Standard: MS-PS4-2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Reflection and Transmission

Suppose you are looking out a window and see some friends walking by. You yell to get their attention. Even though your voice sounds loud to you, your friends on the other side of the glass may only hear a muffled sound. Why does the sound seem so much quieter outside the window than inside?

In order to answer this question, scientists need a model to help them understand how waves move through matter, such as the air and the window. A common way to model the motion of waves is using rays. A ray is a straight arrow in a diagram that is used to represent the direction that a wave travels. By using a ray model, you can describe how a wave behaves as it travels from one medium to another. Two different things happen when waves, such as sound waves, meet a boundary between two media: reflection and transmission.

Reflection Waves travel outward from their source in straight lines when they are in a medium. But a wave may change direction when it meets a boundary between two media, such as sound waves moving from air to the glass of a window. The sound waves in Figure 1A, for example, meet a boundary at walls as they travel through the air in a building. Instead of stopping at a boundary, the waves bounce off.

Reflection happens when a wave reaches a boundary between two media and bounces back. When a wave changes direction, the ray representing that wave points in the new direction.

Transmission Waves are not only reflected when they meet a new medium; they are also transmitted. This is why your friends hear you when you shout at them through the closed classroom window. They are hearing sound waves that were transmitted through the window.

Transmission happens when a wave passes from one medium into and through a new medium. When a wave hits the surface of a new medium, such as a classroom wall, the particles in the new medium vibrate. As these particles push and pull on nearby particles, the wave passes into the new medium, such as the glass of the window. Transmission allows you to hear sounds in the classroom from outside.

Transmission also works in waves that move along strings and ropes. Think about tying a thick rope and thin string together, such as in Figure 1B. When you shake the rope once, you make a wave pulse. The wave pulse travels down the thick rope to the thin string, and it does not stop when it meets the string.
Some of the wave pulse’s energy is reflected and travels back toward you and some of the wave pulse’s energy is transmitted and travels through the thin string.

When a wave is transmitted into a new medium, many of its properties may change. For instance, the wave pulse that is transmitted to the thin string travels faster than it did in the thick rope. Sound waves also change speed when they are transmitted through a wall. They speed up as they travel through the solid parts of the wall, and they slow down on the other side of the wall when they transmit back into air. Being transmitted into a new medium may also change a wave’s amplitude and wavelength.

How much of a wave is reflected or transmitted when it meets a new medium depends on the media’s properties. Hard walls reflect more sound waves than carpeted floors. These reflected waves continue to transfer energy through the same medium (the air). The transmitted waves carry energy through the new medium, which is why your friends only hear sound waves that are transmitted through the window.
Use the reading above to respond to the questions below.

A ________________ helps scientist understand and describe the behavior of waves as they travel from one medium to another.

What are the two things that happen when sound waves meet a boundary between 2 media?
1. ____________________________________        2. __________________________________

When a wave reaches a boundary and bounces back it is __________________________.

When some sound moves through the new medium it is _______________________ as well as reflected.

We are able to hear outdoor sounds while inside because of ___________________________.

When waves are transmitted the properties of it change. Name two examples of this happening.
1. ___________________________________________________________________
2. ___________________________________________________________________

Which media reflects sound waves the best?  A carpeted floor or hard walls. (Circle your response.)

Refraction

You watch distant waves as they approach the beach. When they are far away, you watch them travel in observable directions. But as they approach the shore, their direction changes. They seem to bend toward the shore. What makes ocean waves bend toward the beach?

Reasons Waves Refract Ocean waves changing direction and bending toward the beach is an example of refraction. Refraction is the bending of a wave when it changes speed. This usually happens when it travels from one medium to another. It also happens when the properties of a medium change, causing waves in the medium to change speed. When a wave approaches shore, it moves from deep to shallow water. Water waves move slower in shallow water than in deep water, so the waves bend when they move from deep to shallow water.

You can see why a wave speeding up or slowing down causes it to change direction by picturing a line of bikers like the ones in Figure 2A. Suppose you and your friends are biking on the pavement in a straight line. The sidewalk ends at an angle where it meets sand, and you are the first person in the line to reach
the sand. You have to slow down, but your friends can keep biking fast until they reach the sand. By the time the last person in the line reaches the sand, the angle of your line of bikers has changed.

