

# Warm-Up

## Reflection and Refraction

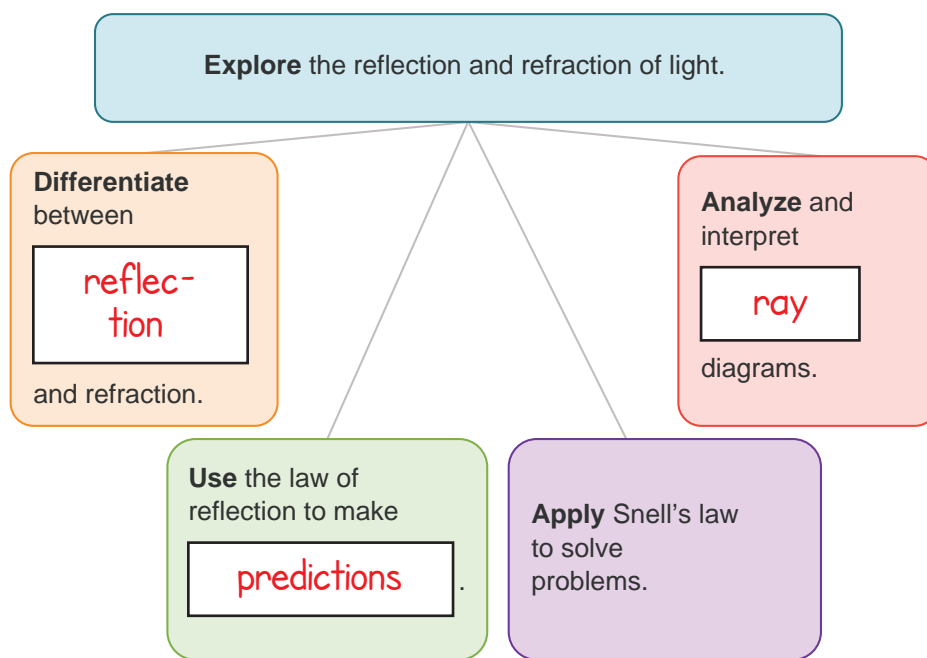


### Lesson Question

How is light reflected and refracted?



### Lesson Goals



### Words to Know

Fill in this table as you work through the lesson. You may also use the glossary to help you.

specular reflection	a type of reflection that occurs when light strikes a smooth surface, resulting in reflected light traveling in the same direction
incident ray	an incoming light ray that strikes a surface
diffuse reflection	a type of reflection that occurs when light strikes a rough surface, resulting in the reflected light traveling in different directions
normal	an imaginary line perpendicular to a surface that goes through the point where an incident ray strikes the surface



### Words to Know

law of reflection	the law that states that the angle of incidence is equal to the angle of reflection
angle of incidence	the angle between the incident ray and the normal line
optical density	a measure of how much light a material allows to pass through
scattering	the deflection of light waves in all directions as they collide with particles or gas molecules in the atmosphere
angle of refraction	angle between the refracted ray and the normal line
Snell's law	the law that states the product of the angle of incidence and index of refraction in the medium light travels from is equal to the product of the angle of refraction and index of refraction in the medium light passes into
index of refraction	the measure of how much light bends in a medium



### Wave Interaction: Reflection

Reflection is the bouncing of a wave off a **surface** or boundary between two media.

### Wave Interaction: Refraction

Refraction is the **bending** of a wave as it passes through a surface or boundary between two **media**.

## Instruction

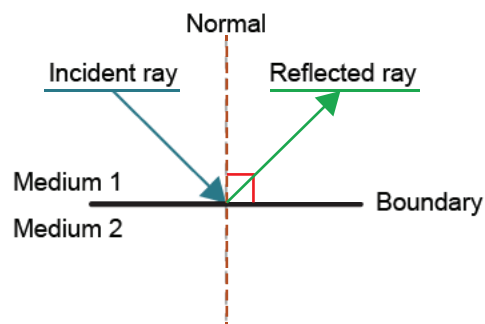
## Reflection and Refraction

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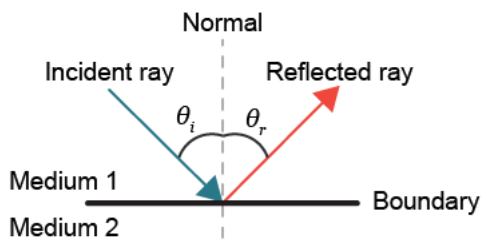
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**Diagram of a Reflected Ray**

- An **incident ray** is a light ray moving toward a **boundary**.
- A reflected ray is a light ray bouncing off a boundary.
- **Normal** denotes an imaginary line **perpendicular** to a boundary that goes through the point where an incident ray strikes the boundary.



- **Angle of incidence** ( $\theta_i$ ) is the angle between the incident ray and the **normal**.
- Angle of reflection ( $\theta_r$ ) is the angle between the **reflected** ray and the normal.



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**Direction of Reflected Ray after Encountering a Boundary**

- The reflected ray bounces off the boundary back toward medium 1.
  - Incident and reflected rays have the same **speed**.

## Instruction

## Reflection and Refraction

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**Determination of Direction of a Reflected Ray: Law of Reflection**

- The **law of reflection** states that the angle of **incidence** ( $\theta_i$ ) is equal to the angle of reflection ( $\theta_r$ ).

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**Direction of Reflected Light on Smooth, Flat, and Curved Surfaces**

- **Specular reflection** occurs when light strikes a **smooth** surface, resulting in reflected light traveling in the **same** direction.

**Direction of Reflected Light on a Rough Surface**

- **Diffuse reflection** occurs when light strikes a rough surface, resulting in the reflected light traveling in **different** directions.

