DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS

AP PHYSICS

LSN 11-7: WAVE MOTION
LSN 11-8: TYPES OF WAVES; LONGITUDINAL AND TRANSVERSE
LSN 11-9: ENERGY TRANSPORTED BY WAVES

Physics of Waves

Questions From Reading Activity?

Big Idea(s):

- *Waves can transfer energy and momentum from one location to another without the permanent transfer of mass and serve as a mathematical model for the description of other phenomena.*

Enduring Understanding(s):

- A wave is a traveling disturbance that transfers energy and momentum.
- A periodic wave is one that repeats as a function of both time and position and can be described by its amplitude, frequency, wavelength, speed, and energy.

Essential Knowledge(s):

- Waves can propagate via different oscillation modes such as transverse and longitudinal.
  - Mechanical waves can be either transverse or longitudinal. Examples should include waves on a stretched string and sound waves.
- For propagation, mechanical waves require a medium, while electromagnetic waves do not require a physical medium. Examples should include light traveling through a vacuum and sound not traveling through a vacuum.

Essential Knowledge(s):

- The amplitude is the maximum displacement of a wave from its equilibrium value.
- Classically, the energy carried by a wave depends upon and increases with amplitude. Examples should include sound waves.

Essential Knowledge(s):

- For a periodic wave, the period is the repeat time of the wave. The frequency is the number of repetitions of the wave per unit time.
- For a periodic wave, the wavelength is the repeat distance of the wave.

Essential Knowledge(s):

- A simple wave can be described by an equation involving one sine or cosine function involving the wavelength, amplitude, and frequency of the wave.
- For a periodic wave, wavelength is the ratio of speed over frequency.
- The observed frequency of a wave depends on the relative motion of source and observer. This is a qualitative treatment only.

Learning Objective(s):

- The student is able to use a visual representation to construct an explanation of the distinction between transverse and longitudinal waves by focusing on the vibration that generates the wave.
- The student is able to describe representations of transverse and longitudinal waves.

Learning Objective(s):

- The student is able to analyze data (or a visual representation) to identify patterns that indicate that a particular mechanical wave is polarized and construct an explanation of the fact that the wave must have a vibration perpendicular to the direction of energy propagation.
- The student is able to describe sound in terms of transfer of energy and momentum in a medium and relate the concepts to everyday examples.

Learning Objective(s):

- The student is able to contrast mechanical and electromagnetic waves in terms of the need for a medium in wave propagation.
- The student is able to use graphical representation of a periodic mechanical wave to determine the amplitude of the wave.

Learning Objective(s):

- The student is able to explain and/or predict qualitatively how the energy carried by a sound wave relates to the amplitude of the wave, and/or apply this concept to a real-world example.
- The student is able to use a graphical representation of a periodic mechanical wave (position versus time) to determine the period and frequency of the wave and describe how a change in the frequency would modify features of the representation.

Learning Objective(s):

- The student is able to use a visual representation of a periodic mechanical wave to determine wavelength of the wave.
- The student is able to construct an equation relating the wavelength and amplitude of a wave from a graphical representation of the electric or magnetic field value as a function of position at a given time instant and vice versa, or construct an equation relating the frequency or period and amplitude of a wave from a graphical representation of the electric or magnetic field value at a given position as a function of time and vice versa.

Learning Objective(s):

- The student is able to design an experiment to determine the relationship between periodic wave speed, wavelength, and frequency and relate these concepts to everyday examples.
- The student is able to create or use a wave front diagram to demonstrate or interpret qualitatively the observed frequency of a wave, dependent upon relative motions of source and observer.

Properties of Waves

What is a wave?

- Video: Pulses and Waves

What is a wave?

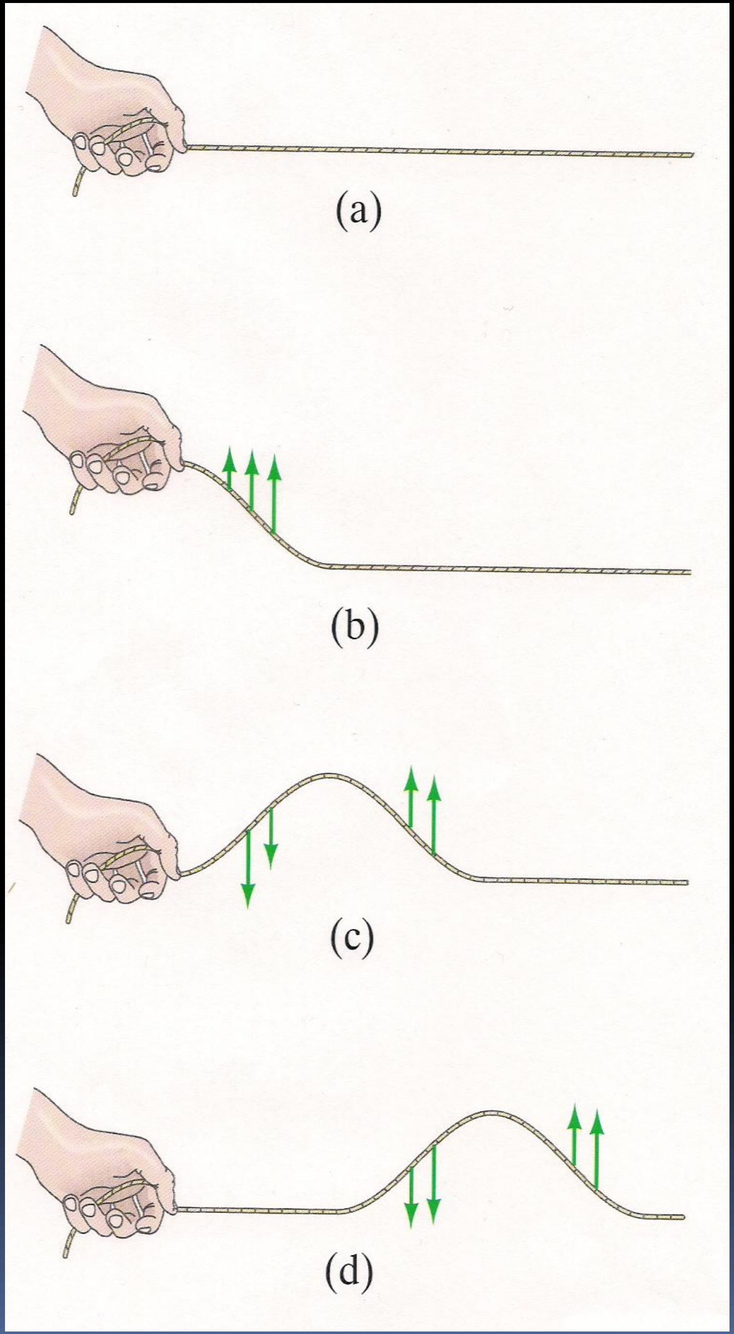
- Examples:
  - Life is a beach
  - Light from the sun
  - Soprano breaking a glass
  - Light travels in a vacuum – no medium required – an ***electromagnetic*** wave
  - Sound and water require a medium – ***mechanical*** waves

What is a wave?

- Waves occur because something is disturbed (some thing not someone)
- *A wave is a disturbance that travels, transferring energy and momentum from one place to another, but without the actual large-scale motion of a material body. The direction of energy transfer is the direction of propagation of the wave.*

