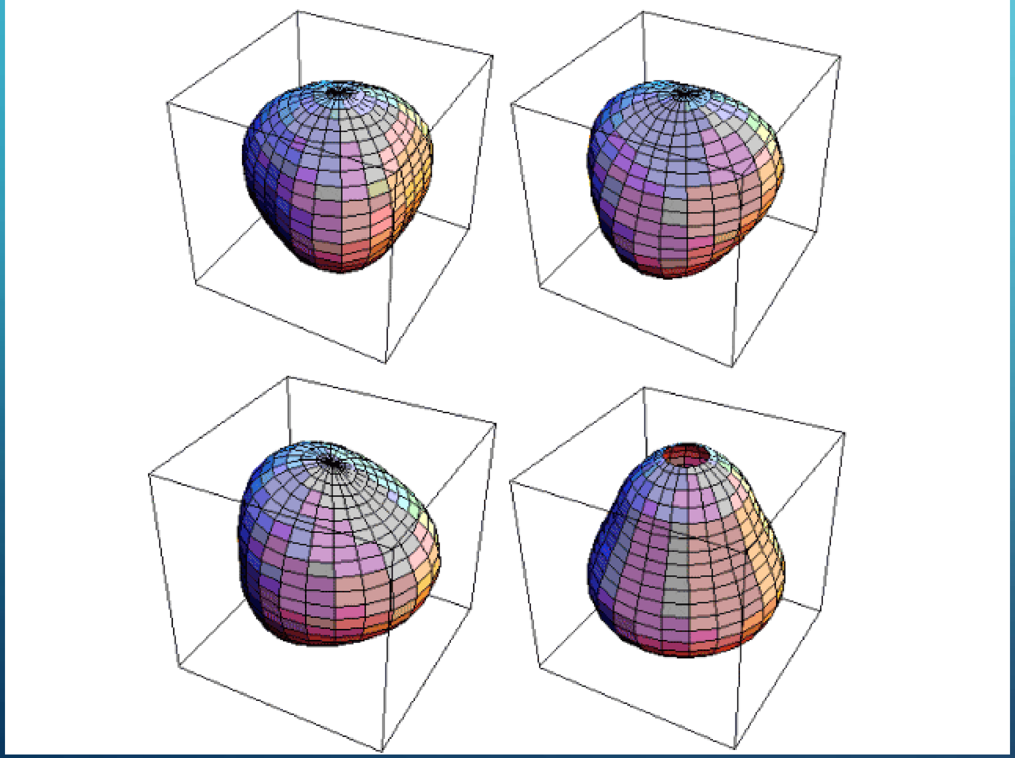
2-D STANDING WAVES

- Along a surface like a thin sheet of metal.
- When struck, a sheet will vibrate at its natural frequency.
- Many interference patterns can be visualized by controlling the frequency.

Also has a resonant effect.

3-D STANDING WAVES

- Within or through a 3-D object.
- Asteroseismology is an example.
- And structures.



Also has a resonant effect.