Lesson 3

Reflection and Refraction

- **transparent**
- **opaque**
- **reflection**
- **Law of Reflection**
- **light ray**
- **incident ray**
- **reflected ray**
- **normal**
- **angle of incidence**
- **angle of reflection**
- **refraction**
- **Laws of Refraction**

Learning Outcomes

After completing this lesson you will be able to

- explain the laws of reflection
- identify examples of reflection in daily life
- compare the refraction of light through substances of different densities
- explain how reflection and refraction produce natural phenomena

How Does Light Interact with Objects?

At the beginning of this unit, when you were brainstorming what you knew about light, you may have included some of the ways that light interacts with objects. In Grade 4 you learned that objects can be classified as **transparent** (let light pass through) or **opaque** (don't let light pass through). In this section you'll examine in more detail what happens when light interacts with opaque objects that are reflective in nature, and also with transparent objects.

Question: Reflection

There are many instances where a **reflection** can be observed in everyday life, for example, your face in a bathroom mirror. What are other examples of where you might encounter your reflection over the course of a day? Give two or three examples.

_____

_____

_____

_____

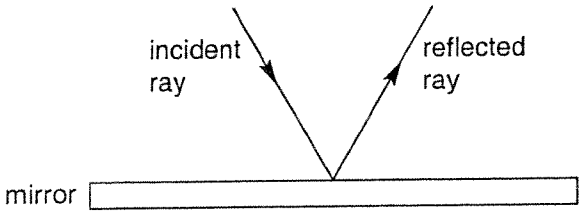
In order to explain how light reflects, scientists have created the **Law of Reflection**. You'll explore this law in the following pages.

How Does Light Reflect?*

How does a ball bounce back to you after you throw it against a wall? It depends how you throw it. If you throw the ball straight, it will bounce back straight. If you throw it at an angle, it will bounce back at an angle.

Light, you know, can bounce. "Bounced" light is reflected light. We can predict how reflected light will behave. Just follow the explanation.

A single beam of light is called a **light ray**. Light is made up of many, many light rays. But let us look at one light ray.

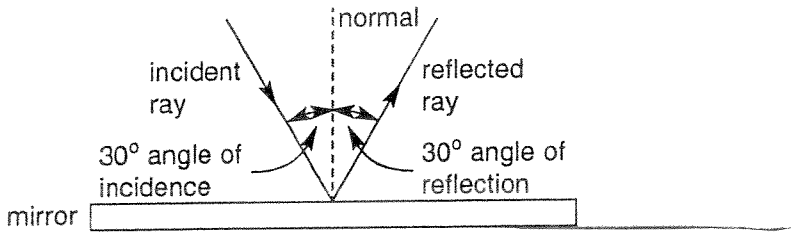


This is a single light ray. It is hitting a flat mirror at an angle. Then it is bouncing off. It is reflecting.

The ray that hits the mirror is called the **incident ray**.

The ray that bounces off the mirror is called the **reflected ray**.

Now let's draw a line that makes a right angle (90 degrees) where the incident ray hits the mirror. This line is called the **normal**.



- The angle between the incident ray and the normal is called the **angle of incidence**.
- The angle between the reflected ray and the normal is called the **angle of reflection**.

The **Law of Reflection** states that "the angle of incidence is equal to the angle of reflection."

In the example on this page, the angle of incidence is 30 degrees. The angle of reflection, then, is also 30 degrees.

* From *Physics Workshop 3: Understanding Light and Sound* by Seymour Rosen.

Practice: How Does Light Reflect?

Two reflecting rays are shown in Figures A and B. Identify the parts shown by number. Choose from the following:

incident ray
reflected ray
normal
angle of incidence
angle of reflection

Write your answers next to the correct numbers.

