Boundary Behavior of Waves
Lesson Notes

Learning Outcomes
- How does a wave behave when it reaches a free or fixed end?
- How does a wave behave when it crosses a boundary from one medium into another?

What is Boundary Behavior?
Boundary behavior describes the manner in which a wave behaves when it reaches the end of the medium. Boundary Behavior can also describe how a wave behaves when it reaches an obstacle in its path.

Our Questions:
- How does a wave behave when it reaches a …

… fixed end … free end … boundary with a different medium

- What happens to the pulse? Does it bounce back, pass into, or disappear altogether?
- How are the amplitude, the wavelength, the speed, and the frequency of the wave affected by the behavior that occurs at the boundary?

Terminology
When the energy carried by a wave reaches the end of the medium, a portion is reflected back into the medium and a portion is transmitted across the boundary.
- **Incident wave**: the wave that approaches the boundary.
- **Reflected wave**: the wave that bounces off the boundary and remains in the original medium.
- **Transmitted wave**: the wave that passes into the obstacle or the new medium on the opposite side of the boundary.

Before **After**

Incident **Reflected** **Transmitted**

<table>
<tr><th>Fixed End Reflection Observations</th><th>Free End Reflection Observations</th></tr>
<tr><td>• The reflected pulse is inverted.</td><td>• The reflected pulse is not inverted.</td></tr>
<tr><td colspan="2">• Reflection off a fixed end does not result in any changes in frequency, speed, or wavelength (for both fixed- and free-end reflection).
• Some energy is transmitted across the boundary, the reflected wave may have less amplitude than the incident wave (for both fixed- and free-end reflection).</td></tr>
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Boundary Crossing - More to Less Dense

A pulse in a more dense medium reaches the boundary with a less dense medium. What do you observe?

- Neither the reflected or transmitted pulse are inverted.

• **Frequency**: $f_{incident} = f_{reflected} = f_{transmitted}$	Handshake Logic
• **Speed (v)**: $v_{incident} = v_{reflected}$ and $v_{reflected} < v_{transmitted}$	Speed depends on density
• **Wavelength (λ)**: $\lambda_{incident} = \lambda_{reflected}$ and $\lambda_{reflected} < \lambda_{transmitted}$	Math Logic; $\lambda = v/f$
• **Amplitude (A)**: $A_{incident} > A_{reflected}$	Energy Considerations

Boundary Crossing - Less to More Dense

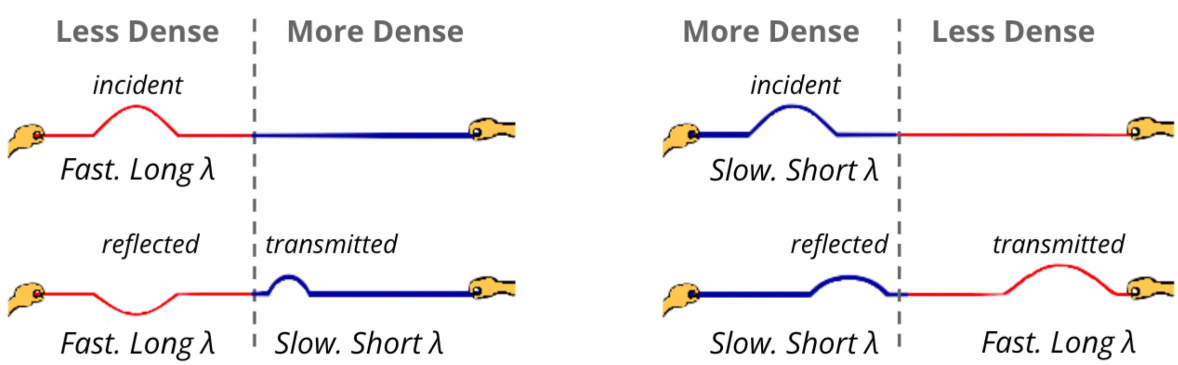
A pulse in a less dense medium reaches the boundary with a more dense medium. What do you observe?

- The reflected pulse is **inverted**.

• **Frequency**: $f_{incident} = f_{reflected} = f_{transmitted}$	Handshake Logic
• **Speed (v)**: $v_{incident} = v_{reflected}$ and $v_{reflected} > v_{transmitted}$	Speed depends on density
• **Wavelength (λ)**: $\lambda_{incident} = \lambda_{reflected}$ and $\lambda_{reflected} > \lambda_{transmitted}$	Math Logic; $\lambda = v/f$
• **Amplitude (A)**: $A_{incident} > A_{reflected}$	Energy Considerations

Summary of Boundary Crossing

The general principles for a wave crossing a boundary are …



- The **frequency** is the same in each medium.
- The **speed** is greatest in the least dense medium.
- The **wavelength** is greatest in the least dense medium.
- The reflected wave becomes **inverted** when the incident wave is in the less dense medium.