Student of the Week

DEVIL PHYSICS
THE BADDEST CLASS ON CAMPUS
AP PHYSICS

LSN 11-11: REFLECTION AND TRANSMISSION OF WAVES

LSN 11-12: INTERFERENCE: PRINCIPLES OF SUPERPOSITION

LSN 11-13: STANDING WAVES; RESONANCE

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):

- Only waves exhibit interference and diffraction.
- Interference and superposition lead to standing waves and beats.

Essential Knowledge(s):

- When two waves cross, they travel through each other; they do not bounce off each other. Where the waves overlap, the resulting displacement can be determined by adding the displacements of the two waves. This is called superposition.
- Two or more wave pulses can interact in such a way as to produce amplitude variations in the resultant wave. When two pulses cross, they travel through each other; they do not bounce off each other. Where the pulses overlap, the resulting displacement can be determined by adding the displacements of the two pulses. This is called superposition.

Essential Knowledge(s):

- Two or more traveling waves can interact in such a way as to produce amplitude variations in the resultant wave.
- Standing waves are the result of the addition of incident and reflected waves that are confined to a region and have nodes and antinodes. Examples should include waves on a fixed length of string, and sound waves in both closed and open tubes.

Essential Knowledge(s):

- The possible wavelengths of a standing wave are determined by the size of the region to which it is confined.
  - A standing wave with zero amplitude at both ends can only have certain wavelengths. Examples should include fundamental frequencies and harmonics.
  - Other boundary conditions or other region sizes will result in different sets of possible wavelengths.

Essential Knowledge(s):

- Essential Knowledge 6.D.5: Beats arise from the addition of waves of slightly different frequency.
  - Because of the different frequencies, the two waves are sometimes in phase and sometimes out of phase. The resulting regularly spaced amplitude changes are called beats. Examples should include the tuning of an instrument.
  - The beat frequency is the difference in frequency between the two waves.

Learning Objective(s):

- The student is able to make claims and predictions about the net disturbance that occurs when two waves overlap. Examples should include standing waves.
- The student is able to construct representations to graphically analyze situations in which two waves overlap over time using the principle of superposition.

Learning Objective(s):

- The student is able to use representations of individual pulses and construct representations to model the interaction of two wave pulses to analyze the superposition of two pulses.
- The student is able to design a suitable experiment and analyze data illustrating the superposition of mechanical waves (only for wave pulses or standing waves).

Learning Objective(s):

- The student is able to design a plan for collecting data to quantify the amplitude variations when two or more traveling waves or wave pulses interact in a given medium.
- The student is able to analyze data or observations or evaluate evidence of the interaction of two or more traveling waves in one or two dimensions (i.e., circular wave fronts) to evaluate the variations in resultant amplitudes.

Learning Objective(s):

- The student is able to refine a scientific question related to standing waves and design a detailed plan for the experiment that can be conducted to examine the phenomenon qualitatively or quantitatively.
- The student is able to predict properties of standing waves that result from the addition of incident and reflected waves that are confined to a region and have nodes and antinodes.

Learning Objective(s):

- The student is able to plan data collection strategies, predict the outcome based on the relationship under test, perform data analysis, evaluate evidence compared to the prediction, explain any discrepancy and, if necessary, revise the relationship among variables responsible for establishing standing waves on a string or in a column of air.
- The student is able to describe representations and models of situations in which standing waves result from the addition of incident and reflected waves confined to a region.

Learning Objective(s):

- The student is able to challenge with evidence the claim that the wavelengths of standing waves are determined by the frequency of the source regardless of the size of the region.
- The student is able to use a visual representation to explain how waves of slightly different frequency give rise to the phenomenon of beats.

Learning Objective(s):

- The student is able to calculate wavelengths and frequencies (if given wave speed) of standing waves based on boundary conditions and length of region within which the wave is confined, and calculate numerical values of wavelengths and frequencies. Examples should include musical instruments.

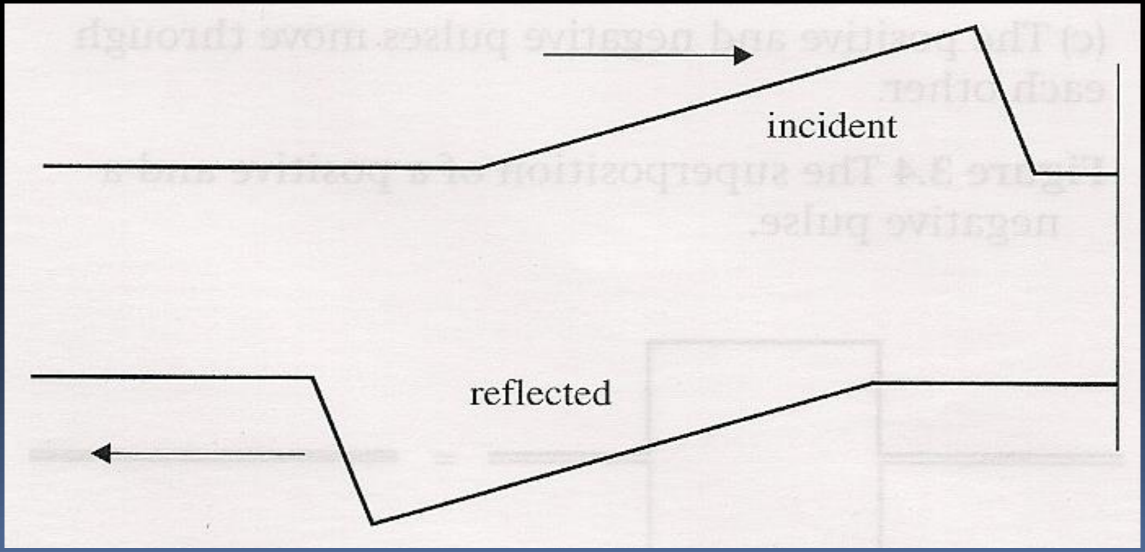
Light Reflection and Refraction

Law of Reflection

- ***What happens to a pulse on a rope tied to a wall?***

Law of Reflection

- ***What happens to a pulse on a rope tied to a wall?***
  - **The pulse reflects inverted and traveling in the opposite direction**

