Light Intensity Problems

Light is a form of energy. **Light intensity** describes the amount of energy per second falling on a surface, using units of watts per meter squared (W/m²). Light intensity follows an inverse square law. This means that the intensity decreases as the square of the distance from the source. For example, if you double the distance from the source, the light intensity is one-fourth its original value. If you triple the distance, the light intensity is one-ninth its original value.

Most light sources distribute their light equally in all directions, producing a spherical pattern. The area of a sphere is $4\pi r^2$, where $r$ is the radius or the distance from the light source. For a light source, the intensity is the power per area. The light intensity equation is:

$$I = \frac{P}{A} = \frac{P}{4\pi r^2}$$

Remember that the power in this equation is the amount of light emitted by the light source. When you think of a “100 watt” light bulb, the number of watts represents how much energy the light bulb uses, not how much light it emits. Most of the energy in an incandescent light bulb is emitted as heat, not light. That 100-watt light bulb may emit less than 1 watt of light energy with the rest being lost as heat.

Solve the following problems using the intensity equation. The first problem is done for you.

1. For a light source of 60 watts, what is the intensity of light 1 meter away from the source?

   $$I = \frac{P}{A} = \frac{P}{4\pi r^2} = \frac{60 \text{ W}}{4\pi (1 \text{ m})^2} = 4.8 \text{ W/m}^2$$

2. For a light source of 60 watts, what is the intensity of light 10 meters away from the source?

3. For a light source of 60 watts, what is the intensity of light 20 meters away from the source?

4. If the distance from a light source doubles, how does light intensity change?

5. Answer the following problems for a distance of 4 meters from the different light sources.
   a. What is the intensity of light 4 meters away from a 1-watt light source?
   b. What is the intensity of light 4 meters away from a 10-watt light source?
   c. What is the intensity of light 4 meters away from a 100-watt light source?
   d. What is the intensity of light 4 meters away from a 1,000-watt light source?

6. What is the relationship between the watts of a light source and light intensity?
The Law of Reflection

The law of reflection works perfectly with light and the smooth surface of a mirror. However, you can apply this law to other situations. It can help you win a game of pool or pass a basketball to a friend on the court.

In this skill sheet you will review the law of reflection and perform practice problems that utilize this law. Use a protractor to make your angles correct in your diagrams.

The law of reflection states that when an object hits a surface, its angle of incidence will equal the angle of reflection. This is true when the object is light and the surface is a flat, smooth mirror. When the object and the surface are larger and lack smooth surfaces (like a basketball and a gym floor), the angles of incidence and reflection are nearly but not always exactly equal. The angles are close enough that understanding the law of reflection can help you improve your game.

Example

A light ray strikes a flat mirror with a 30-degree angle of incidence. Draw a ray diagram to show how the light ray interacts with the mirror. Label the normal line, the incident ray, and the reflected ray.

Solution:

1. When we talk about angles of incidence and reflection, we often talk about the normal. The normal to a surface is an imaginary line that is perpendicular to the surface. The normal line starts where the incident ray strikes the mirror. A normal line is drawn for you in the sample problem above.
   a. Draw a diagram that shows a mirror with a normal line and a ray of light hitting the mirror at an angle of incidence of 60 degrees.
   b. In the diagram above, label the angle of reflection. How many degrees is this angle of reflection?
2. Light strikes a mirror’s surface at 20 degrees to the normal. What will the angle of reflection be?

3. A ray of light strikes a mirror. The angle formed by the incident ray and the reflected ray measures 90 degrees. What are the measurements of the angle of incidence and the angle of reflection?

4. In a game of basketball, the ball is bounced (with no spin) toward a player at an angle of 40 degrees to the normal. What will the angle of reflection be? Draw a diagram that shows this play. Label the angles of incidence and reflection and the normal.

Use a protractor to figure out the angles of incidence and reflection for the following problems.

5. Because a lot of her opponent’s balls are in the way for a straight shot, Amy is planning to hit the cue ball off the side of the pool table so that it will hit the 8-ball into the corner pocket. In the diagram, show the angles of incidence and reflection for the path of the cue ball. How many degrees does each angle measure?