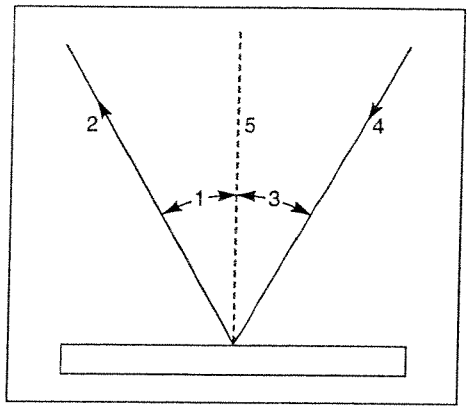


Figure A

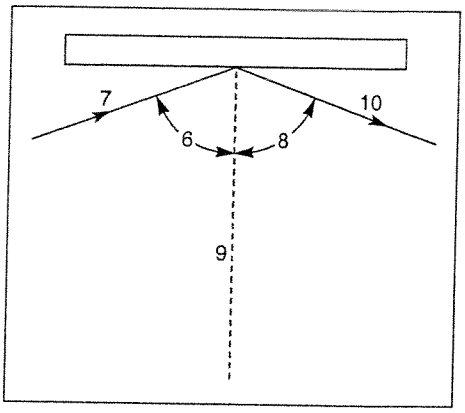


Figure B

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

11. State the Law of Reflection. _____

_____

12. Which of the angles above are equal? (Use numbers.)
    a. In Figure A, _____ and _____ are equal.
    b. In Figure B, _____ and _____ are equal.

Refraction

You've seen that light travels in straight lines and that it can be reflected off of surfaces. There is also something else that light can do—it can bend! This bending is called **refraction**. The following pages will describe how refraction works through different substances.

What is Refraction?*

Light travels in straight lines. But light rays can also "bend." They can change direction.

You have seen that light changes direction when it is reflected. Light also changes direction when it passes at an angle from one medium into another medium. This bending is called refraction.

Refraction causes us to see objects at positions different from their actual positions. You may have experienced refraction. Did you ever reach into a fish tank to pick up a rock? Was the rock exactly where you thought it was?

How can refraction be explained?

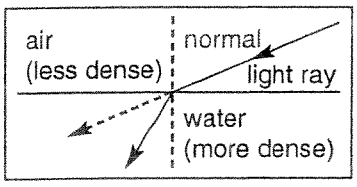
Light travels at different speeds through different mediums. Light travels at about 300,000 kilometers (186,000 miles) per second in air. But light slows down in other substances. In water, for example, light slows down to about 225,000 kilometers (140,000 miles) per second.

The speed at which light travels through a medium depends upon the density of that medium. Density has to do with how closely packed the molecules of a substance are. The more closely packed the molecules are, the more dense the substance is.

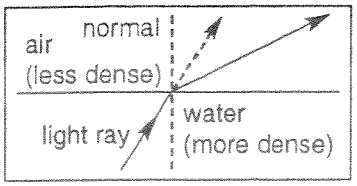
Different substances have different densities. For example, water is more dense than air.

The following are the **Laws of Refraction**. They explain how light bends.

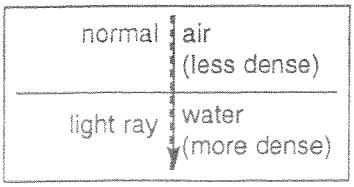
a) Light that moves at an angle from a less dense medium to a more dense medium bends toward the normal.



b) Light that moves at an angle from a more dense medium to a less dense medium bends away from the normal.



c) Light that moves straight on from one medium to another does not bend. It is not refracted.



* From *Physics Workshop 3: Understanding Light and Sound* by Seymour Rosen. © by Globe Fearon, an imprint of Pearson Learning Group, a division of Pearson Education, Inc. Used by permission.

Practice: What is Refraction?