A similar change happens with water waves. Water waves slow down when they move from deep to shallow water. The part of the wave that meets the shallow water first slows down first. The other parts of the wave travel farther before they meet the boundary and slow down. As a result, the wave refracts. After the wave bends, it continues traveling in a straight line until its medium changes again.

**Amount of Refraction** The direction a wave bends and how much it bends vary. A wave does not bend at all if its direction is perpendicular to the boundary between the media. When it is perpendicular, it meets the new medium straight on. The ray showing the wave’s direction forms a 90° angle with the boundary between media. All of the parts at the front of the wave meet the boundary and change speed at the same time, so the wave passes straight into the medium without changing direction. Figure 2B shows that when a water wave moves from deep to shallow water at a 90° angle it passes straight into shallow water and does not refract.

Refraction only happens when a wave meets the new medium at an angle other than 90°. How much the wave refracts depends on how different the angle is from 90° and how much the wave changes speed. As shown by Figure 2B, the further the wave is from being 90° to the boundary, the more it bends, or refracts.
Figure 2B
Water waves refract, or bend, when they move from deep to shallow water because they travel slower in shallow water than in deep water. The further the waves are from being perpendicular to the boundary between the shallow and deep water, the more they bend.
Absorption

When you walk through the hallway on your way to your next class, you are surrounded by all kinds of sounds. However, when you enter the music classroom and close the door, the noise disappears. Why does the sound not follow you into this classroom?

A wave may pass into the surface of a new medium but not travel all the way through the medium. Absorption happens when a wave transfers its energy into the medium it is passing through. When sound waves meet a concrete wall, they are partly reflected. Some of the waves also pass into the wall and are absorbed by the wall.

You do not hear sound waves that are absorbed. As you can see by the direction of the narrow red arrows in Figure 3, the energy of the absorbed waves is transferred to the wall. The energy may heat the wall, causing the particles in the wall to vibrate faster. As the sound wave’s energy is absorbed by the wall, the sound wave’s amplitude gets smaller, and the sound gets quieter.
The amount of energy that is absorbed by a wave’s medium depends on the medium. Some media, such as air, hardly absorb any energy at all as waves pass through them. Waves can travel long distances through these media without losing too much energy. Other media, such as a foam wall, absorb most of the energy of waves passing through them. Even a thin foam wall will absorb most of the energy of sound waves that are transmitted through it.

The amount of energy absorbed by a medium can also depend on the properties of the wave. For example, some media will absorb high frequency waves, but have little effect on low frequency waves.

In order to muffle sounds in a room, people will often put soft materials on the walls or floor, such as carpet or fabric wall hangings. Explain why these materials help make a room seem less noisy using the concepts of reflection, transmission, and absorption.

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**Word Bank**

Transverse waves  rarefaction  wave  mechanical
Surface wave  wave speed  compression  medium  hertz
Longitudinal waves  crest  frequency  refraction  trough  reflection
Interference  standing wave amplitude  wavelength  electromagnetic
Across:

1. In a ________ the particles vibrate back and forth along the path of the wave.
5. ________ waves do not require a medium but can travel through empty space.
7. In a ________ one part may seem stationary, while another part has increased amplitude.
8. In a longitudinal wave, the sections were the particles are more crowded together is called ________
10. In ________ the particles vibrate in an up-and-down motion.
15. The substance a wave travels through is called a ________
16. The ________ is the distance between crests
17. Waves that require a medium to travel through are called ________ waves
19. The highest point on a transverse wave is the ________
20. The lowest point between each crest is called a ________.

Down:

2. When waves occur at the boundary between two different media they form ________
3. A section of a wave where the particles are less crowded than usual is called a ________
4. A ________ is any disturbance that transmits energy through matter or space.
6. When a wave bounces off something it is called ________
9. When two or more waves overlap each other the result is called ________
11. The ________ of a wave is the distance or height of the vibration.
12. When a wave is bent at an angle as it passes through a new medium it is called ________
13. The ________ is measured as distance traveled over time.
14. The number of waves produced in a given time is the ________ of the wave.
18. The frequency of a wave is measured in ________________