**Red Sunrises and Sunsets**

- **Scattering** is the **deflection** of light waves in all directions as they collide with particles or gas molecules in the atmosphere.
  - Short wavelengths (blue and green) are scattered the most.
  - Short wavelengths become more scattered as the amount of **atmosphere** they pass through increases.

## Instruction

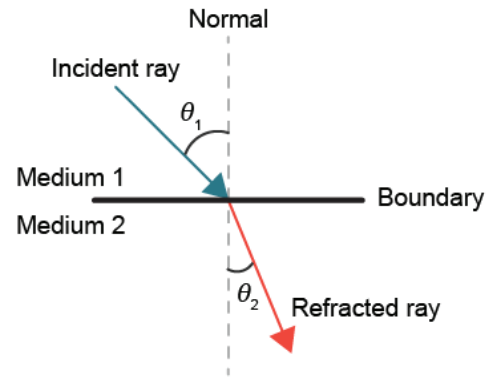
## Reflection and Refraction

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## Diagram of a Refracted Ray

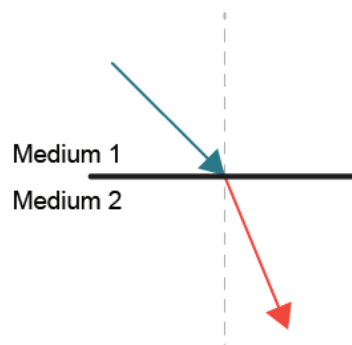
- Incident ray
- Refracted ray
  - Ray that **passes** through the boundary
- Normal
- Angle of **incidence**:  $\theta_1$
- **Angle of refraction**:  $\theta_2$ 
  - Angle between the refracted ray and the normal in the **new** medium



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## Direction of a Refracted Ray after Encountering a Boundary

- A ray changes **direction** when it passes into the second medium.
  - Incident and refracted rays do not have the same **speed** due to difference in the **optical densities** of media.
    - The optical density of a material is a measure of how much **light** a material allows to pass through.



# Instruction

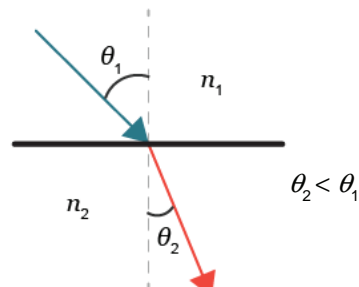
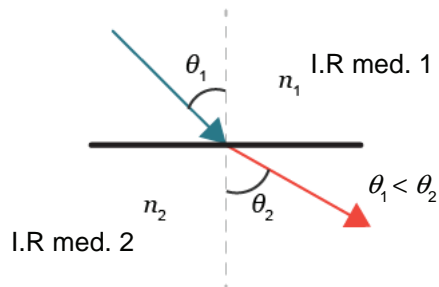
## Reflection and Refraction

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### Index of Refraction

- Index of refraction ( $n$ ) is a measure of the **bending** of a refracted ray.



When medium 1 is more dense than medium 2, the ray bends **away** from the normal.

When medium 1 is less **dense** than medium 2, the ray bends toward the normal.

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### Index of Refraction of Different Materials

- Each material has its own index of refraction.
- The index of refraction ( $n$ ) of a medium is the ratio of the speed of light in a **vacuum** to the speed of light in that medium.

Material	Index of Refraction
Vacuum	1.00
Air	1.0003
Water	<b>1.33</b>
Diamond	2.42

$$n = \frac{\text{speed of light in vacuum}}{\text{speed of light in medium}}$$

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**Determination of Direction of a Refracted Ray: Snell's Law**

- **Snell's law** shows the relationship between the indices of refraction of the two **media** and the angles of incidence and refraction.

- $n_1$  – the index of **refraction** of medium 1
- $\theta_1$  – the angle of incidence
- $n_2$  – the index of refraction of medium 2
- $\theta_2$  – the angle of the refraction

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

**Determination of the Angle of Refraction Using Snell's Law****EXAMPLE**

An incident ray strikes water at an angle of 15 degrees. Given that the index of refraction of air is 1.0003 and the index of refraction of water is 1.33, what is the angle of refraction?

- Given
  - $n_1 = 1.0003$
  - $\theta_1 = 15$  degrees
  - $n_2 = 1.33$
- Unknown:  $\theta_2$
- Formula:  $\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$

Solution:

$$\sin \theta_2 = \frac{n_1 \sin \theta_1}{n_2}$$

$$\sin \theta_2 = \frac{1.0003(\sin(15^\circ))}{1.33}$$

1.33

$$\theta_2 = \sin^{-1}(0.18)$$

$$= 11^\circ$$

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**Water Magnification**

- As light hits the boundary of the water, it is refracted.
  - The **curved** shape of the water droplet and the index of refraction of water cause the bending of light.
  - Wood images are **spread** and enlarged, or magnified.

## Summary

## Reflection and Refraction

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## Lesson Question

How is light reflected and refracted?

✓

## Answer

(Sample answer) Light is reflected when it bounces off a boundary, changes direction, and travels back into the medium from where it came. Light is refracted when it passes through a boundary, changes direction, and travels to another medium.

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## Review: Key concepts

Ray diagrams can be used to analyze what happens when light is reflected or refracted

Interaction	Behavior of ray at boundary	Medium ray travels in	Ray speed	Formula
Reflection	Bounces off boundary	Reflected ray stays in original medium	Same as incident ray	Law of reflection: $\theta_i = \theta_r$
Refraction	Passes through boundary	Refracted ray passes into another medium	Different from incident ray	Snell's law: $n_1 \sin \theta_1 = n_2 \sin \theta_2$



# Summary

## Reflection and Refraction

*Use this space to write any questions or thoughts about this lesson.*

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