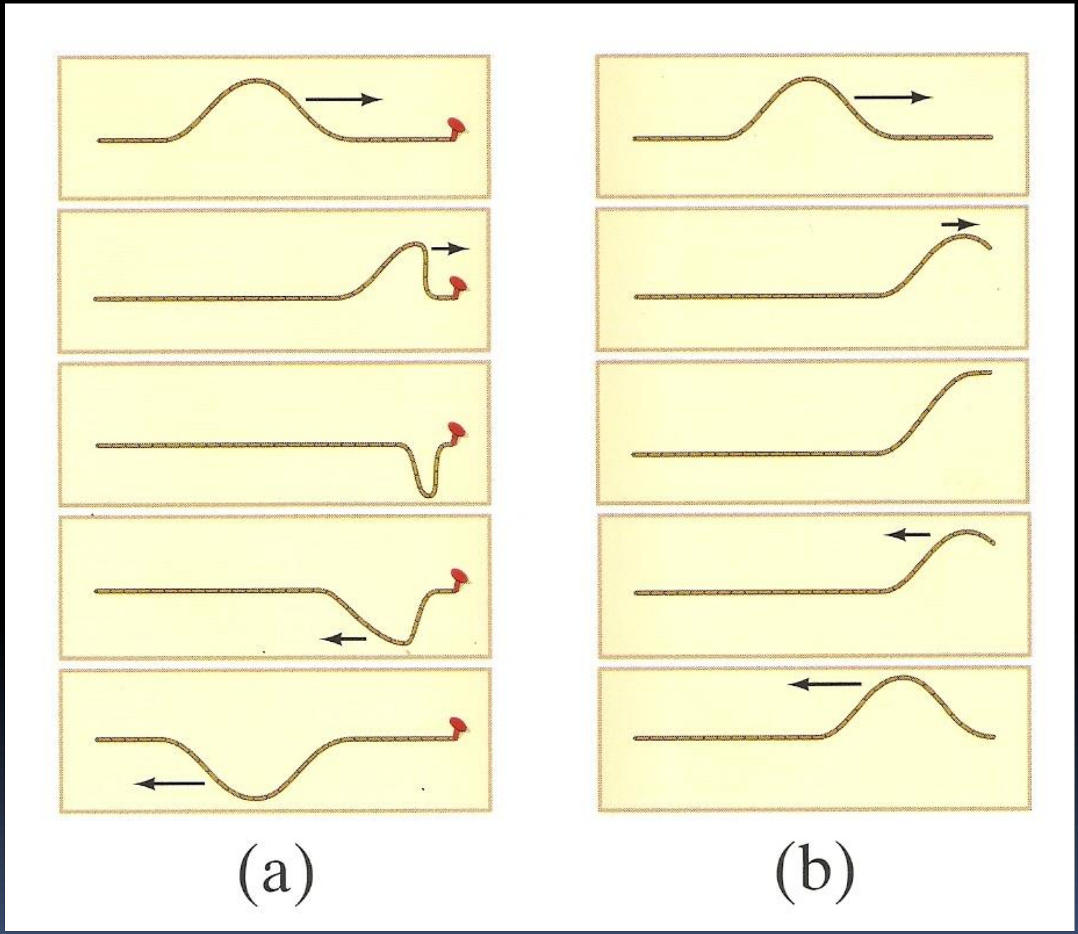


Law of Reflection

- ***What happens to a pulse on a rope with the end free?***

Law of Reflection

- ***What happens to a pulse on a rope with the end free?***
  - **The pulse reflects *upright* and traveling in the opposite direction**

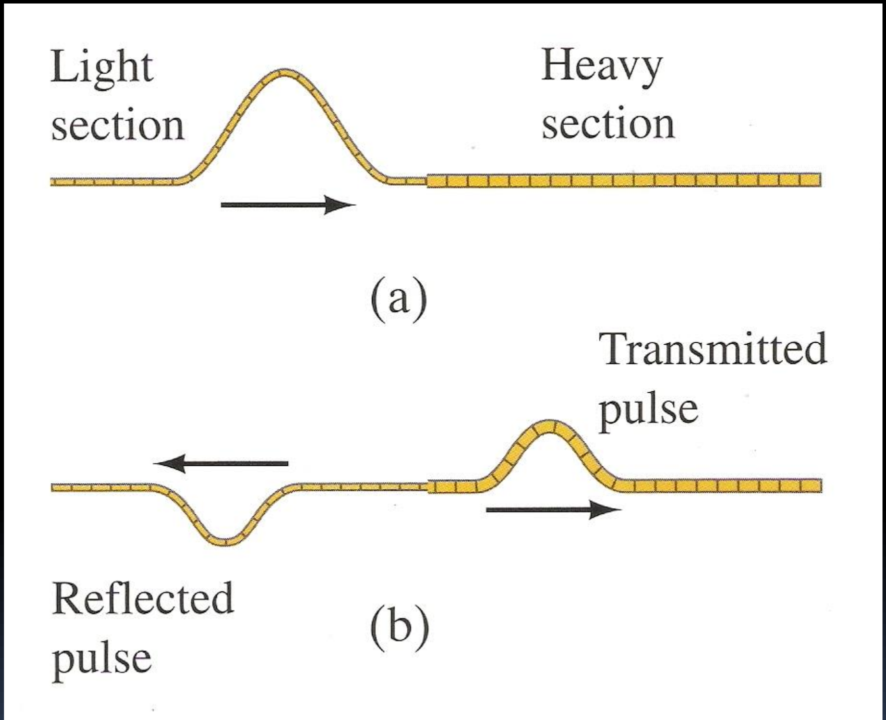


Law of Reflection

- ***What happens to a pulse on a rope that goes from a small to a larger diameter?***

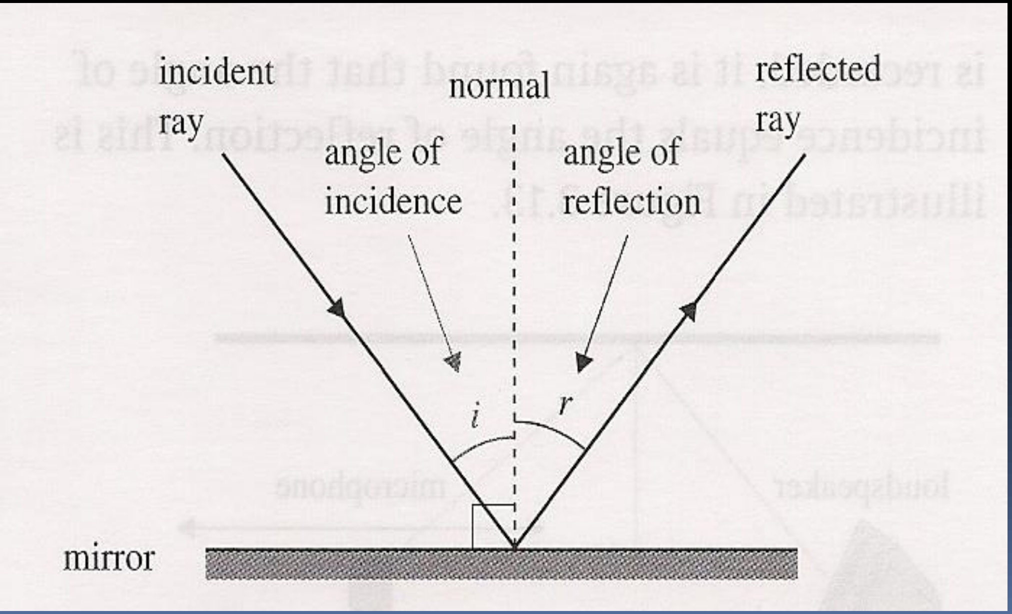
Law of Reflection

- ***What happens to a pulse on a rope that goes from a small to a larger diameter?***
  - A portion of the pulse is reflected inverted and another portion is transmitted to the larger diameter rope
  - Elastic collision????