6. You and a friend are playing pool. You are playing solids and he is playing stripes. You have one ball left before you can try for the eight ball. Stripe balls are in the way. You plan on hitting the cue ball behind one of the stripe balls so that it will hit the solid ball and force it to follow the pathway shown in the diagram. Use your protractor to figure out what angles of incidence and reflection are needed at points A and B to get the solid ball into the far side pocket.
Refraction

When light rays cross from one material to another they bend. This bending is called refraction. Refraction is a useful phenomenon. All kinds of optics, from glasses to camera lenses to binoculars depend on refraction.

If you are standing on the shore looking at a fish in a stream, the fish appears to be in a slightly different place than it really is. That's because light rays that bounce off the fish are refracted at the boundary between water and air. If you are a hunter trying to spear this fish, you better know about this phenomenon or the fish will get away.

Why do the light rays bend as they cross from water into air?

A light ray bends because light travels at different speeds in different materials. In a vacuum, light travels at a speed of $3 \times 10^8$ m/sec. But when light travels through a material, it is absorbed and re-emitted by each atom or molecule it hits. This process of absorption and emission slows the light ray’s speed. We experience this slowdown as a bend in the light ray. The greater the difference in the light ray’s speed through two different materials, the greater the bend in the path of the ray.

The index of refraction ($n$) for a material is the ratio of the speed of light in a vacuum to the speed of light in the material.

$$\text{Index of refraction} = \frac{\text{speed of light in a vacuum}}{\text{speed of light in a material}}$$

The index of refraction for some common materials is given below:

<table>
<thead>
<tr>
<th>Material</th>
<th>Index of refraction ($n$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum</td>
<td>1.0</td>
</tr>
<tr>
<td>Air</td>
<td>1.0001</td>
</tr>
<tr>
<td>Water</td>
<td>1.33</td>
</tr>
<tr>
<td>Glass</td>
<td>1.5</td>
</tr>
<tr>
<td>Diamond</td>
<td>2.42</td>
</tr>
</tbody>
</table>

PRACTICE 1

1. Could the index of refraction for a material ever be less than 1.0? Explain.
2. Explain why the index of refraction for air (a gas) is smaller than the index of refraction for a solid like glass.
3. Calculate the speed of light in water, glass, and diamond using the index of refraction and the speed of light in a vacuum ($3 \times 10^8$ m/sec).
4. When a light ray moves from water into air, does it slow down or speed up?
5. When a light ray moves from water into glass, does it slow down or speed up?
Which way does the light ray bend?

Now let’s look at some ray diagrams showing refraction. To make a refraction ray diagram, draw a solid line to show the boundary between the two materials (water and air in this case). Arrows are used to represent the incident and refracted light rays. The normal is a dashed line drawn perpendicular to the boundary between the surfaces. It starts at the point where the incident ray hits the boundary.

As you can see, the light ray is bent toward the normal as it crosses from air into water. Light rays always bend toward the normal when they move from a low-\(n\) to a high-\(n\) material. The opposite occurs when light rays travel from a high-\(n\) to a low-\(n\) material. These light rays bend away from the normal.

The amount of bending that occurs depends on the difference in the index of refraction of the two materials. A large difference in \(n\) causes a greater bend than a small difference.

**PRACTICE 2**

1. A light ray moves from water (\(n = 1.33\)) to a transparent plastic (polystyrene \(n = 1.59\)). Will the light ray bend toward or away from the normal?

2. A light ray moves from sapphire (\(n = 1.77\)) to air (\(n = 1.0001\)). Does the light ray bend toward or away from the normal?

3. Which light ray will be bent more, one moving from diamond (\(n = 2.42\)) to water (\(n = 1.33\)), or a ray moving from sapphire (\(n = 1.77\)) to air (\(n = 1.0001\))?

4.

<table>
<thead>
<tr>
<th>Material</th>
<th>Index of refraction ((n))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium</td>
<td>1.00004</td>
</tr>
<tr>
<td>Water</td>
<td>1.33</td>
</tr>
<tr>
<td>Emerald</td>
<td>1.58</td>
</tr>
<tr>
<td>Cubic Zirconia</td>
<td>2.17</td>
</tr>
</tbody>
</table>

The diagrams below show light traveling from water (A) into another material (B). Using the chart above, label material B for each diagram as helium, water, emerald, or cubic zirconia.
Ray Diagrams

This skill sheet gives you some practice making ray diagrams. A ray diagram helps you determine where an image produced by a lens will form and shows whether the image is upside down or right side up. For each question on this skill sheet, read the directions carefully and plot your ray diagram in the space provided.