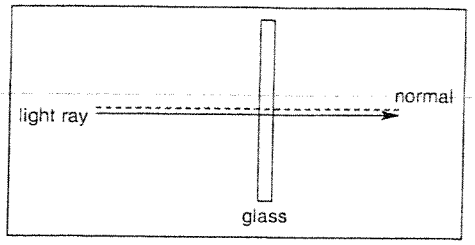


Figure A

1. From your own experience, you know that glass is _____ dense than air.
   (more, less)
2. In Figure A, light is passing from _____.
   (glass to air, air to glass)
3. The light is hitting the glass _____.
   (at an angle, straight on)
4. The light _____ bending. It _____ being refracted.
   (is, is not) (is, is not)
5. Why isn't the light being refracted?

   _____

6. Write the part of the Law of Refraction that explains why this is happening.

   _____

   _____

   _____

Look at Figures B through G. In each, light is being refracted. The dotted line in colour is the normal. Is the light being refracted toward the normal or away from the normal? Complete the sentence under each figure.

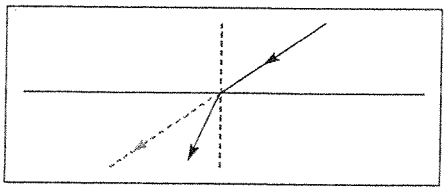


Figure B

7. Light is being refracted _____ the normal.
   (toward, away from)

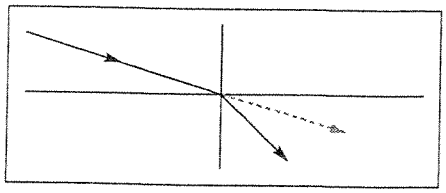


Figure C

8. Light is being refracted _____ the normal.
   (toward, away from)

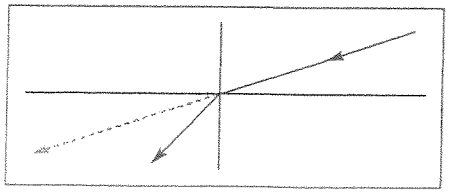


Figure D

9. Light is being _____

   _____

   _____.

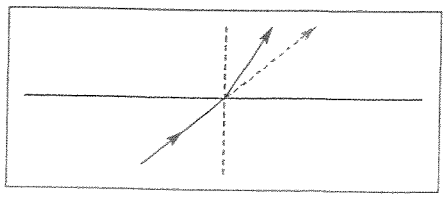


Figure E

10. Light _____

    _____

    _____.

Now, answer with complete sentences.

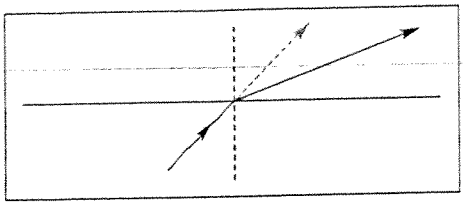


Figure F

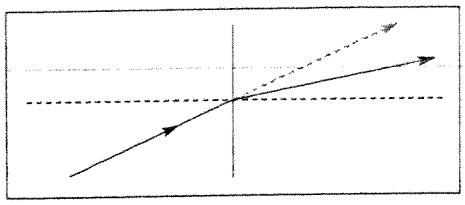


Figure G

11. _____
_____
_____.

12. _____
_____
_____.

Questions: What's Happening?

Look at Figures H and I. Answer the questions with each.

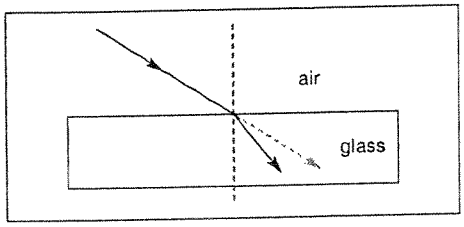


Figure H

1. a. In Figure H, light is passing from _____ (glass to air, air to glass).

   b. Glass is _____ (more, less) dense than air.