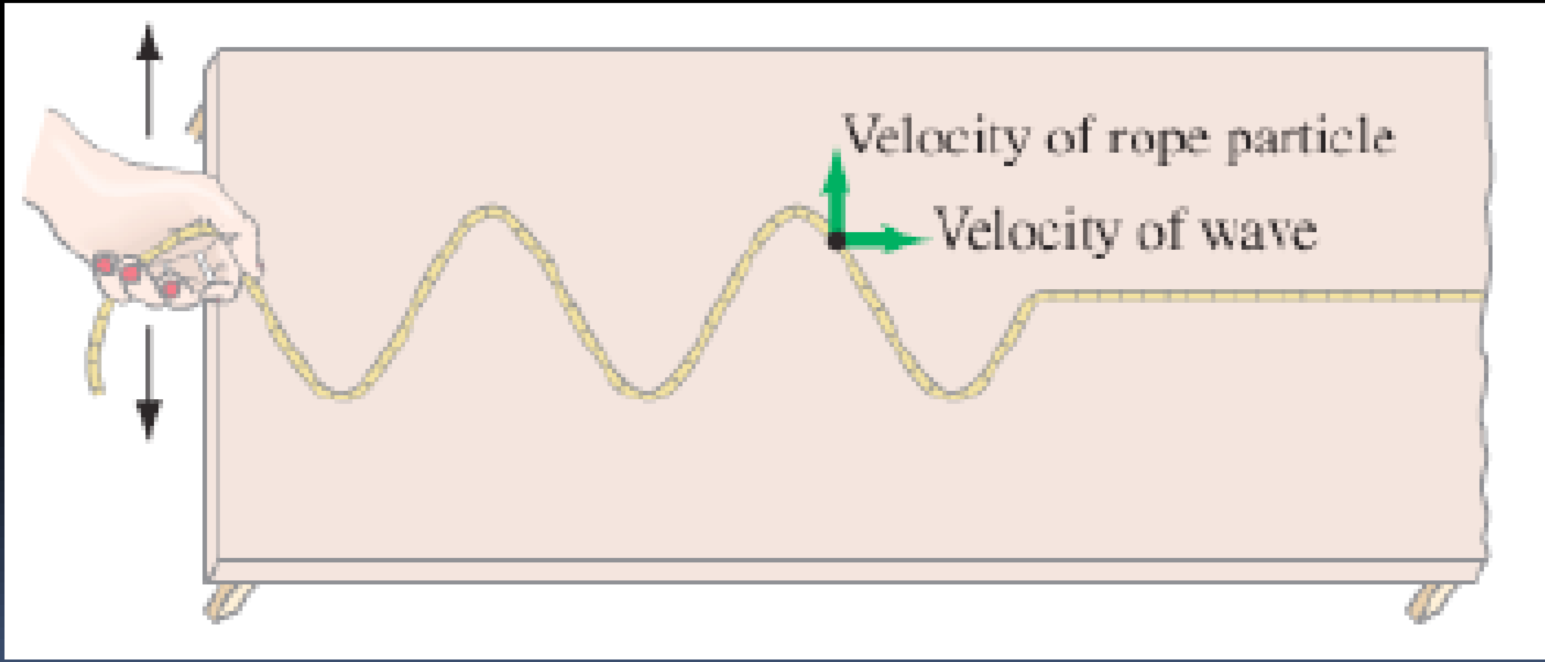
Wave pulses

- rope tricks
  - half-pulse vs. full pulse



Wave pulses

- **Wave pulses travel with a given speed**



Wave pulses

- **Wave pulses travel with a given speed**
  - speed is distance divided by time
  - period is defined as the time it takes one complete pulse (one wavelength) to pass a given point
  - so wave speed can be defined as,

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

or

$$f = \frac{1}{T}$$

$$v = \lambda f$$

Wave pulses

- Wave pulses travel with a given speed
  - wave speed in a rope is determined by the tension in the rope and mass per unit length, $\mu = m/L$

$$v = \sqrt{\frac{T}{\mu}}$$

$$v = \sqrt{\frac{F_T}{m/L}}$$

Wave pulses

- Wave pulses travel with a given speed
  - *the speed of the wave is determined by the properties of the medium and not by how the wave is created*,
  - i.e. independent of shape or how fast you produced it

Harmonic/Continuous/Periodic Waves

- Source is a disturbance that is continuous and oscillating – a vibration
- If the source vibrates sinusoidally, the wave will exhibit SHM

Harmonic/Continuous/Periodic Waves

- ***<u>Definitions:</u>***
  - ***<u>amplitude (A):</u> maximum height of a crest or depth of a trough relative to the equilibrium level***
  - ***<u>wavelength (λ)</u>*** **– length of a wave (surprise!), distance between any two successive, identical points on a wave**

Harmonic/Continuous/Periodic Waves

- ***Definitions:***
  - ***frequency (f)*** – number of crests (or complete cycles) per unit time
    - equal to 1/T
    - unit is s^{-1} or Hz
  - ***period (T)*** – time to complete one full wave or cycle
    - equal to 1/f
    - unit is s

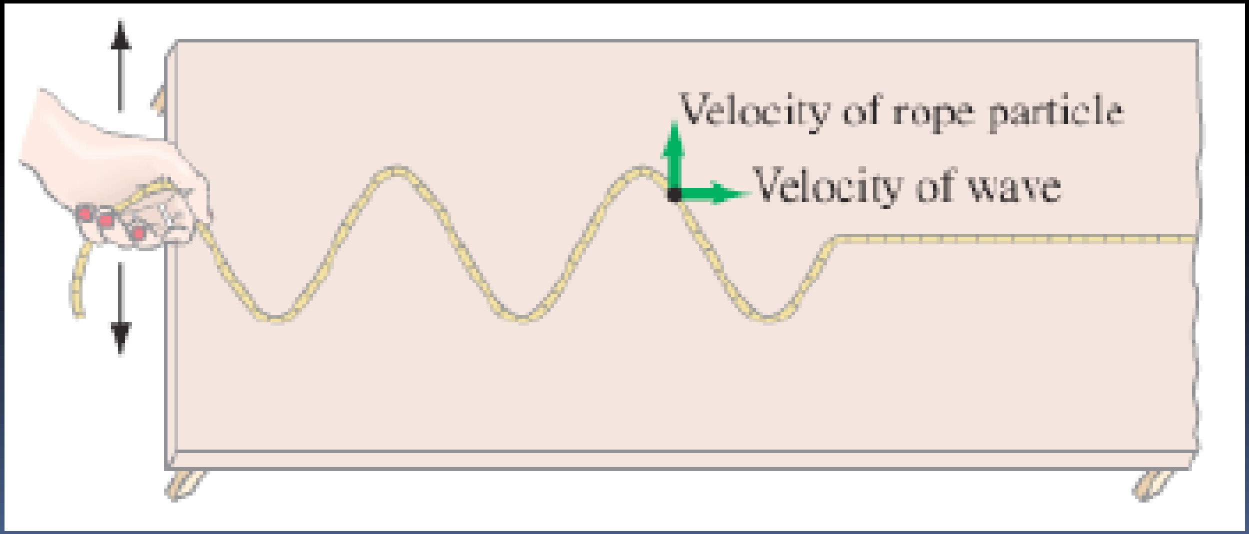
Harmonic/Continuous/Periodic Waves

- ***Definitions:***
  - ***velocity (v)*** **– equal to one wavelength (m) per the period (s)**

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

$$f = \frac{1}{T}$$

$$v = \lambda f$$



Harmonic/Continuous/Periodic Waves

- ***Definitions:***
  - ***displacement (y)*** **– height obtained above or below the undisturbed point due to the disturbance**
    - **it is a function of the distance (x) and time (t)**
    - **amplitude is max displacement**

Sample Problem

- *WQYK broadcasts at a frequency of 99.5 MHz. What is the wavelength of the waves emitted? (Since they are electromagnetic waves, they travel at the speed of light, $3x10^8$ m/s)*

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$$f = 99.5x10^6 \cdot s^{-1}$$

$$v = \lambda f$$

$$\lambda = \frac{v}{f} = \frac{3x10^8 m/s}{99.5x10^6 \cdot s^{-1}} = 3.02m$$

Sample Problem #2

- *A sound wave of frequency 450Hz is emitted from A and travels towards B, a distance of 150m away. Take the speed of sound to be 341 m s^{-1} . How many wavelengths fit in the distance from A to B?*