1. Of the diagrams below, which one correctly illustrates how light rays come off an object? Explain your answer.

   - **A.** All directions
   - **B.** Only one direction
   - **C.** All directions, corkscrew pathways

2. Of the diagrams below, which one correctly illustrates how a light ray enters and exits a piece of thick glass? Explain your answer.

   - **A.** Light through thick glass
   - **B.** Light through thick glass
   - **C.** Light through thick glass

In your own words, explain what happens to light as it enters glass from the air. Why does this happen? Use the terms refraction and index of refraction in your answer.

3. Of the diagrams below, which one correctly illustrates how parallel light rays enter and exit a converging lens? Explain your answer.

   - **A.** Parallel light rays enter, converge, and exit
   - **B.** Parallel light rays enter, diverge, and exit
   - **C.** Parallel light rays enter, converge, and exit

4. Draw a diagram of a converging lens that has a focal point of 10 centimeters. In your diagram, show three parallel lines entering the lens and exiting the lens. Show the light rays passing through the focal point of the lens. Be detailed in your diagram and provide labels.
A ray diagram helps you see where the image produced by a lens appears. The components of the diagram include the lens, the principal axis, the focal point, the object, and three lines drawn from the tip of the object and through the lens. These light rays meet at a point and intersect on the other side of the lens. Where the light rays meet indicates where the image of the object appears.

**EXAMPLE**

A lens has a focal length of 2 centimeters. An object is placed 4 centimeters to the left of the lens. Follow the steps to make a ray diagram using this information. Trace the rays and predict where the image will form.

**Steps:**
- Draw a lens and show the principal axis.
- Draw a line that shows the plane of the lens.
- Make a dot at the focal point of the lens on the right and left sides of the lens.
- Place an arrow (pointing upward and perpendicular to the principle axis) at 4 centimeters on the left side of the lens.
- **Line 1:** Draw a line from the tip of the arrow that is parallel to the principal axis on the left, and that goes through the focal point on the right of the lens.
- **Line 2:** Draw a line from the tip of the arrow that goes through the center of the lens (where the plane and the principal axis cross).
- **Line 3:** Draw a line from the tip of the arrow that goes through the focal point on the left side of the lens, through the lens, and parallel to the principal axis on the right side of the lens.
- Lines 1, 2, and 3 converge on the right side of the lens where the tip of the image of the arrow appears.
- The image is upside down compared with the object.
1. A lens has a focal length of 4 centimeters. An object is placed 8 centimeters to the left of the lens. Trace the rays and predict where the image will form. Is the image bigger, smaller, or inverted as compared with the object?

2. **Challenge question:** An arrow is placed at 3 centimeters to the left of a converging lens. The image appears at 3 centimeters to the right of the lens. What is the focal length of this lens? (HINT: Place a dot to the right of the lens where the image of the tip of the arrow will appear. You will only be able to draw lines 1 and 2. Where does line 1 cross the principal axis if the image appears at 3 centimeters?)

3. What happens when an object is placed at a distance from the lens that is less than the focal length? Use the term *virtual image* in your answer.
Radio waves, microwaves, visible light, and x-rays are familiar kinds of electromagnetic waves. All of these waves have characteristic wavelengths and frequencies. Wavelength is measured in meters. It describes the length of one complete oscillation. Frequency describes the number of complete oscillations per second. It is measured in hertz, which is another way of saying “cycles per second.” The higher the wave’s frequency, the more energy it carries.

In a vacuum, all electromagnetic waves travel at the same speed: \( 3.0 \times 10^8 \text{ m/sec} \). This quantity is often called “the speed of light” but it really refers to the speed of all electromagnetic waves, not just visible light. It is such an important quantity in physics that it has its own symbol, \( c \).

The speed of light is related to frequency \( f \) and wavelength \( \lambda \) by the formula to the right.

The different colors of light that we see correspond to different frequencies. The frequency of red light is lower than the frequency of blue light. Because the speed of both kinds of light is the same, a lower frequency wave has a longer wavelength. A higher frequency wave has a shorter wavelength. Therefore, red light’s wavelength is longer than blue light’s.