Law of Reflection

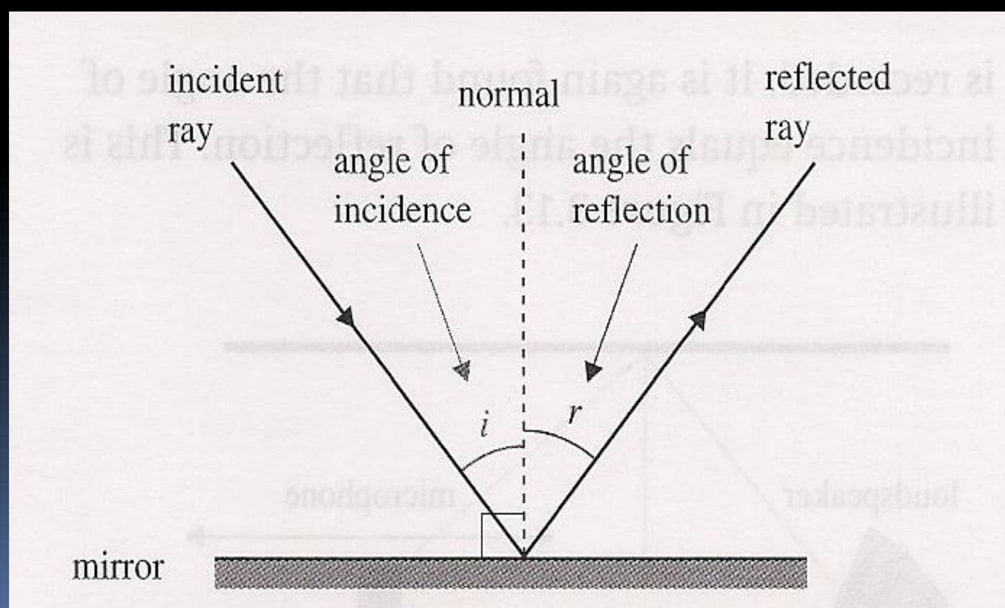
- ***Law of Reflection***: The ***angle of incidence (i,*** angle between the ray and the normal to the reflecting surface at the point of incidence) is equal to the ***angle of reflection,*** (***r,*** angle between the normal and the reflected ray).



Note that the angles are measured from the normal (perpendicular) to the reflecting surface.

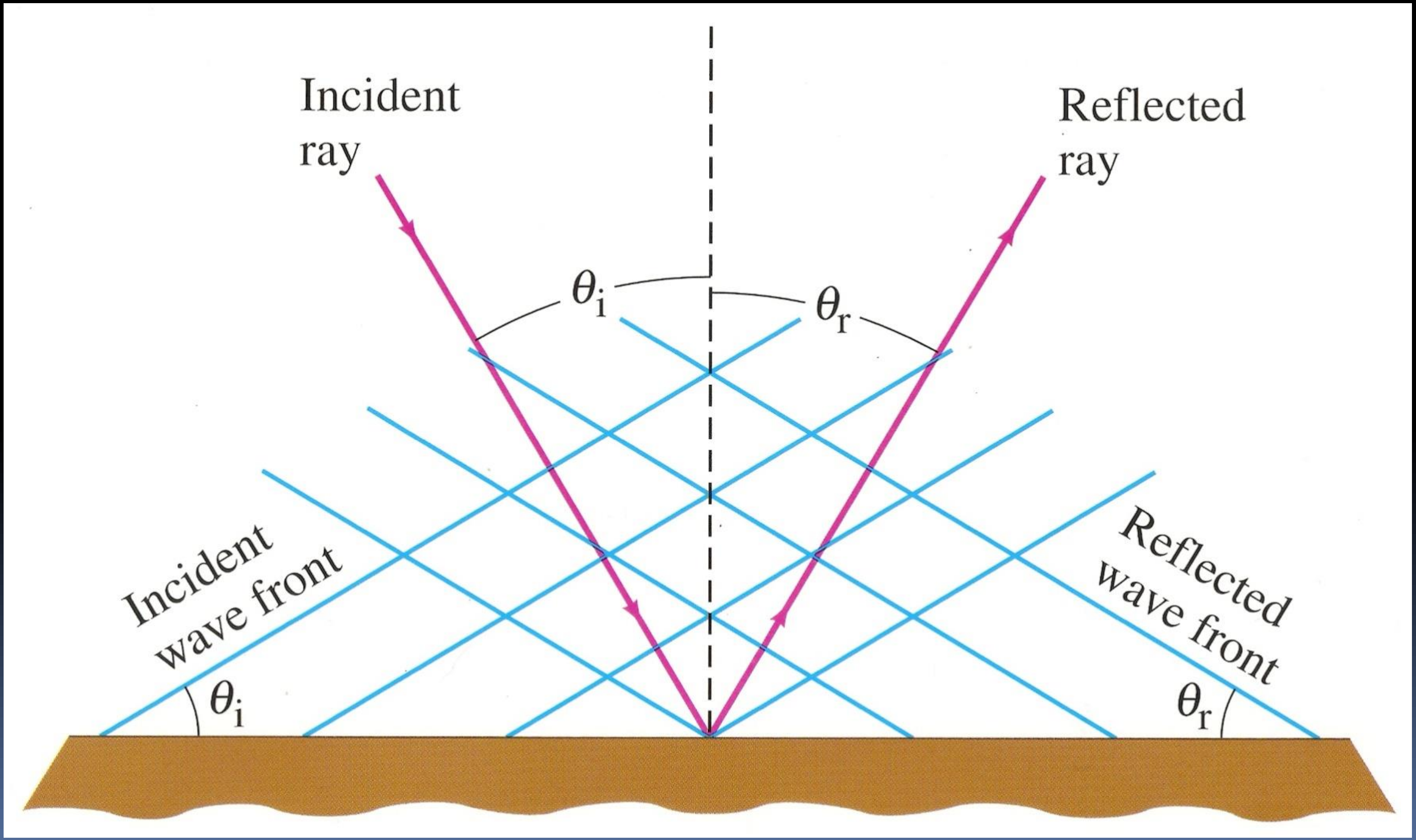
Law of Reflection

- **The reflected and incident rays and the normal to the surface lie on the same plane, called the plane of incidence.**



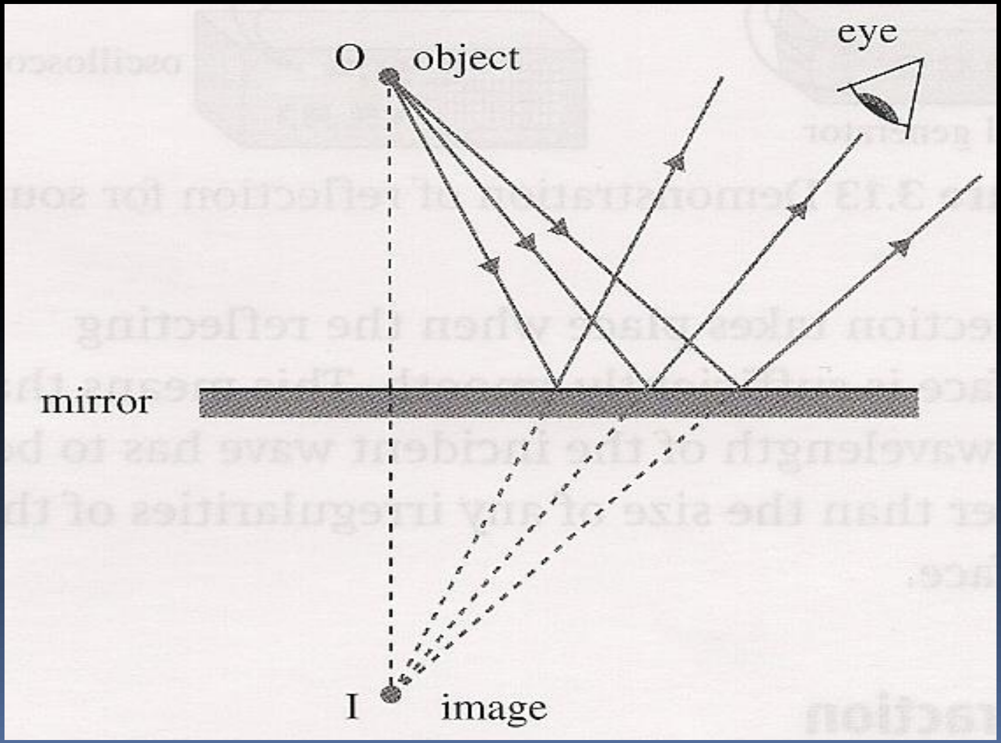
Law of Reflection

- **Remember that we are talking about incident *rays* and reflected *rays*, not *wavefronts*.**