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$$f = 450 \cdot s^{-1}$$

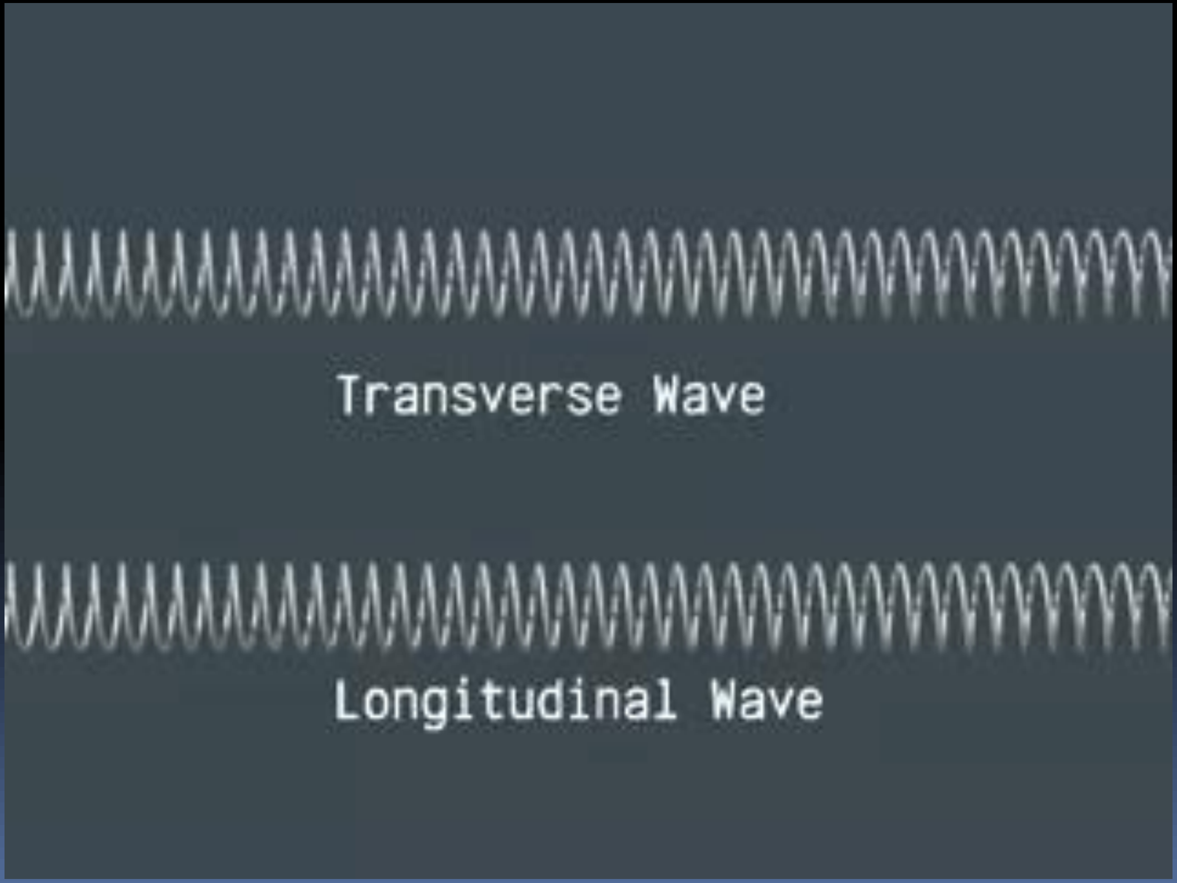
$$v = 341 m / s$$

$$\lambda = \frac{v}{f} = \frac{341 m / s}{450 \cdot s^{-1}} = 0.758 m$$

$$\frac{150}{0.758} = 198 wavelengths$$

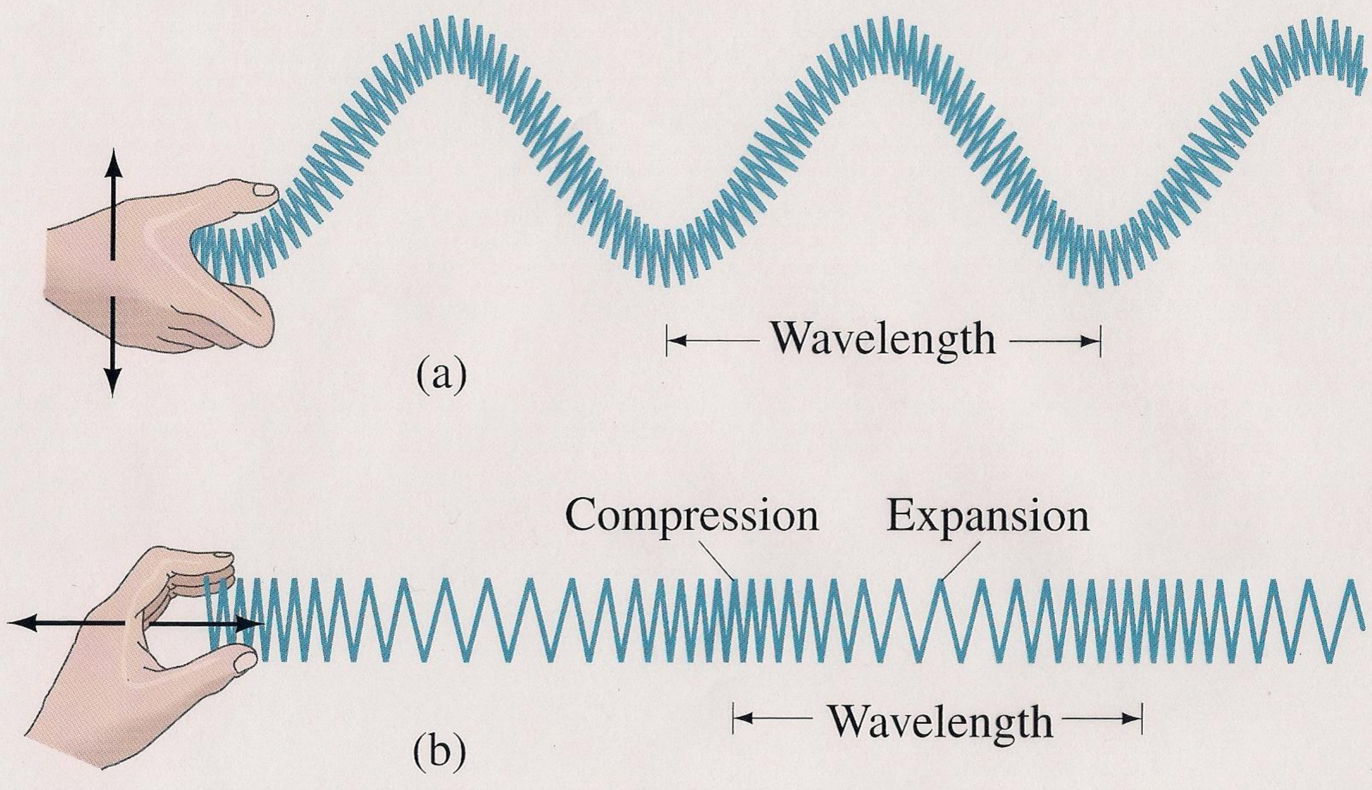
Transverse and Longitudinal Waves

- Video: Longitudinal and Transverse Waves



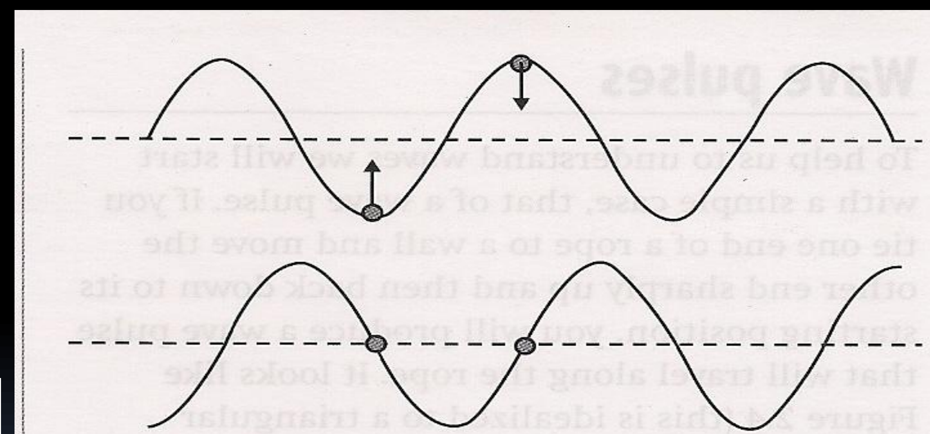
Transverse and Longitudinal Waves

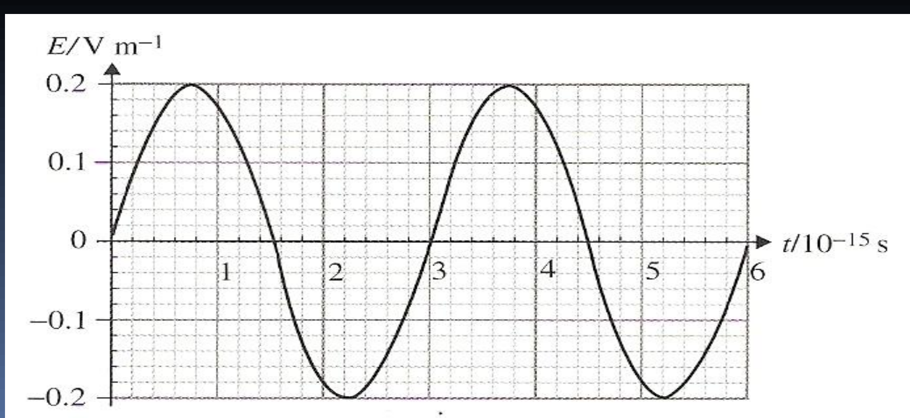
Figure 11-24 (a) Transverse wave; (b) longitudinal wave



Transverse and Longitudinal Waves

- ***Transverse*** **– waves in which the disturbance is at right angles to the direction of energy transfer**
  - **rope tricks**
  - **Electromagnetic waves**





Transverse and Longitudinal Waves

- ***Longitudinal*** **-- waves in which the disturbance is along the direction of energy transfer**
  - ***dominos***
  - **sound waves**