2. The light is hitting the glass _____ (at an angle, straight on).

3. The light _____ (is, is not) bending. It _____ (is, is not) being refracted.

4. The light is being refracted _____ (toward, away from) the normal.

5. Write the part of the Law of Refraction that explains why this is happening.

_____
_____
_____

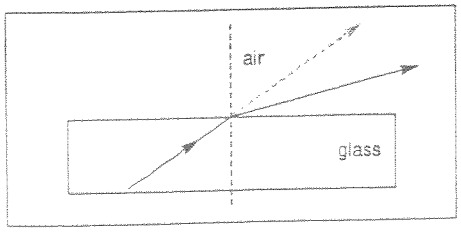


Figure I

6. a. In Figure I, light is passing from _____ (glass to air, air to glass).

   b. Air is _____ (more, less) dense than air.

7. The light is hitting the glass _____ (at an angle, straight on).

8. The light _____ (is, is not) bending. It _____ (is, is not) being refracted.

9. The light is being refracted _____ (toward, away from) the normal.

10. Write the part of the Law of Refraction that explains why this is happening.

_____

_____

_____

Questions: Refraction and Change of Position

Study Figure J. Answer the questions.

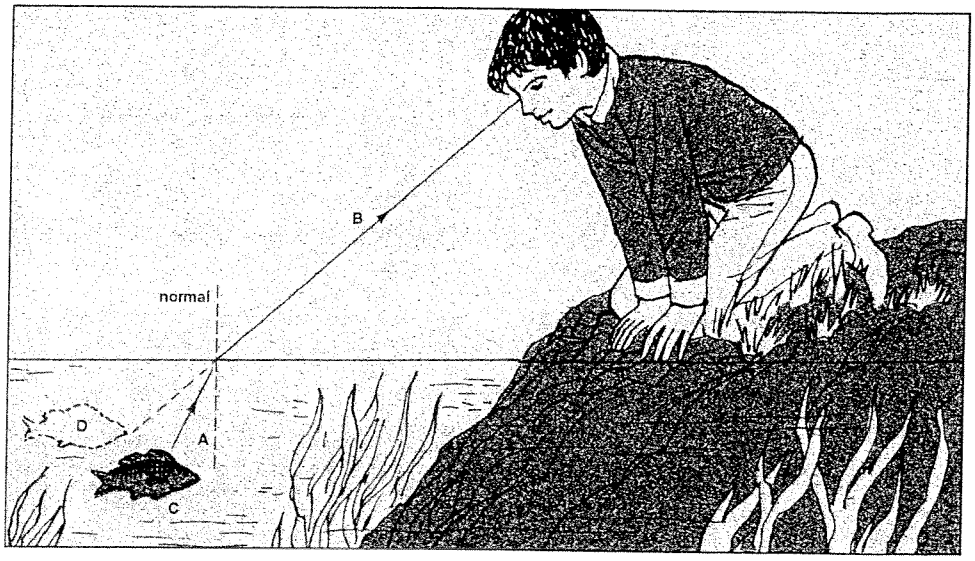


Figure J

The fish is actually at C. But to the boy, the fish appears to be at D.

1. The boy sees the fish because light is travelling _____ (from the boy's eyes to the fish, from the fish to the boy's eyes).

2. The fish is _____ (giving off its own light, reflecting light).

3. The light is moving from _____ (water to air, air to water).

4. The light from the fish is being refracted _____ (toward, away from) the normal.

5. The boy sees the fish in line with the refracted light. The refracted light is _____ (A, B).

6. a. The boy sees the fish _____ (further away, closer) than it really is.

   b. The boy also sees the fish _____ (higher, lower) in the water than it really is.