When we know the frequency of light, the wavelength is given by: \( \lambda = \frac{c}{f} \)

When we know the wavelength of light, the frequency is given by: \( f = \frac{c}{\lambda} \)
Answer the following problems and show your work.

1. Yellow light has a longer wavelength than green light. Which color of light has the higher frequency?
2. Green light has a lower frequency than blue light. Which color of light has a longer wavelength?
3. Calculate the wavelength of violet light with a frequency of $750 \times 10^{12}$ Hz.
4. Calculate the frequency of yellow light with a wavelength of $580 \times 10^{-9}$ m.
5. Calculate the wavelength of red light with a frequency of $460 \times 10^{12}$ Hz.
6. Calculate the frequency of green light with a wavelength of $530 \times 10^{-9}$ m.
7. One light beam has wavelength, $\lambda_1$, and frequency, $f_1$. Another light beam has wavelength, $\lambda_2$, and frequency, $f_2$. Write a proportion that shows how the ratio of the wavelengths of these two light beams is related to the ratio of their frequencies.
8. The waves used by a microwave oven to cook food have a frequency of 2.45 gigahertz ($2.45 \times 10^9$ Hz). Calculate the wavelength of this type of wave.
9. A radio station has a frequency of 90.9 megahertz ($9.09 \times 10^7$ Hz). What is the wavelength of the radio waves the station emits from its radio tower?
10. An x-ray has a wavelength of 5 nanometers ($5.0 \times 10^{-9}$ m). What is the frequency of x-rays?
11. The ultraviolet rays that cause sunburn are called UV-B rays. They have a wavelength of approximately 300 nanometers ($3.0 \times 10^{-7}$ m). What is the frequency of a UV-B ray?
12. Infrared waves from the sun are what make our skin feel warm on a sunny day. If an infrared wave has a frequency of $3.0 \times 10^{12}$ Hz, what is its wavelength?
13. Electromagnetic waves with the highest amount of energy are called gamma rays. Gamma rays have wavelengths of less than 10-trillionths of a meter ($1.0 \times 10^{-11}$ m).
   a. Determine the frequency that corresponds with this wavelength.
   b. Is this the minimum or maximum frequency of a gamma ray?
14. Use the information from this sheet to order the following types of waves from lowest to highest frequency: visible light, gamma rays, x-rays, infrared waves, ultraviolet rays, microwaves, and radio waves.
15. Use the information from this sheet to order the following types of waves from shortest to longest wavelength: visible light, gamma rays, x-rays, infrared waves, ultraviolet rays, microwaves, and radio waves.
You learned about Doppler shift as it relates to sound in Unit 7. The Doppler shift is also an important tool used by astronomers to study the motion of objects, such as stars and galaxies, in space. For example, if an object is moving toward Earth, the light waves it emits are compressed, shifting them toward the blue end (shorter wavelengths, higher frequencies) of the visible spectrum. If an object is moving away from Earth, the light waves it emits are stretched, shifting them toward the red end (longer wavelengths, lower frequencies) of the visible spectrum. In this skill sheet, you will practice solving problems that involve light and doppler shift.

Understanding Doppler shift

Astronomers use a spectrometer to determine which elements are found in stars and other objects in space. When burned, each element on the periodic table produces a characteristic set of spectral lines. When an object in space is moving very fast, its spectral lines show the characteristic patterns for the elements it contains. However, these lines are shifted.

If the object is moving away from Earth, its spectral lines are shifted toward the red end of the spectrum to a longer wavelength. If the object is moving toward Earth, its spectral lines are shifted toward the blue end of the spectrum to a shorter wavelength.

EXAMPLE

By analyzing the shift in wavelength, you can also determine the speed at which a star is moving. The faster a star is moving, the larger the shift in wavelength. The following proportion is used to help you calculate the speed of a moving star. The speed of light is a constant value equal to $3 \times 10^8$ m/sec. The first problem is done for you.

$$\frac{\text{The speed of a star}}{\text{The speed of light}} = \frac{\text{The difference in wavelength}}{\text{The stationary value for wavelength}}$$

The spectral lines emitted by a distant galaxy are analyzed. One of the lines for hydrogen has shifted from 450 nm to 498 nm. Is this galaxy moving away from or toward Earth? What is the speed of galaxy?