Law of Reflection

- ***What happens when a reflected wave runs into an incident wave?***



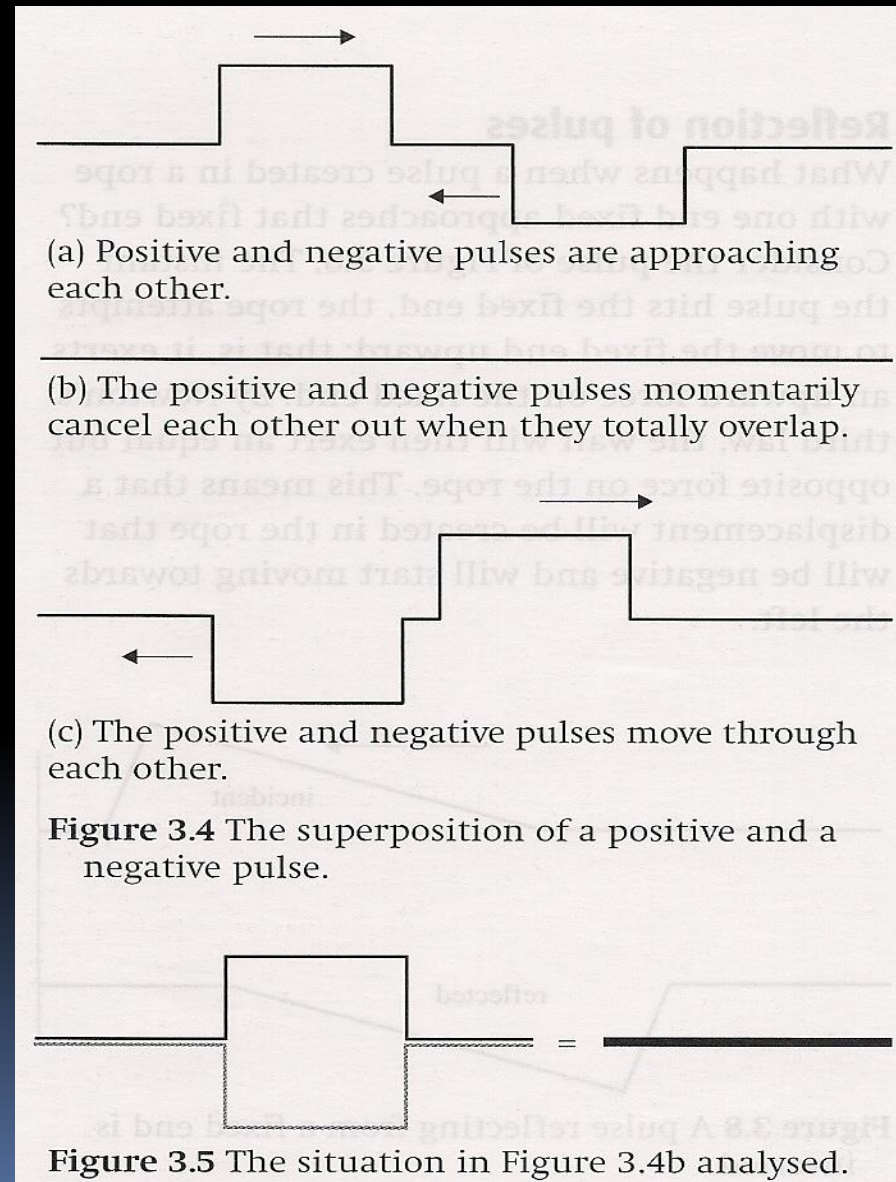
Interference and . . .