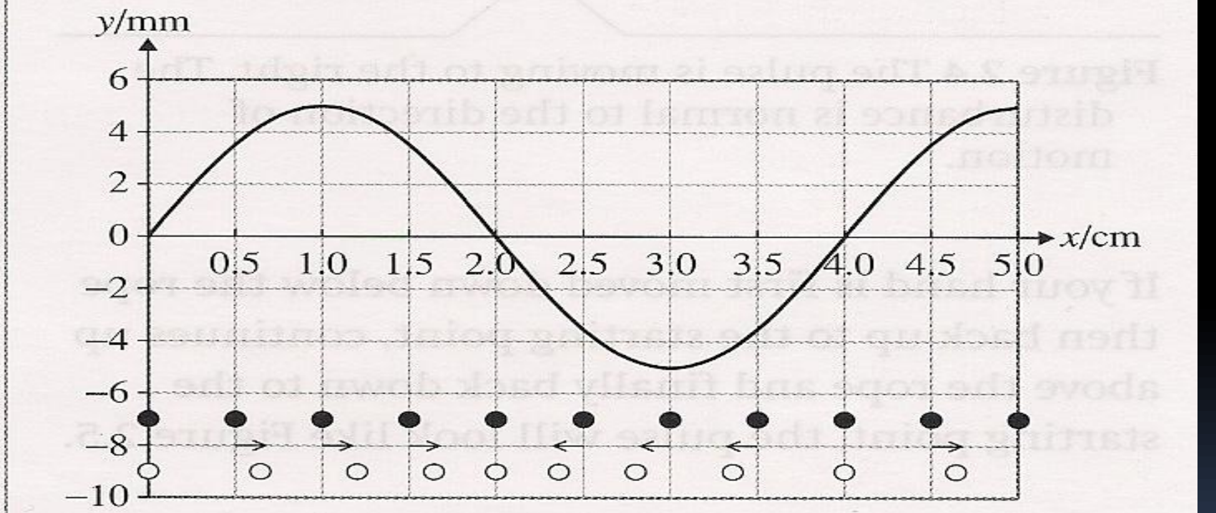


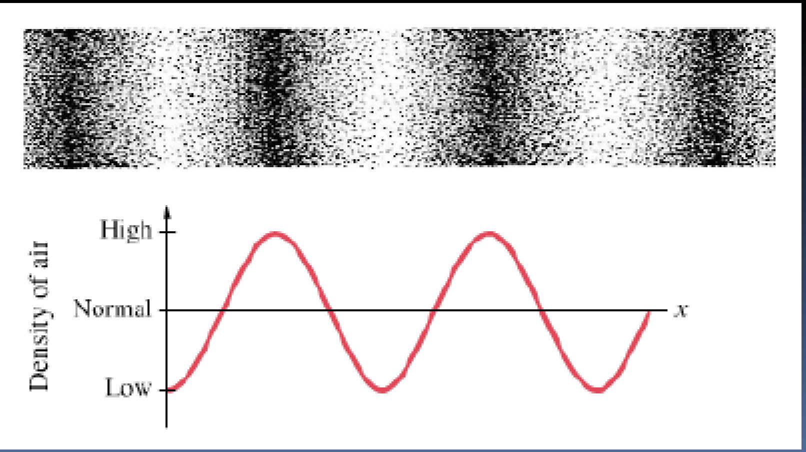
Figure 2.2 The black dots represent air molecules when no wave is present. The uncoloured dots below represent the positions of these molecules at the instant the wave shown by the graph passes.

Transverse and Longitudinal Waves

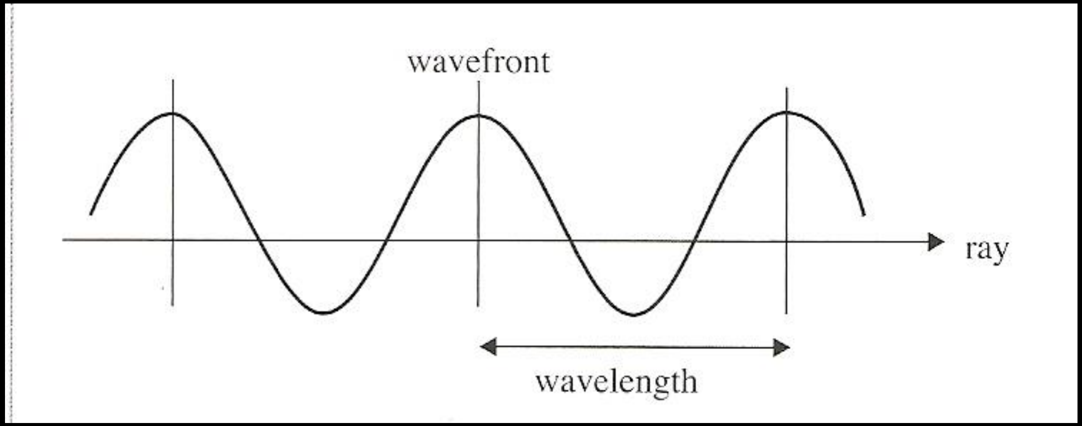
- ***Longitudinal*** **-- waves in which the disturbance is along the direction of energy transfer**
  - **energy propagated through a series of *compressions* (region of higher than normal density) and *expansions* or *rarefactions* (region of lower than normal density)**

Transverse and Longitudinal Waves

- ***Longitudinal*** **-- waves in which the disturbance is along the direction of energy transfer**
  - **When wave movement is dependent on the medium (like for sound [compression] waves), displacement is given in terms of density or in terms of pressure**



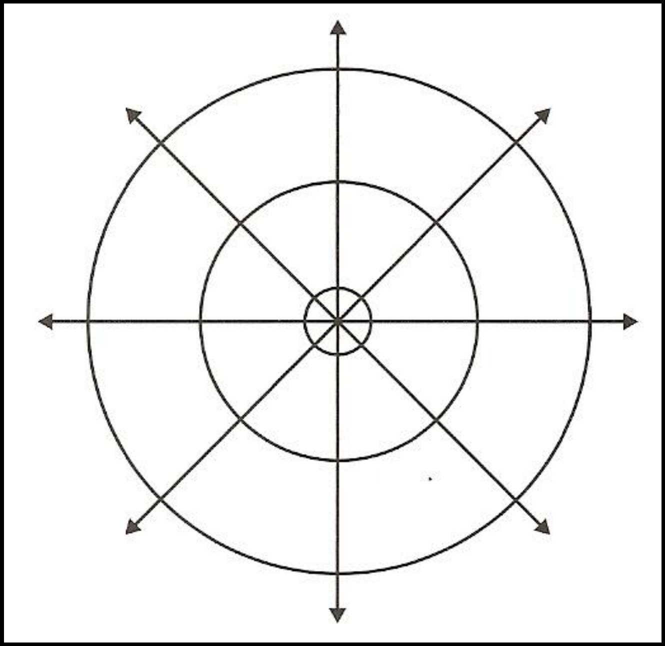
Wave Propagation

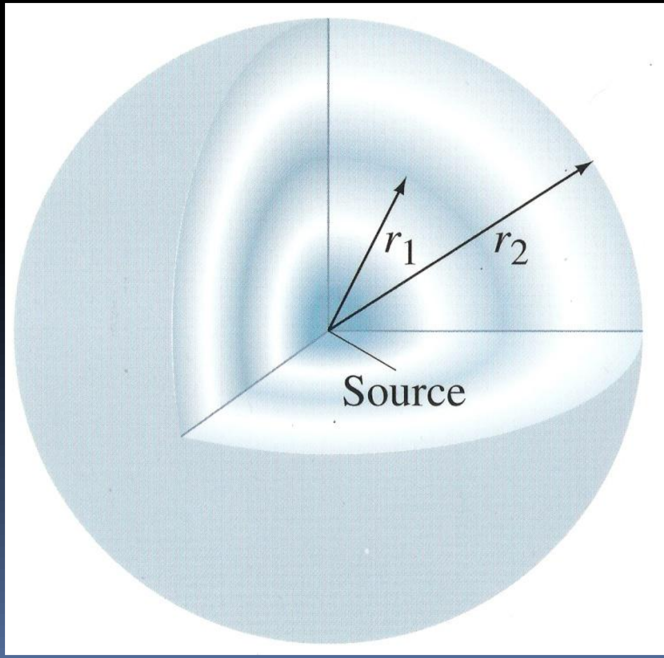


- When we study the characteristics of waves, we tend to think of them one-dimensionally
  - Rays instead of wavefronts

Wave Propagation

- Most waves actually are propagated in multiple directions simultaneously
  - Pebble in a pond
  - Sound waves
  - Light waves