$$\frac{\text{The speed of a star}}{3 \times 10^8 \text{ m/sec}} = \frac{498 \text{ nm} - 450 \text{ nm}}{450 \text{ nm}}$$

$$\text{The speed of a star} = \frac{48 \text{ nm}}{450 \text{ nm}} \times 3 \times 10^8 \text{ m/sec} = 0.11 \times 3 \times 10^8 \text{ m/sec} = 3.2 \times 10^7 \text{ m/sec}$$

The galaxy is moving away from Earth at a speed of 33 million meters per second.
1. One of the spectral lines for a star has shifted from its stationary value of 535 nm to 545 nm.
   a. What is the difference in wavelength?
   b. What is the speed of this star?
   c. Is the star moving away from or toward Earth?

2. One of the spectral lines for a star has shifted from its stationary value of 560 nm to 544 nm.
   a. What is the difference in wavelength?
   b. What is the speed of this star?
   c. Is the star moving away from or toward Earth?

3. An astronomer has determined that two galaxies are moving away from Earth. A spectral line for galaxy A is
   red shifted from 501 nm to 510 nm. The same line for galaxy B is red shifted from 525 nm to 540 nm. Which
   galaxy is moving the fastest? Justify your answer.

4. Does the fact that both galaxies in the question above are moving away from Earth support or refute the Big
   Bang theory? Explain your answer.

5. The graphic to the right shows two spectral lines from an object that is not moving. Use an arrow to indicate the
   direction that the spectrum would appear to shift if the object was moving toward you.

6. The graphic to the right shows the spectral lines emitted by four moving objects. The spectral lines for when the
   object is stationary are shown as dotted lines on each spectrum. The faster a star is moving, the greater the shift
   in wavelength. Use the graphic to help you answer the following questions.
   a. Which of the spectra show an object that is moving toward you?
   b. Which of the spectra show an object that is moving away from you?
   c. Which of the spectra show an object that is moving the fastest away from you?
   d. Which of the spectra show an object that is moving the fastest toward you?

7. A star is moving away from Earth at 7 x 10^6 m/sec.
   a. The stationary wavelength of a spectral line is 450 nm. What is the difference in wavelength between the
      stationary and shifted line?
   b. Is the spectral line be shifted to a shorter or longer wavelength?
   c. What is the wavelength of the shifted line?
An incurable mathematician

Galileo Galilei was born in Pisa, Italy, on February 15, 1564. His father, a musician and wool trader, hoped his son would find a more profitable career. He sent Galileo to a monastery school at age 11 to prepare for medical school. After four years there, Galileo decided to become a monk. The eldest of seven children, he had sisters who would need dowries in order to marry, and his father had planned on his financial help. Galileo was hastily withdrawn from the monastery school.

Two years later, he enrolled as a medical student at the University of Pisa, though his interests were mathematics and natural philosophy. It was evident soon enough that Galileo did not intend to apply himself to medical studies, and so his father finally agreed that he could study mathematics instead.

Seeing through the ordinary

Galileo was insatiably curious. At 20, he found himself watching a lamp swinging from a cathedral ceiling. He used his pulse as a makeshift stopwatch and discovered that the lamp’s long and short swings took the same amount of time. He wrote about this in an early paper titled “On Motion.” Years later, he drew up plans for an invention, a pendulum clock, based on this discovery.

Inventions and experiments

Galileo started teaching at the University of Padua in 1592 and stayed for 18 years. Here he invented a simple thermometer, a water pump, and a compass for accurately aiming cannonballs. He also performed experiments with falling objects, using an inclined plane to slow the object’s motion so it could be more accurately timed. Through these experiments, he realized that all objects fall at the same rate unless acted on by another force.

Crafting better telescopes

In 1609, Galileo heard that a Dutch eyeglass maker had invented an instrument that made things appear larger. Soon he had crafted his own 10-powered telescope. The senate in Venice was impressed with its potential military uses, and in a year, Galileo had refined his invention to a 30-powered telescope. He might well have enjoyed his acclaim and become a man of wealth and leisure for the rest of his life.

Star gazing

Using his powerful telescope, Galileo’s curiosity now turned skyward. He discovered craters on the moon, sunspots, Jupiter’s four largest moons, and the phases of Venus. His observations led him to conclude that Earth could not possibly be the center of the universe, as had been commonly accepted since the time of the Greco-Egyptian astronomer Ptolemy in the second century. Instead, Galileo was convinced that Polish astronomer Nicolaus Copernicus (1473-1543) must have been right: The sun is at the center of the universe and the planets revolve around it.