. . . ***SUPERPOSITION***

Interference and Superposition

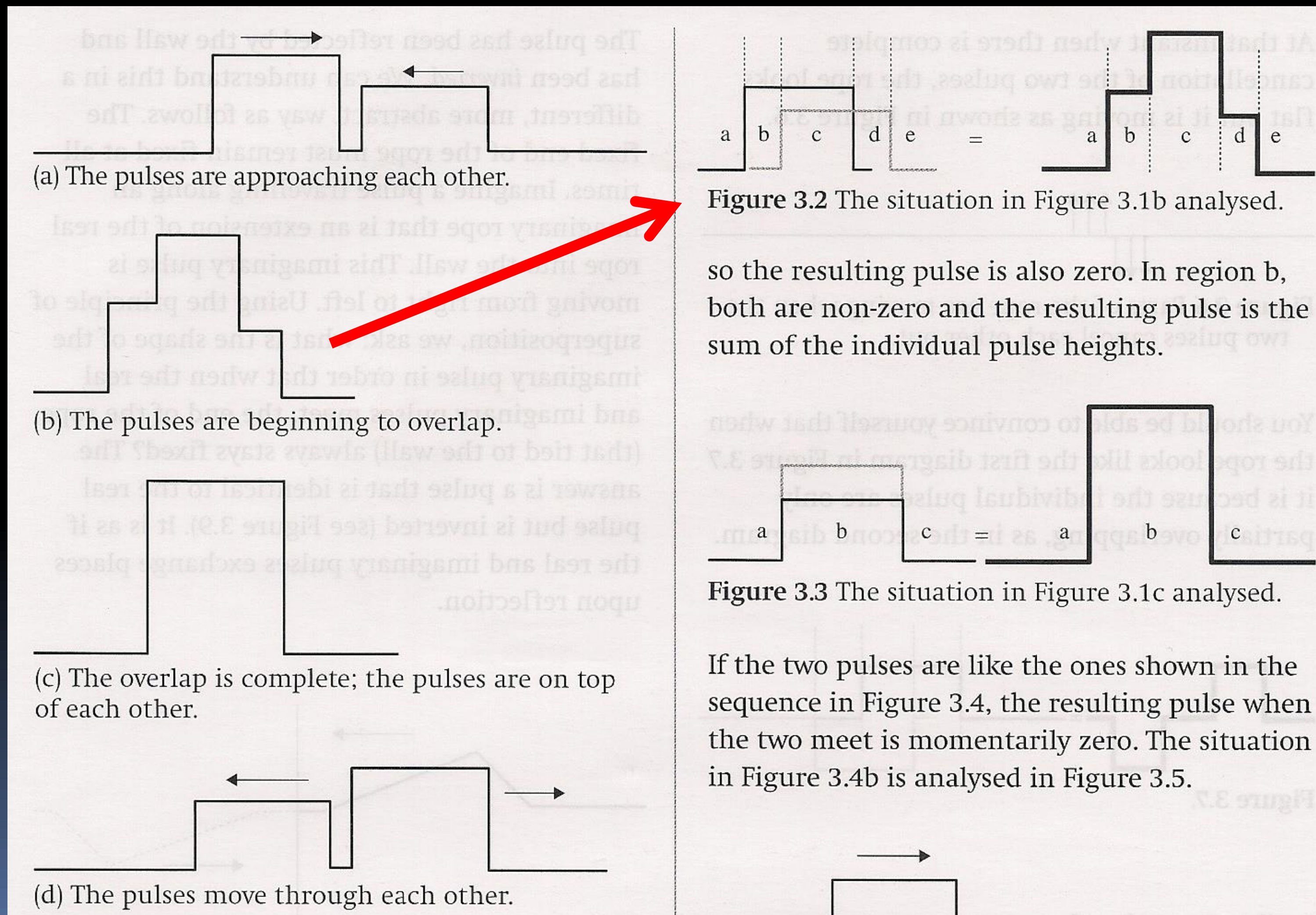
The Principle of Superposition

- When two or more pulses meet, the displacement at that point is the algebraic sum of the individual displacements
- Superposition of two opposite, but equal pulses



The Principle of Superposition

- Superposition of two positive and unequal pulses



(a) The pulses are approaching each other.

(b) The pulses are beginning to overlap.

(c) The overlap is complete; the pulses are on top of each other.

(d) The pulses move through each other.

Figure 3.2 The situation in Figure 3.1b analysed.

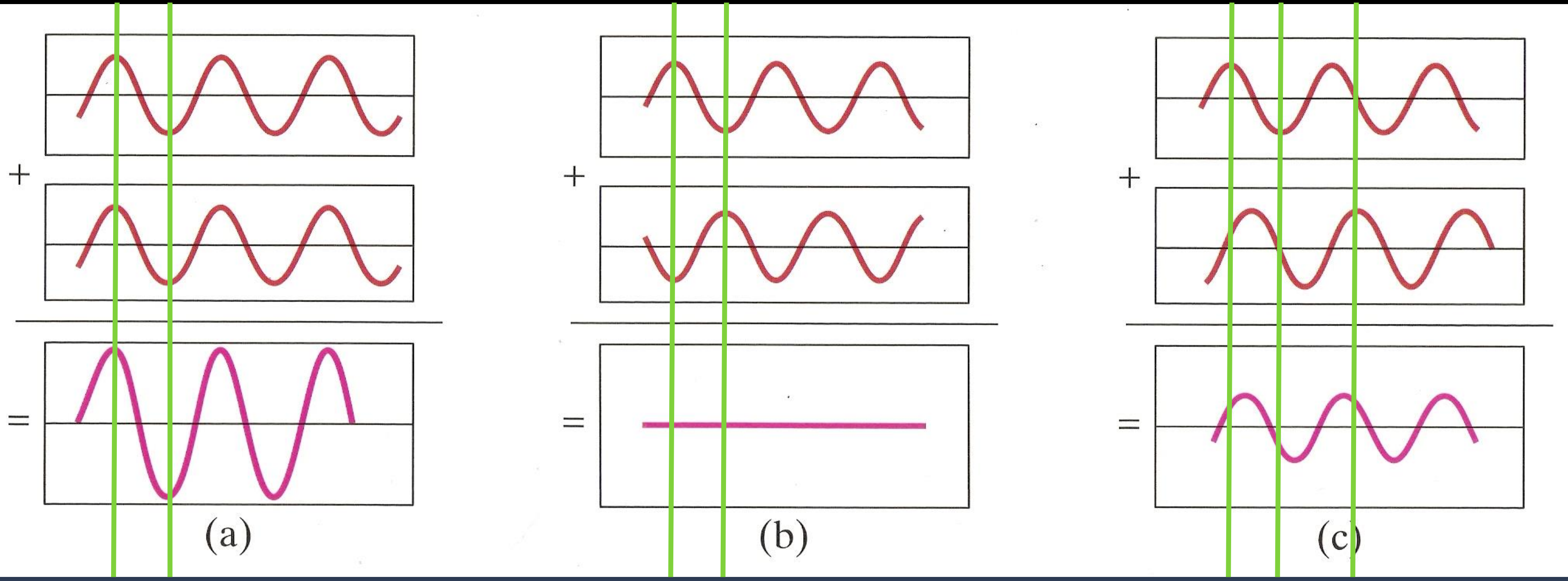
so the resulting pulse is also zero. In region b, both are non-zero and the resulting pulse is the sum of the individual pulse heights.

Figure 3.3 The situation in Figure 3.1c analysed.

If the two pulses are like the ones shown in the sequence in Figure 3.4, the resulting pulse when the two meet is momentarily zero. The situation in Figure 3.4b is analysed in Figure 3.5.