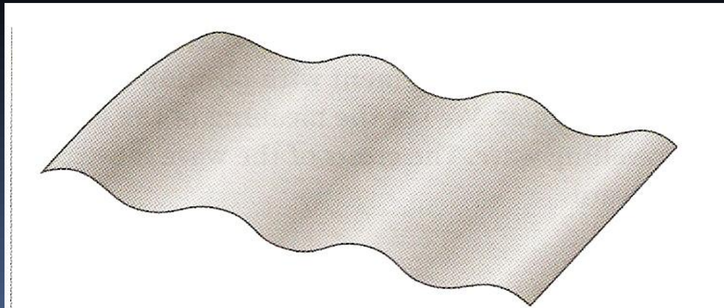
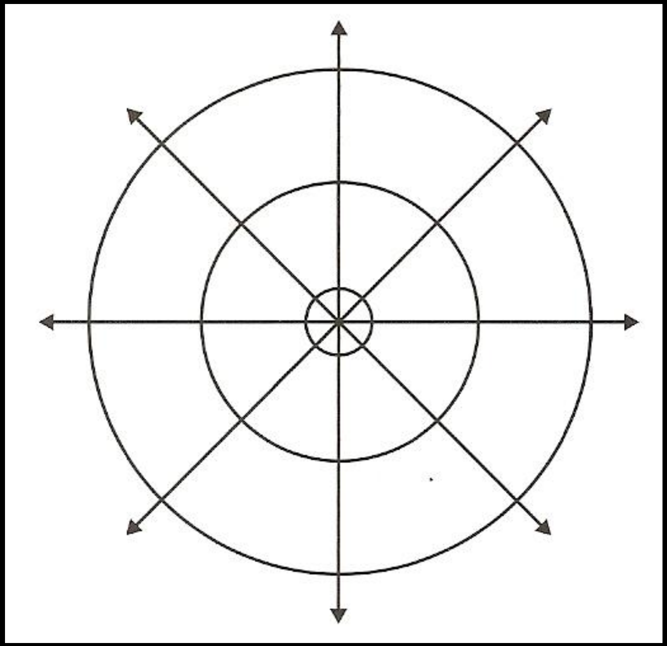
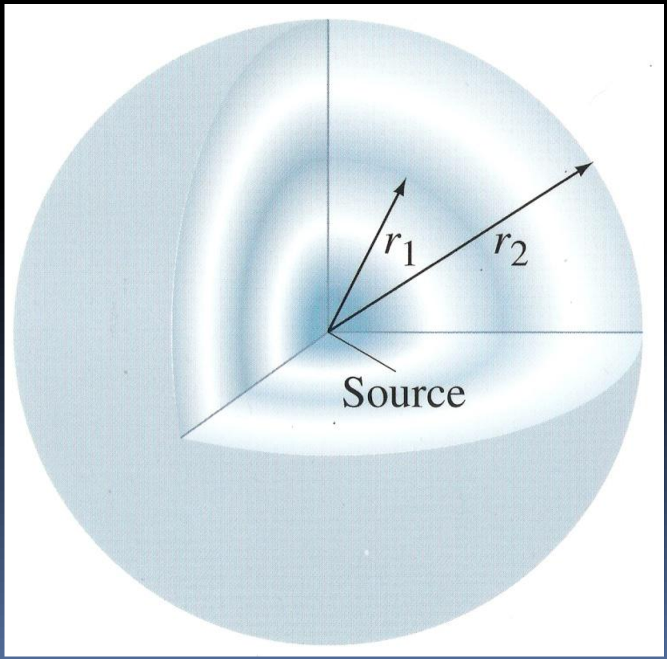


Figure 2.17 A two-dimensional wave.

Wave Propagation

- Wave propagation is all about propagation of ***energy***
- As waves spread out, the energy also spreads out
- Same energy over a larger area means a drop in intensity





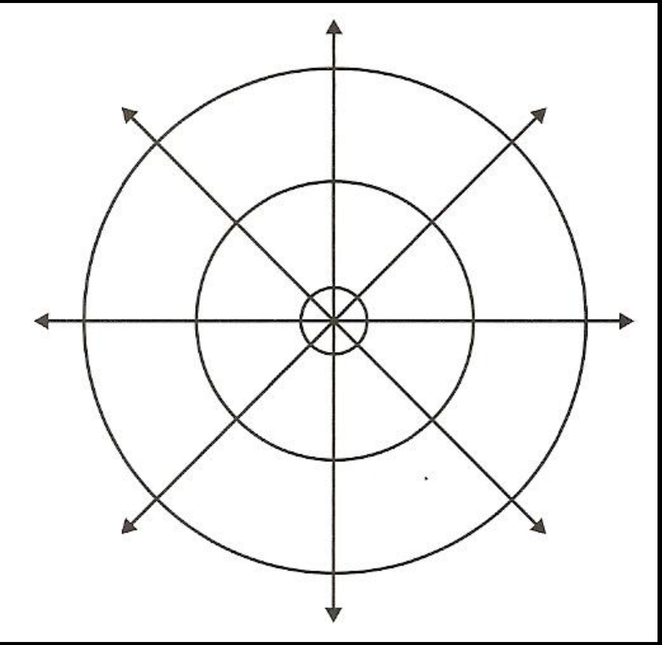
Wave Propagation

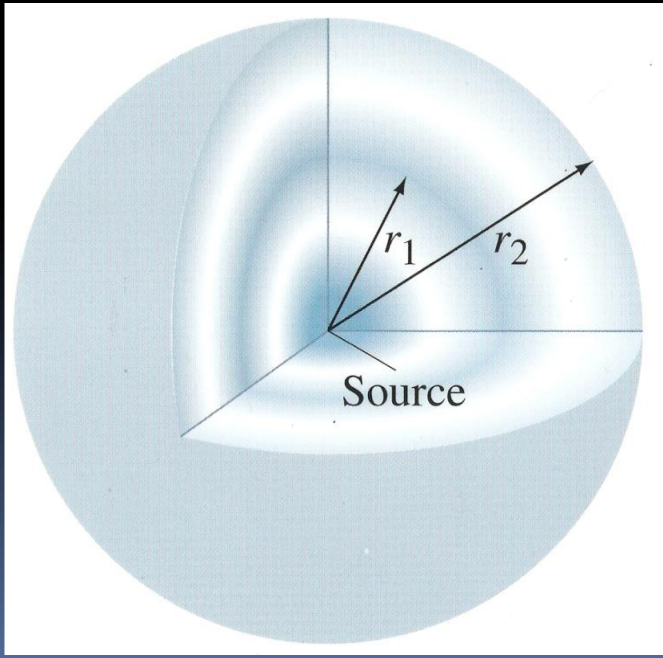
- For particles exhibiting SHM,

$$E = \frac{1}{2} k A^2$$

- Energy is a function of amplitude so,
- ***The energy transported by a wave is proportional to the square of the amplitude***

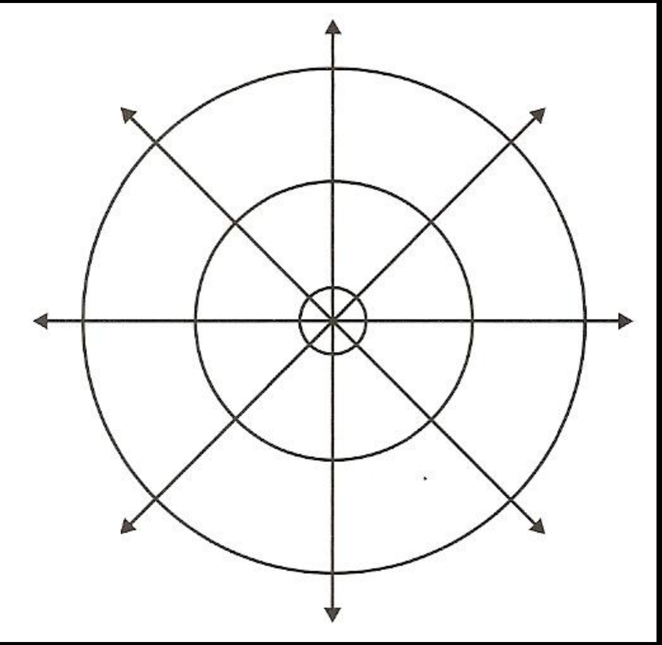
$$E \propto A^2$$





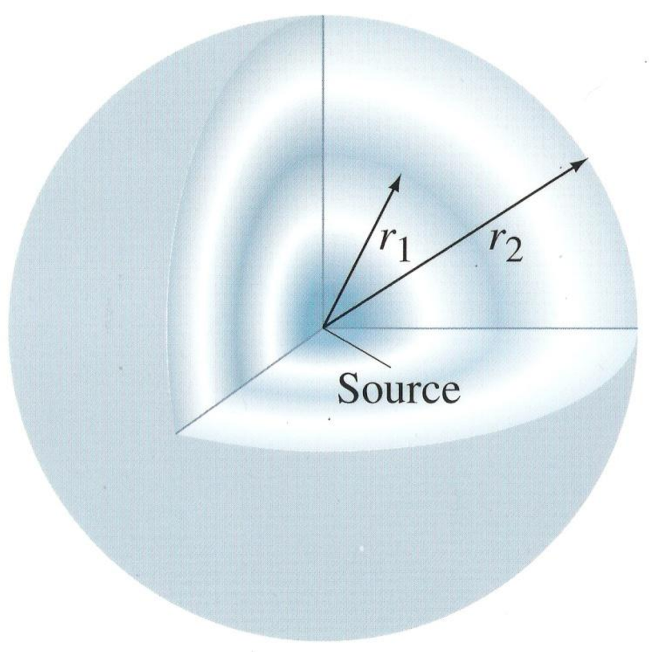
Wave Propagation

- Intensity – *The power (energy per unit time) transported across a unit area perpendicular to the direction of energy flow.*