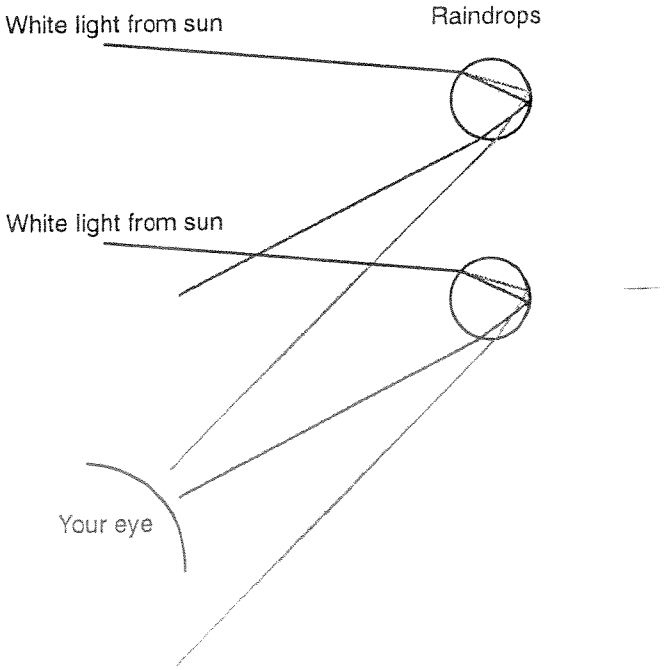
7. Refraction _____ (does, does not) seem to change the position of an object.

Natural Light Phenomena

Several natural phenomena are created by the reflection and/or refraction of light. These include everything from our blue sky to sunsets, sundogs, rainbows, mirages, and perhaps the most impressive—northern lights. The following articles describe some of these phenomena. Read the articles and complete the questions that appear after them.

Rainbow*

In a rainbow, raindrops in the air act as tiny prisms. Light enters the drop, reflects off the side of the drop and exits, and in the process is broken into a spectrum just like it is in a triangular glass prism. Like this:



*Reprinted from <http://www.howstuffworks.com/question41.htm>

The angle between the ray of light coming in and the red ray coming out of the drops is 42 degrees for red, and 40 degrees for violet. You can see in this diagram that the angles cause different colours from different drops to reach your eye, forming a circular rim of colour in the sky—a rainbow! In a double rainbow, the second bow is produced because droplets can have two reflections internally and get the same effect. The droplets have to be the right size to get two reflections to work.

Why Is the Sky Blue?

Here is something interesting to think about. When you look at the sky at night it is black, with the stars and the moon forming points of light on that black background. So why is it that, during the day, the sky does not remain black with the sun acting as another point of light? Why does the daytime sky turn a bright blue and the stars disappear?

The first thing to recognize is that the sun is an extremely bright source of light—much brighter than the moon. The second thing to recognize is that the atoms of nitrogen and oxygen in the atmosphere have an effect on the sunlight that passes through them. There is a physical phenomenon called "Rayleigh scattering" that causes light to scatter when it passes through particles that have a diameter 1/10th of that of the wavelength (colour) of the light. Sunlight is made up of all different colours of light, but because of the elements in the atmosphere, the colour blue is scattered much more efficiently than other colours.

So when you look at the sky on a clear day, you can see the sun as a bright disk. The blueness you see everywhere else is all of the atoms in the atmosphere scattering blue light toward you (but not scattering red light, yellow light, green light, etc., nearly as well).

Sundogs*

Explanation: What if you woke up one morning and saw more than one sun in the sky? Most probably, you would be seeing *sundogs*, extra images of the sun created by falling ice crystals in the earth's atmosphere. As water freezes in the atmosphere, small, flat, six-sided, ice crystals might be formed. As these crystals flutter to the ground, much time is spent with their

*Reprinted from <http://antwrp.gsfc.nasa.gov/apod/ap990823.html>

faces flat, parallel to the ground. An observer may pass through the same plane as many of the falling ice crystals near sunrise or sunset. During this alignment, each crystal can act like a miniature lens, refracting sunlight into our view and creating *parhelia*, the technical term for sundogs.

Questions: Natural Light Phenomena

1. Which phenomenon is created by the refraction of light and what medium causes the refraction?

2. Which phenomenon is created by the reflection of light and off what material is light being reflected?

3. Were any phenomena created through any combination of reflection, dispersion, and/or refraction? If so, which?