

## Reflection and transmission of Waves in One Dimension

In this lesson we will discuss what happens when a wave reaches the end of the medium that it is traveling through. In general, there are three ways that a medium can end:

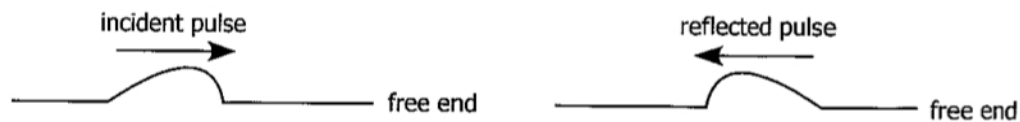
1. A **fixed end** is when the medium ends and is held firmly in place (i.e. the end of the medium can't move).
2. A **free end** is when the medium ends and is not held in place (i.e. the end of the medium is free to move).
3. A **boundary** is a point where the first medium ends, but a second medium exists and the wave continues to travel into the second medium.

When a wave reaches the end of its medium, two things can occur: reflection and transmission.

**Reflection** is the bouncing of a wave back into the medium that it was in to begin with. We use the word **incident** to describe the wave before the reflection occurred, and the word **reflected** to describe the wave after the reflection has occurred.

### Reflection from a Free End

The diagram on the left shows the incident pulse moving to the right towards the free end. The diagram on the right shows the reflected pulse moving to the left.

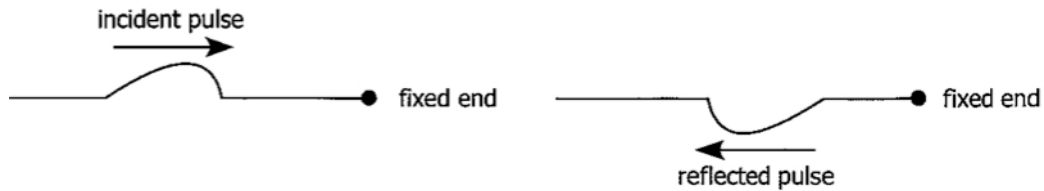


Notice that pulses reflected from a free end are:

- **upright** – they remain on the same side of the medium as the incident pulse, meaning a crest reflects as a crest and a trough reflects as a trough
- **equal in amplitude** to the incident pulse
- traveling at the **same speed** as the incident pulse
- **equal in length** to the incident pulse

## Reflection from a Fixed End

The diagram on the left shows the incident pulse moving to the right towards the fixed end. The diagram on the right shows the reflected pulse moving to the left.



Notice that pulses reflected from a fixed end are:

- **inverted** – they reflect on the opposite side of the medium, meaning that a crest reflects as a trough and a trough reflects as a crest
- **equal in amplitude** to the incident pulse
- traveling at the **same speed** as the incident pulse
- **equal in length** to the incident pulse

## Boundary Reflection and Transmission

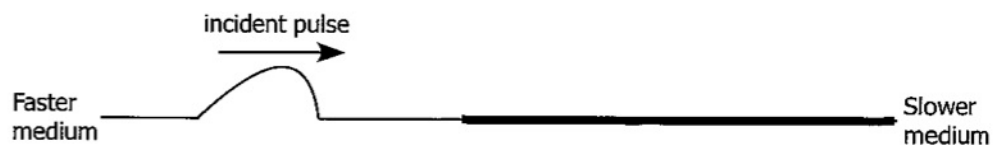
When a pulse reaches the boundary separating two media, the pulse will partially reflect (some of the wave bounces back) and partially transmit (some of the wave continues to move forward, into the new medium).

The exact nature of **partial reflection** and **partial transmission** depends on how the two media compare to each other in terms of speed.