$$I = \frac{energy\,/\,time}{area} = \frac{power}{area}$$

$$I \propto A^2$$

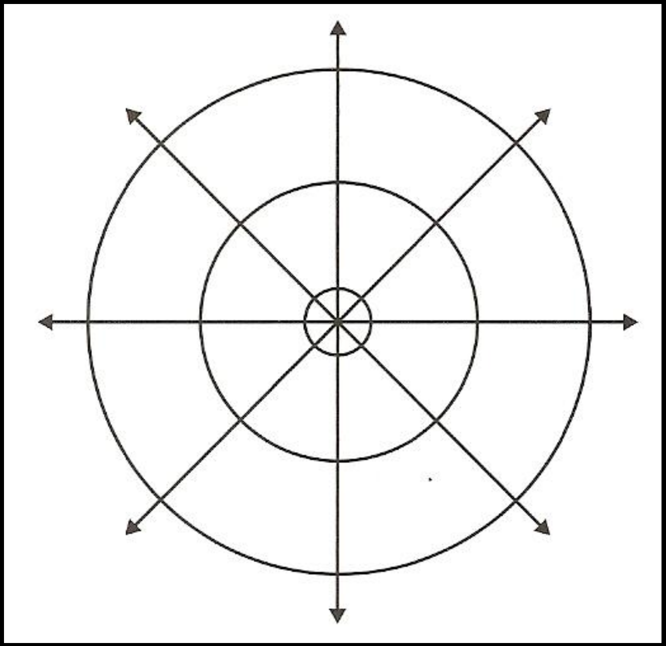


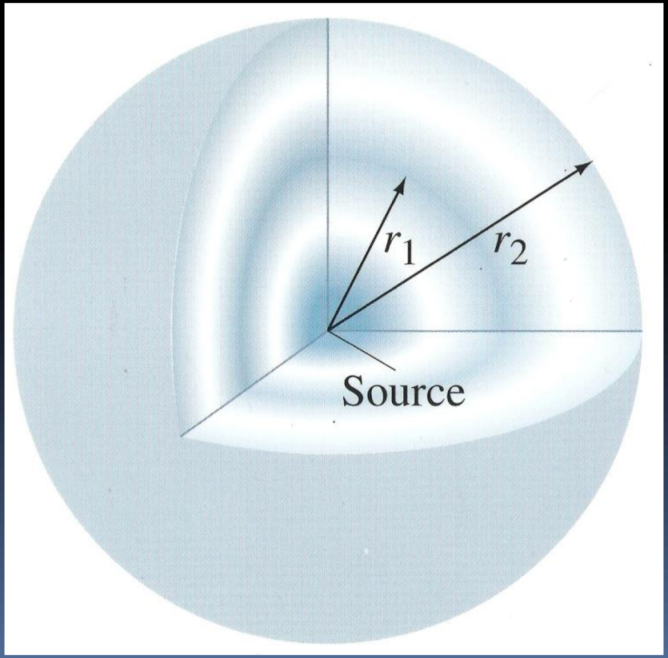
Wave Propagation

- Spherical Wave – *A wave that spreads out symmetrically in all directions from its source.*