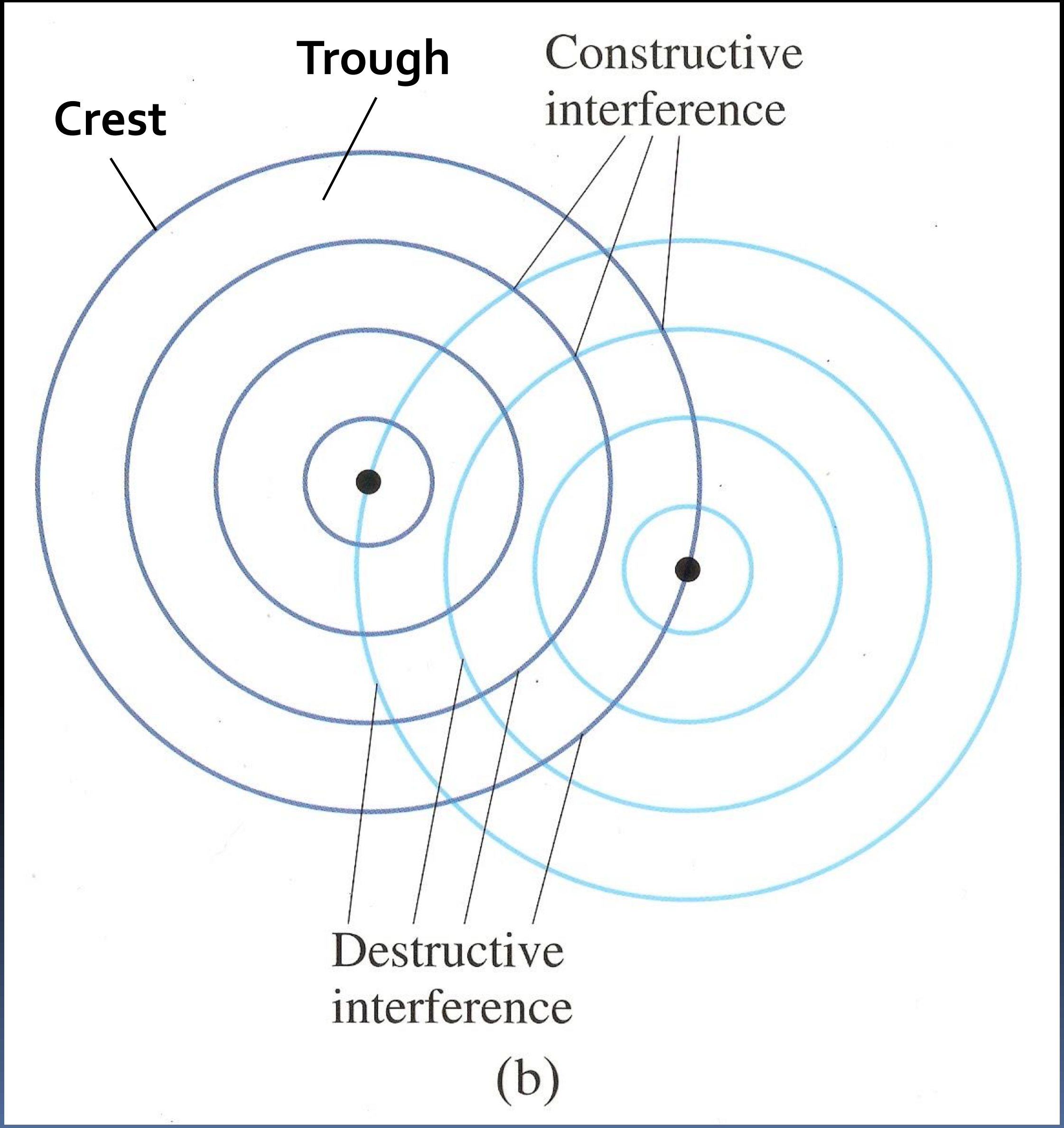
The Principle of Superposition

- **Superposition of two identical waves, 3 cases**



The Principle of Superposition

- **Superposition of two identical spherical / cylindrical waves from two different sources**



Standing Waves

- When the Law of Reflection is combined with the Principle of Superposition, we get . . . . .

Standing Waves

- When the Law of Reflection is combined with the Principle of Superposition, we get . . . . .

STANDING WAVES

World Record Standing Wave

Standing Waves

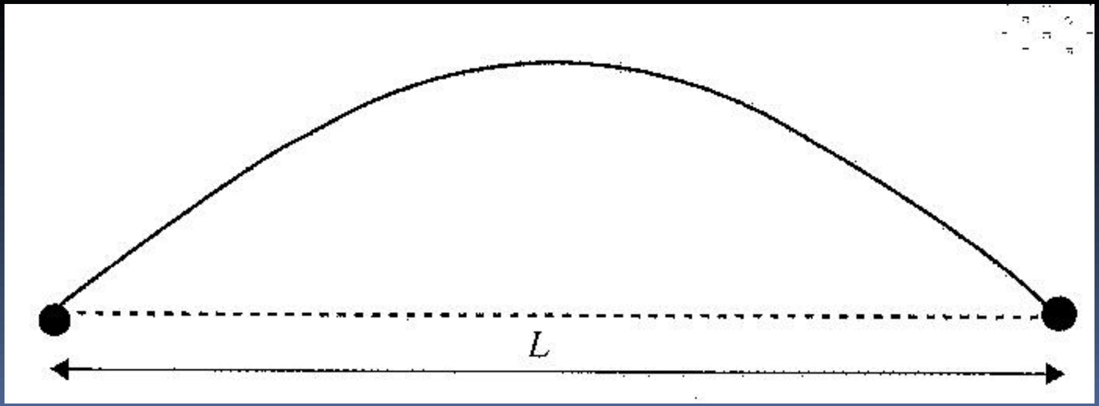
Making Standing Waves

Standing Waves on Strings

- *"When two waves of the same speed and wavelength and equal, or almost equal, amplitudes travelling in opposite directions meet, a standing wave is formed."*
- *"This wave is the result of the superposition of the two waves travelling in opposite directions."*

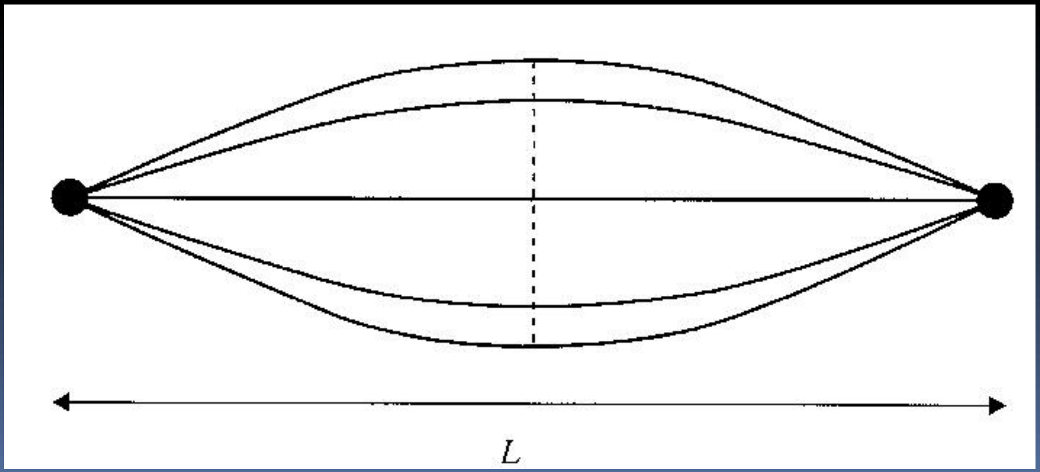
Standing Waves on Strings

- Difference between standing and traveling waves
  - No energy or momentum is transferred in a standing wave
  - Standing wave has points where the displacement is ***always*** zero (nodes)
  - Points of maximum displacement are called antinodes



Standing Waves on Strings

- A standing wave with a single antinode is known as a ***fundamental standing wave***
- When the string is in the stretched position, all of its energy is potential energy
- When the string is in its unstretched position, all the energy is kinetic energy

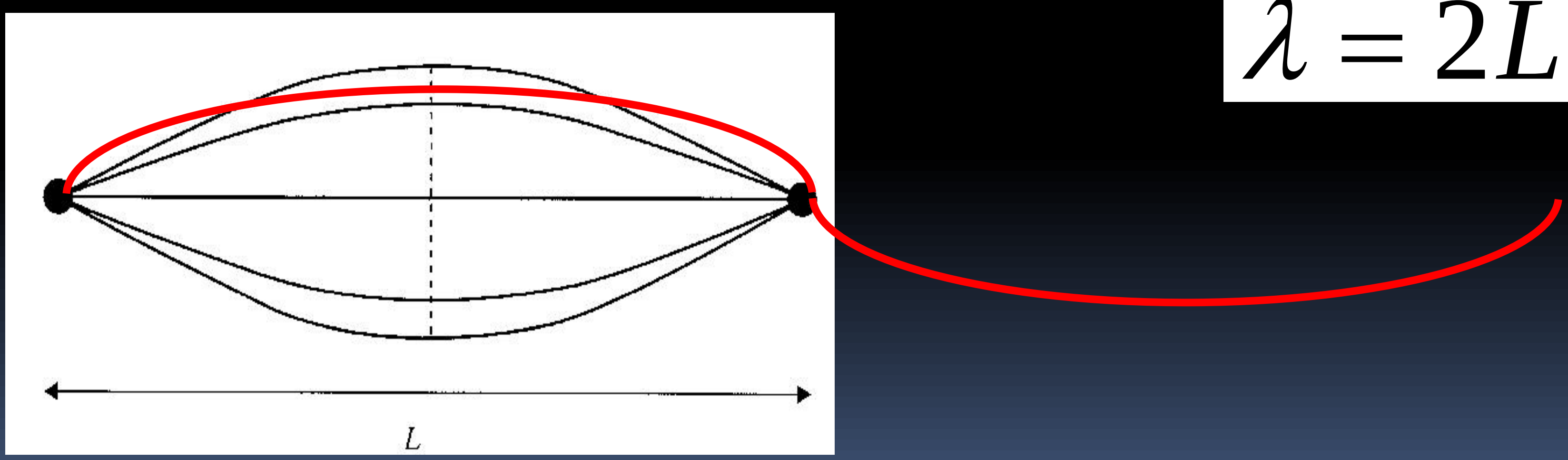


Standing Waves on Strings

- In this picture, there is one-half of one wavelength depicted
- Therefore, the wavelength is:

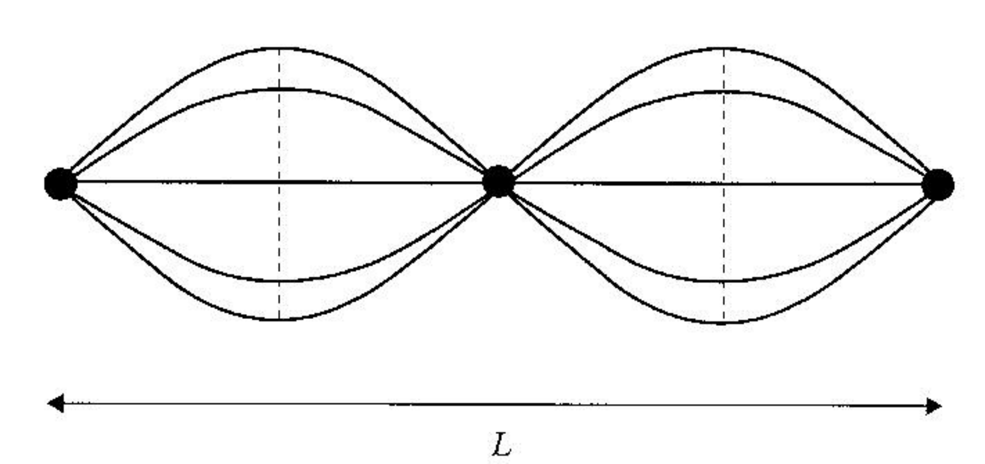
$$L = \frac{\lambda}{2}$$

$$\lambda = 2L$$



Standing Waves on Strings

- This picture also depicts a standing wave, with one entire wavelength between the ends
- The string has three nodes and two antinodes
- The wavelength is:



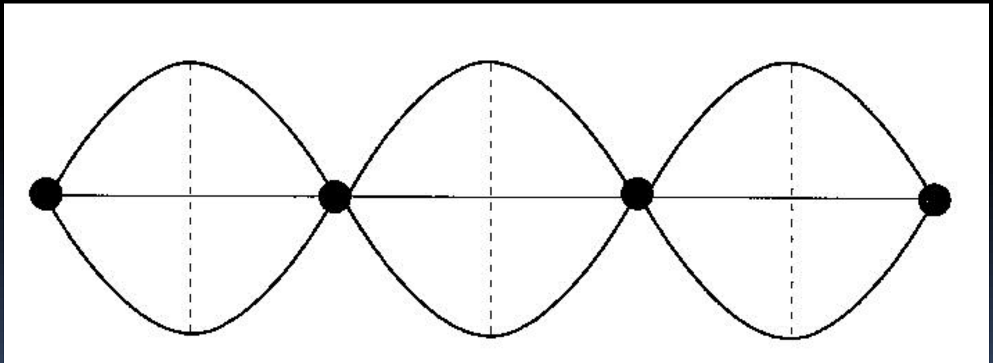
$$L = \lambda$$

Standing Waves on Strings

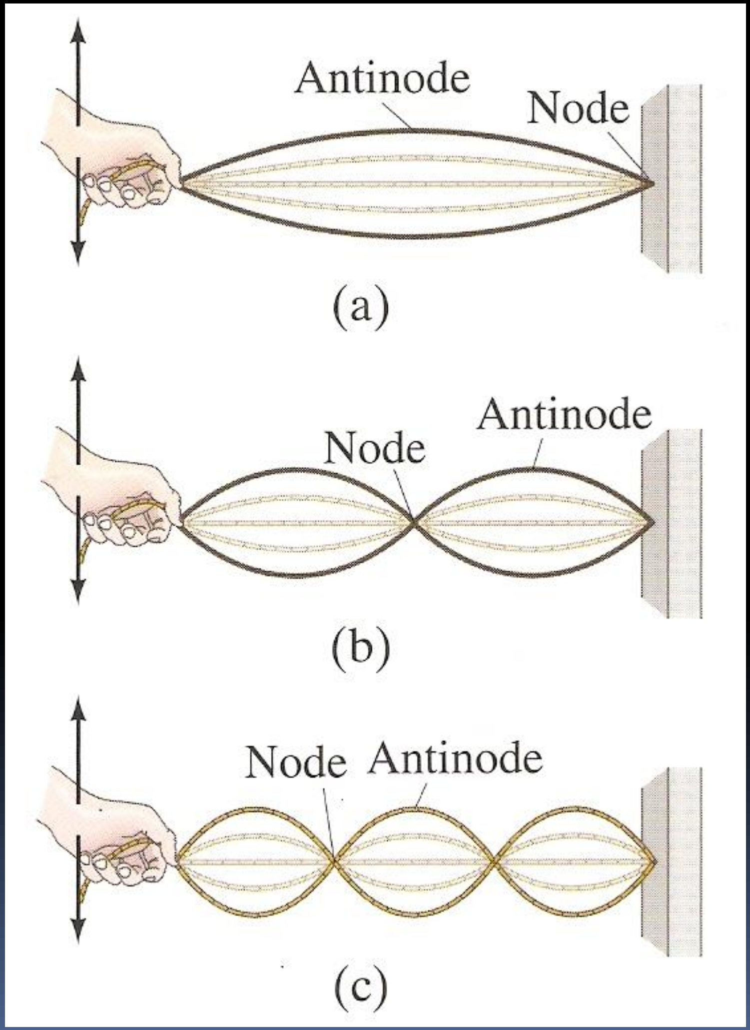
- This standing wave has four nodes and three antinodes
- The wavelength is:

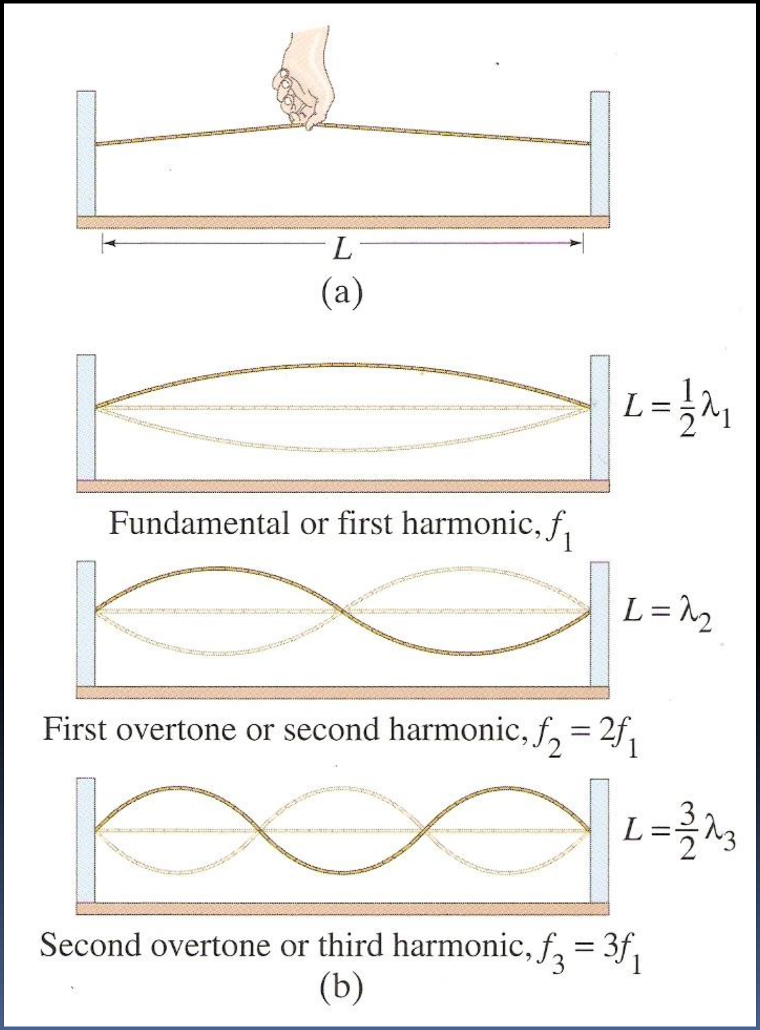
$$L = \frac{3}{2}\lambda$$

$$\lambda = \frac{2L}{3}$$



Standing Waves on Strings





Standing Waves on Strings

- A general formula for finding the wavelength of a string with both ends fixed is:

$$\lambda = \frac{2L}{n} \qquad n = 1,2,3,4,\ldots$$

$$L = \frac{\lambda n}{2} \qquad n = 1,2,3,4,\ldots$$

- *n* is called the ***mode*** and n = 1 is call the ***fundamental mode*** or ***first harmonic*** of the string

Standing Waves on Strings

- There is a frequency associated with the fundamental mode called, coincidentally, the fundamental or natural frequency (f_n)
- All other harmonics will have frequencies that are integral multiples of f_n

$$\lambda = \frac{2L}{n}$$

$$n = 1,2,3,4,\ldots$$

$$f_n = \frac{v}{\lambda_n}$$

Standing Waves on Strings

- Note that the smallest frequency is associated with the fundamental mode (largest wavelength)

$$\lambda = \frac{2L}{n}$$

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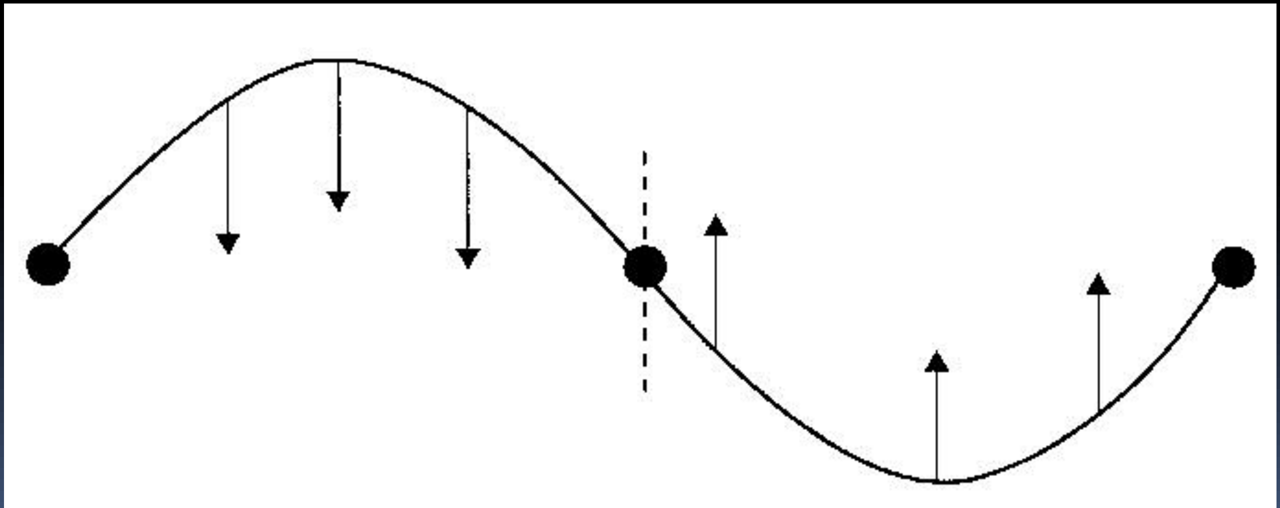
$$f = \frac{nv}{2L}$$

Standing Waves on Strings

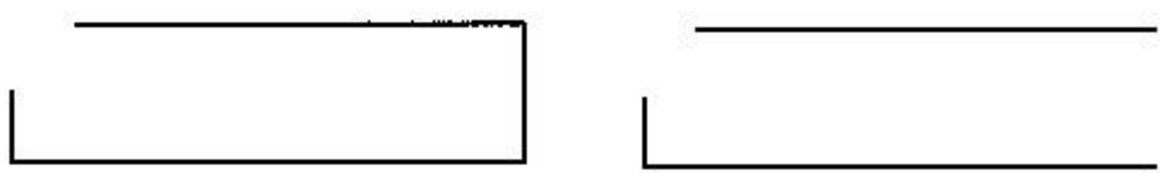
- All points between two consecutive nodes move in the same direction
- Particles between adjacent nodes move in the opposite direction



Fun With PhET

Standing Waves in Tubes

- Same as waves on a string
- Open end – string free - antinode
- Closed end – string fixed - node



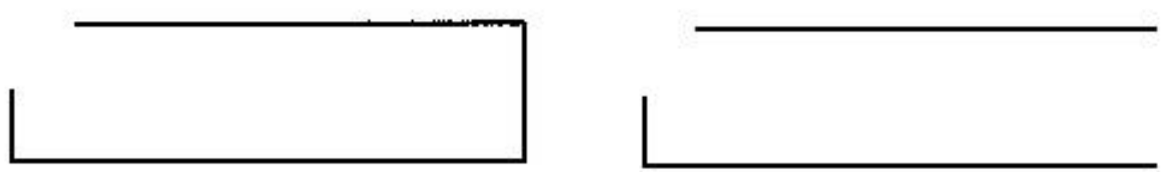
(a) left end (mouth) is open, right end is closed

(b) left end (mouth) is open, right end is open

Standing Waves in Tubes

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

- General Principle:
  - As the length of the tube gets smaller the wavelength for each harmonic gets smaller
  - Assuming constant wave speed (like sound), the smaller the wavelength, the higher the frequency
  - Think of the sound made when filling up a bottle of water



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QUESTIONS?

Homework

#51-61