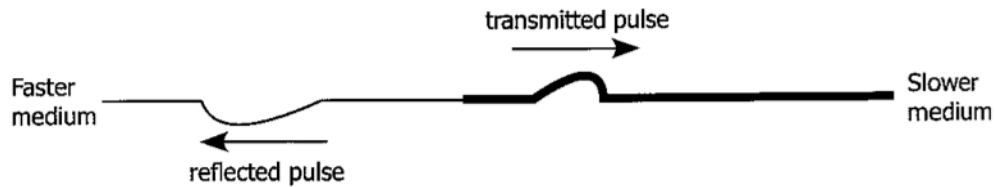
### Faster Medium to Slower Medium

When a wave passes from a faster medium into a slower medium (for example, from a lighter spring to a heavier spring), the partial reflection will resemble that from a fixed end.

The diagram below shows a wave that is incident on the boundary between two media. The wave travels faster in the medium on the left than it does in the medium on the right.



The next diagram shows how the media would appear a short while after the incident pulse has reached the boundary. The reflected pulse and the transmitted pulse are both shown.



Notice that when a wave pulse moves from a faster medium to a slower medium:

- the transmitted pulse is upright
- the reflected pulse is inverted
- the reflected pulse travels with the same speed as the incident pulse, while the transmitted pulse travels more slowly
- the amplitudes of both the reflected and transmitted pulses are smaller than the incident pulse
- the reflected pulse has the same wavelength as the incident pulse
- the transmitted pulse has a shorter wavelength than the incident pulse

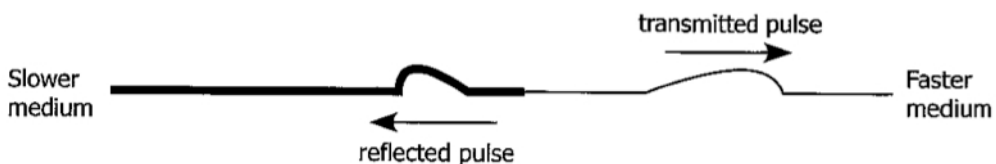
#### Slower Medium to Faster Medium

When a wave passes from a slower medium into a faster medium (for example, from a heavier spring to a lighter spring), the partial reflection will resemble that from a free end.

The diagram below shows a wave that is incident on the boundary between two media. The wave travels slower in the medium on the left than it does in the medium on the right.



The next diagram shows how the media would appear a short while after the incident pulse has reached the boundary. The reflected pulse and the transmitted pulse are both shown.



Notice that when a wave pulse moves from a slower medium to a faster medium:

- the transmitted pulse is upright
- the reflected pulse is upright
- the reflected pulse travels with the same speed as the incident pulse, while the transmitted pulse travels more quickly
- the amplitudes of both the reflected and transmitted pulses are smaller than the incident pulse
- the reflected pulse has the same wavelength as the incident pulse
- the transmitted pulse has a longer wavelength than the incident pulse

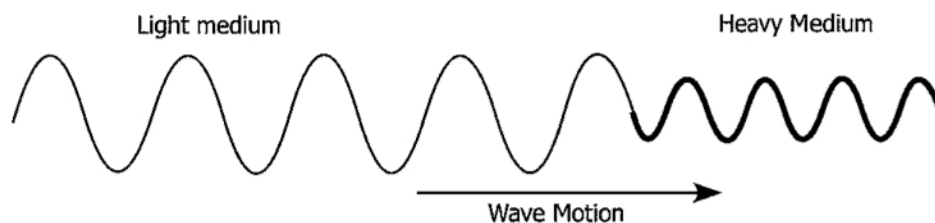
### Periodic Wave Transmission

When a periodic wave moves from one medium into another, the speed of the wave will change. The frequency of the incident wave will be equal to the frequency of the source that created them. Similarly, the frequency of the transmitted wave will be the same as the frequency of their source as well. However, in this case, the source of the transmitted wave is the incident wave. Thus, the frequency of the transmitted wave and the frequency of the incident wave will be equal.

If the frequency of a wave is constant, and the speed of the wave changes, then the wavelength must change also. Thus, when a periodic wave moves from one medium into another, its wavelength will change.