$$I = \frac{power}{area} = \frac{P}{4\pi r^2}$$

$$I \propto \frac{1}{r^2}$$





Wave Propagation

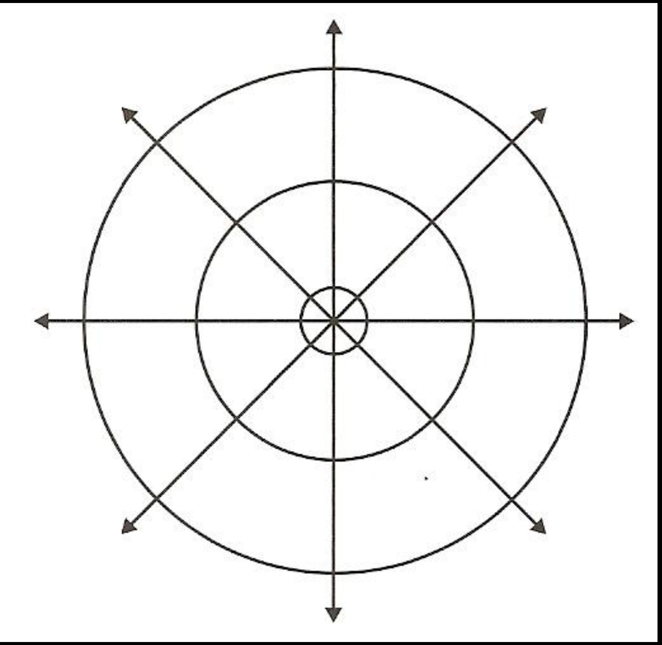
$$I = \frac{P}{4\pi r^2}$$

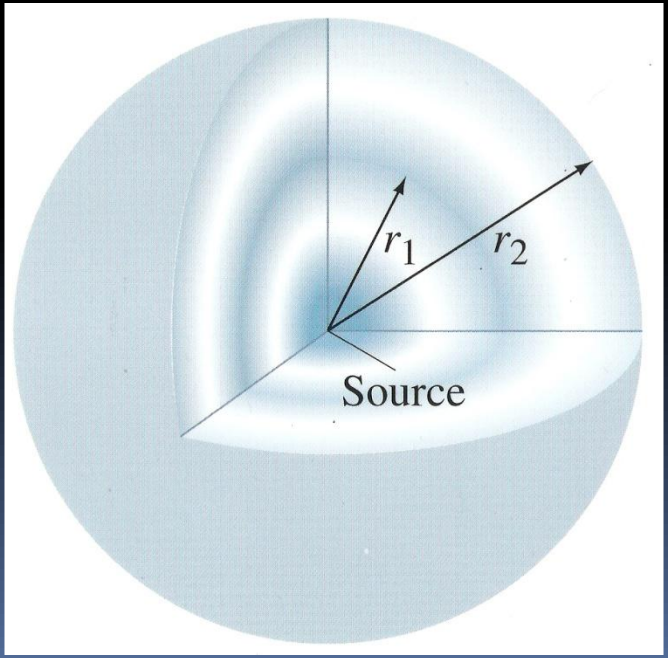
$$I\left(4\pi r^2\right) = P$$

$$P_1 = P_2$$

$$I_1 r_1^{\,2} = I_2 r_2^{\,2}$$

$$\frac{I_1}{I_2} = \frac{r_2^{\,2}}{r_1^{\,2}}$$





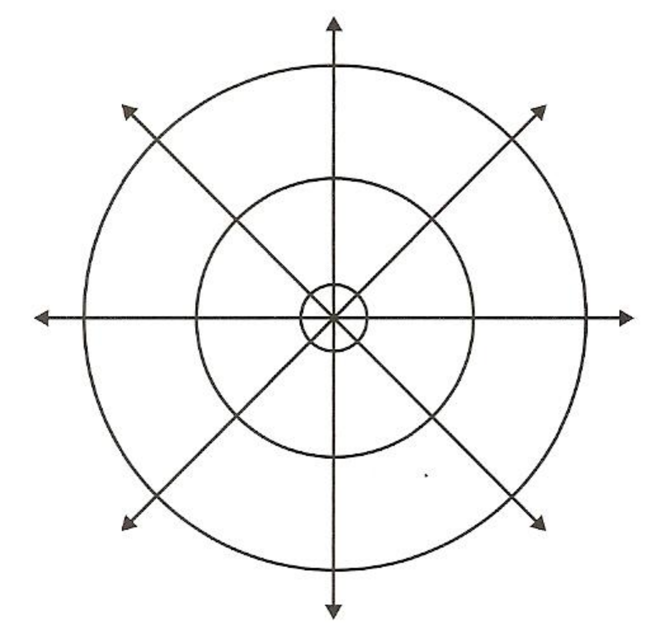
Wave Propagation

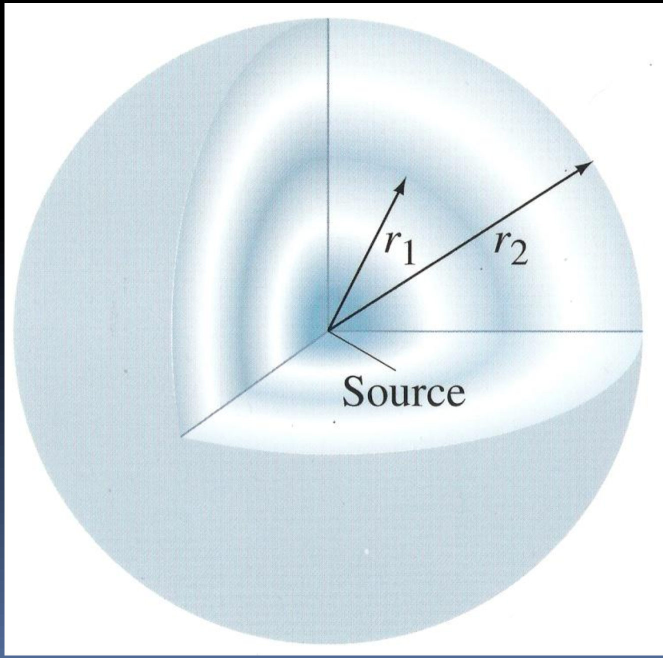
$$I \propto A^2$$

$$I \propto \frac{1}{r^2}$$

$$A^2 \propto \frac{1}{r^2}$$

$$A \propto \frac{1}{r}$$

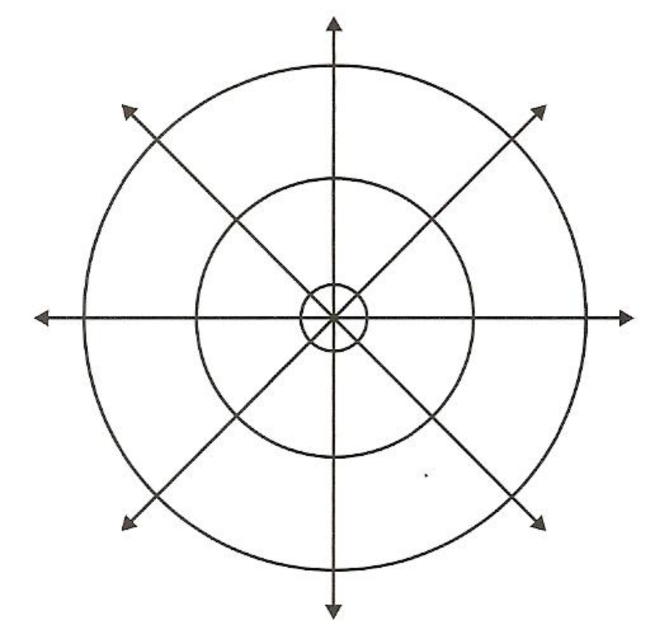


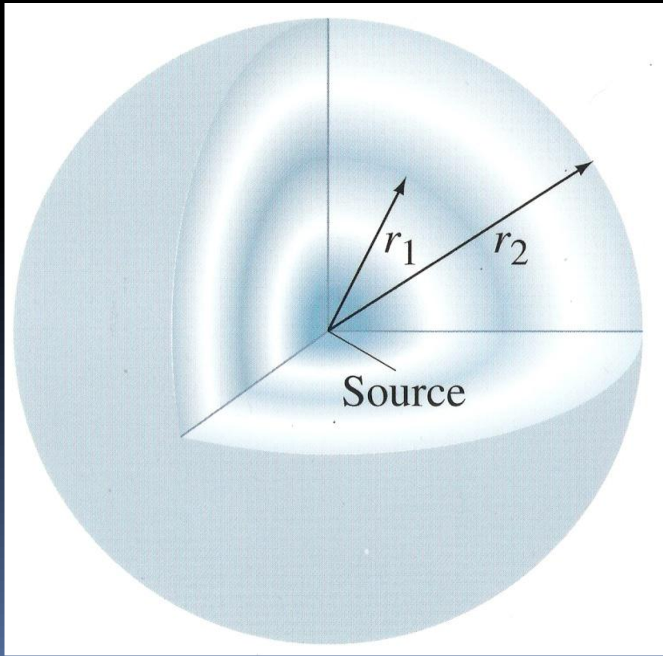


Wave Propagation

$$A \propto \frac{1}{r}$$

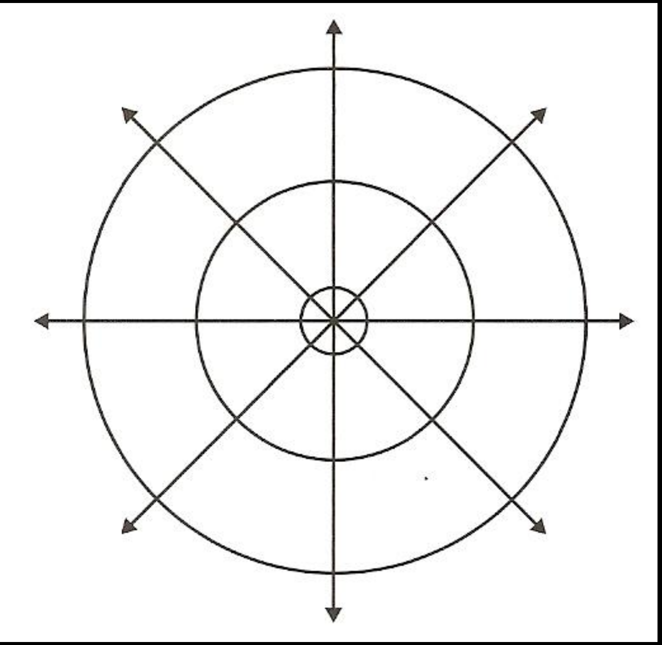
$$\frac{A_2}{A_1} = \frac{r_1}{r_2}$$

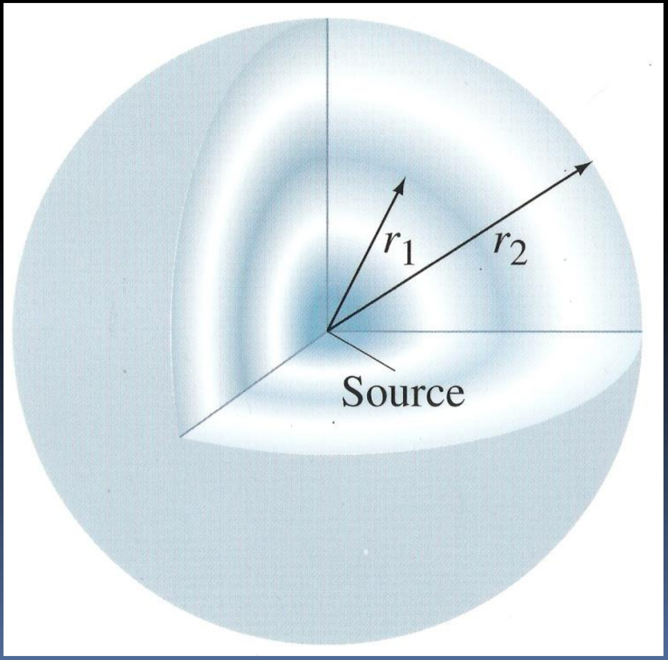




Wave Propagation – One-Dimension

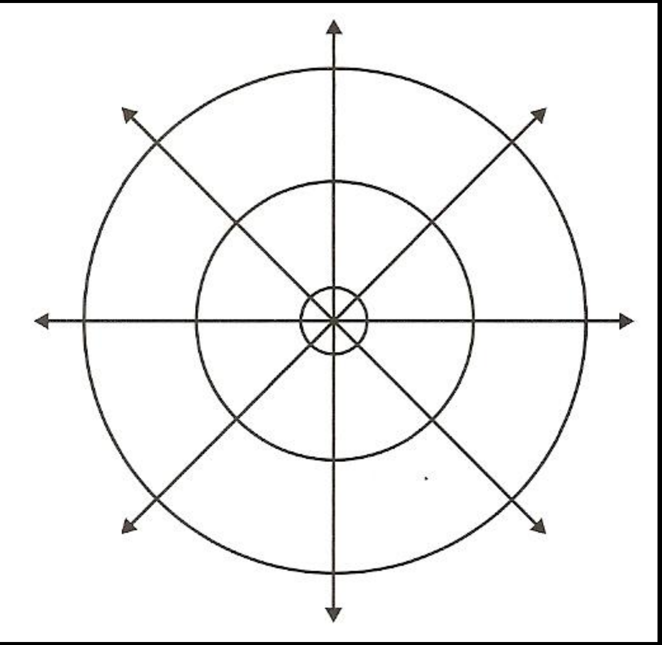
- *What's different for a one-dimensional wave like along a solid bar or within a tube?*