#### Faster Medium to Slower Medium

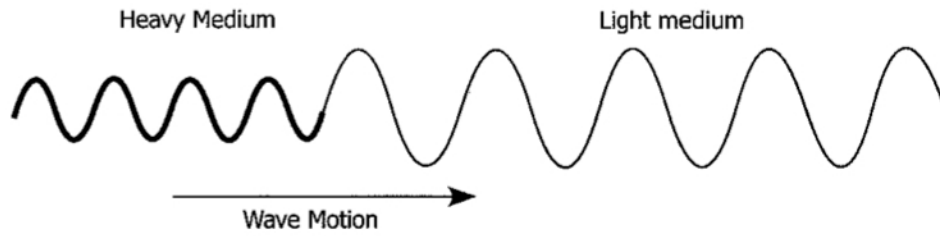
When a periodic wave travels from a faster medium to a slower medium, the wavelength of the transmitted wave will be shorter than the wavelength of the incident wave.



Note that we are ignoring the reflection of the incident waves in order to simplify the idea of waves changing speed and wavelength, but not frequency when they are transmitted across the boundary between two different media.

#### Slower Medium to Faster Medium

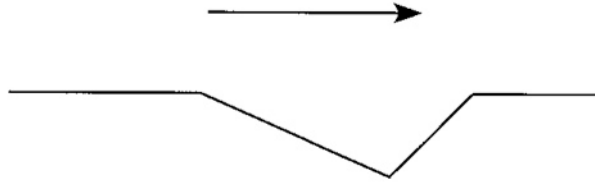
When a periodic wave travels from a slower medium to a faster medium, the wavelength of the transmitted wave will be longer than the wavelength of the incident wave.



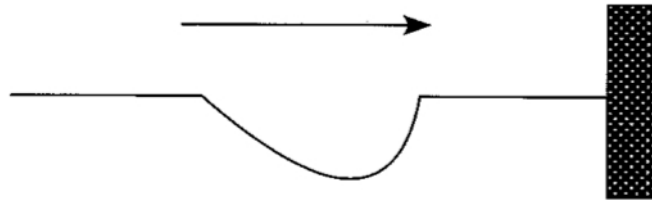


## Waves Worksheet #2

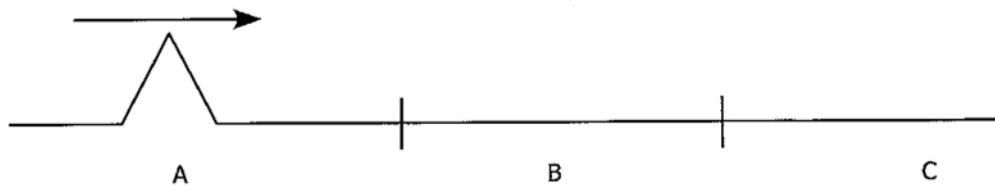
1. A pulse is sent down a spring that is attached to another spring with unknown properties. The pulse returns inverted and with a smaller amplitude. Compared to the first spring, is the speed of the waves slower or faster in the second spring?
2. The following pulse is sent along a light spring towards a junction with a free end. Draw and describe the reflected pulse.



3. The following pulse is sent along a light spring towards a junction with a fixed end. Draw and describe the reflected pulse.



4. A triangular pulse is created in medium A and passes through mediums B and C. The speeds of the pulses in mediums A, B, and C are  $1.0 \text{ m/s}$ ,  $2.0 \text{ m/s}$ , and  $1.5 \text{ m/s}$  respectively. The arrow shows the direction of motion of the pulse. For each of the following situations as the wave moves along the medium, draw diagrams to show the wavelength, the approximate amplitude, and whether or not the pulse is inverted.



- a) The partially reflected pulse in medium A.
- b) The pulse transmitted to B.
- c) The partially reflected pulse in medium B.
- d) The partially transmitted pulse in medium C.

5. A pulse traveling in a heavy medium is incident upon the junction with a light medium, as indicated in the diagram below. Draw the reflected and transmitted pulses that will result.