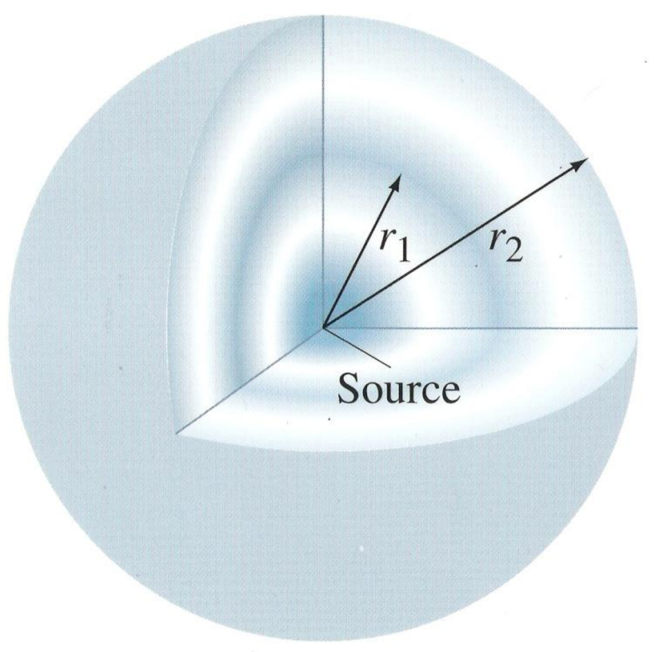




Wave Propagation – One-Dimension

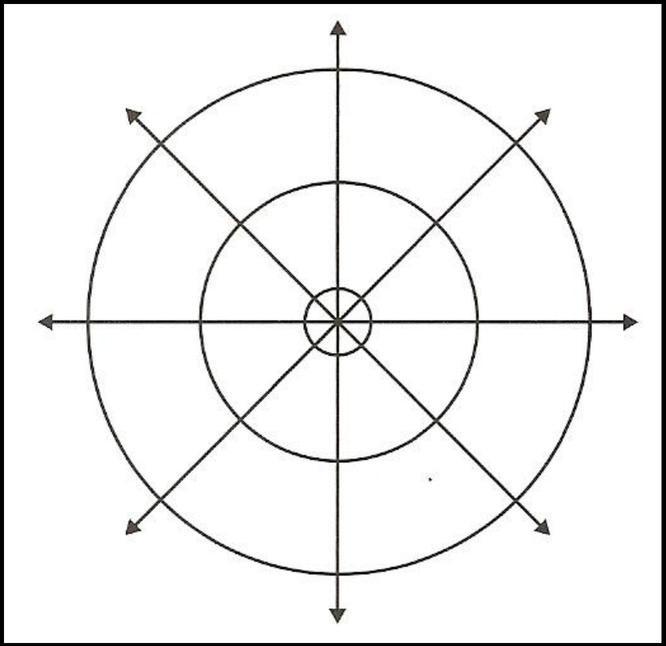
- *What's different for a one-dimensional wave like along a solid bar or on a string?*
  - ***Area remains constant***
  - ***Amplitude remains constant so,***
  - ***Intensity remains constant***

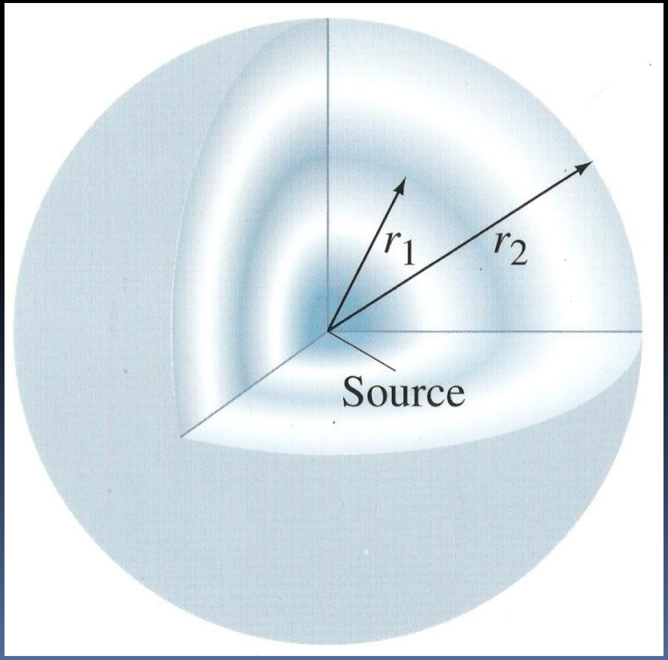




Wave Propagation – Real Life

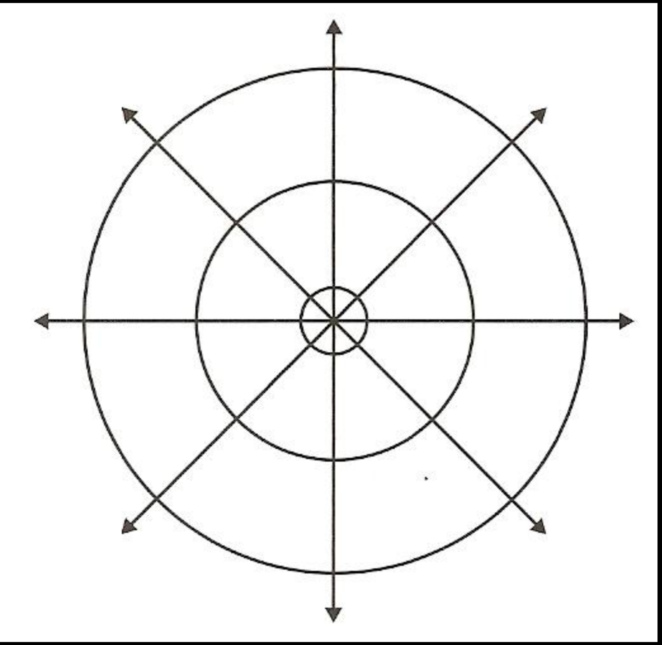
- *What's different in real life?*

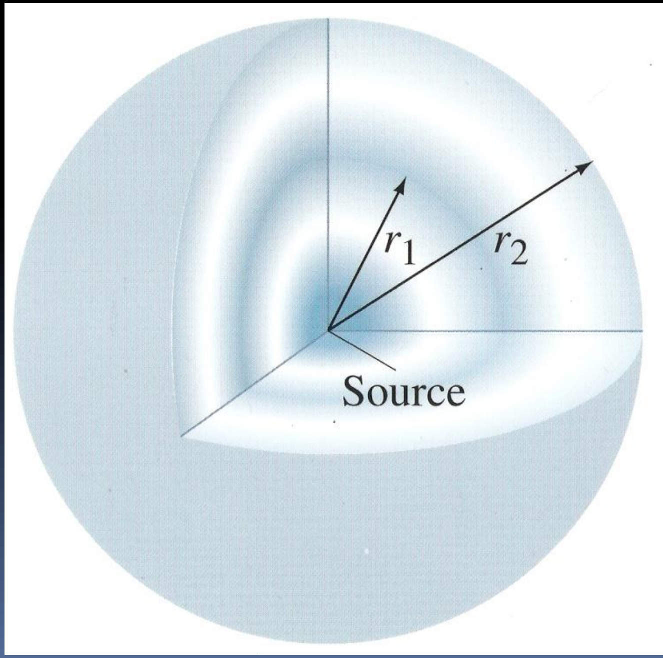




Wave Propagation – Real Life

- *What's different in real life?*
  - ***Frictional damping***
  - ***Amplitude, energy and intensity DO decrease in one dimensional waves***
  - ***Intensity decreases more than the equations predict for spherical waves***





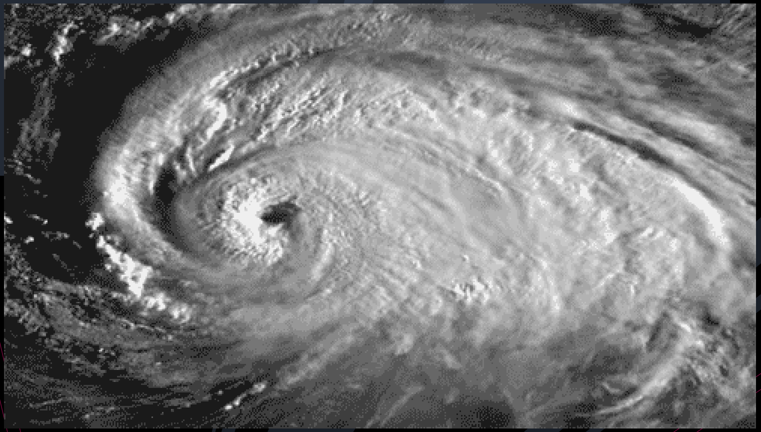
Summary Video

QUESTIONS?

Homework

A-students, #36-44, 46, 47

All others, #36-47, skip 45



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