House arrest

The Roman Catholic Church held that Ptolemy’s theory was truth and Copernican theory was heresy. Galileo, who had been told by the Inquisition in 1616 to abandon Copernican theory and its promulgation, pursued his thinking and writing. In February 1632, he published his ideas in the form of a conversation between two characters, the one representing Ptolemy’s view seeming foolish and bullheaded, the other arguing Copernicus’s theory. This provoked the church, whose permission was needed for publishing books, to call Galileo before the Inquisition in Rome, where under formal threat of torture he renounced his error in promoting Copernican theory. He was sentenced to house arrest, and lived until his death in 1642 watched over by Inquisition guards.
Reading reflection

1. What scientific information was presented in Galileo’s paper “On Motion”?

2. Research one of Galileo’s inventions and draw a diagram showing how it worked.

3. How were Galileo’s views about the position of Earth in the universe supportive of Copernicus’s ideas?

4. Imagine you could travel back in time to January 1632 to meet with Galileo just before he publishes his “Dialogue Concerning the Two Chief World Systems.” What would you say to him?

5. In your opinion, which of Galileo’s ideas or inventions had the biggest impact on history? Why?
Arthur Walker

Arthur Walker pioneered several new space-based research tools that brought about significant changes in our understanding of the sun and its corona. He was instrumental in the recruitment and retention of minority students at Stanford University, and he advised the United States Congress on physical science policy issues.

Not to be discouraged

Arthur Walker was born in Cleveland in 1936. His father was a lawyer and his mother a social worker. When Arthur was 5, the family moved to New York. Arthur was an excellent student and his mother encouraged him to take the entrance exam for the Bronx High School of Science.

Arthur passed the exam, but when he entered school a faculty member told him that the prospects for a black scientist in the United States were bleak. Rather than allow him to become dissuaded from his aspirations, Arthur’s mother visited the school and told them that her son would pursue whatever course of study he wished.

Making his mark in space

Walker went on to earn a bachelor’s degree in physics, with honors, from Case Institute of Technology in Cleveland and, by 1962, his master’s and doctorate from the University of Illinois. He then spent three years’ active duty with the Air Force, where he designed a rocket probe and satellite experiment to measure radiation that affects satellite operation. This work sparked Walker’s lifelong interest in developing new space-based research tools.

After completing his military service, Walker worked with other scientists to develop the first X-ray spectrometer used aboard a satellite. Their device helped determine the temperature and composition of the sun’s corona and provided new information about how matter and radiation interact in plasma.

Snapshots of the sun

In 1974, Walker joined the faculty at Stanford University. There he pioneered the use of a new multilayer mirror technology in space observations. The mirrors selectively reflected X rays of certain wavelengths, and enabled Walker to obtain the first high-resolution images showing different temperature regions of the solar atmosphere. He then worked to develop telescopes using the multilayer mirror technology, and launched them into space on rockets. The telescopes produced detailed photos of the sun and its corona. One of the pictures was featured on the cover of the journal Science in September 1988.

A model for student scientists

Walker was a mentor to many graduate students, including Sally Ride, who went on to become the first American woman in space. He worked to recruit and retain minority applicants to Stanford’s natural and mathematical science programs, and was instrumental in helping Stanford produce more black doctoral physicists than any university in the United States.

At work in other orbits

Public service was important to Walker, who served on several committees of the National Aeronautics and Space Administration (NASA), National Science Foundation, and National Academy of Science, working to develop policy recommendations for Congress. He was also appointed to the presidential commission that investigated the 1986 space shuttle Challenger accident.

Reading reflection

1. Use your textbook, an Internet search engine, or a dictionary to find the definition of each word in bold type. Write down the meaning of each word. Be sure to credit your source.

2. What have you learned about pursuing goals from Arthur Walker’s biography?

3. Why is a spectrometer a useful device for measuring the temperature and composition of something like the sun’s corona?

4. **Research:** Use a library or the Internet to find one of Walker’s revolutionary photos of the sun and its corona. Present the image to your class.

5. **Research:** Use a library or the Internet to find more about the commission that investigated the explosion of the space shuttle Challenger in 1986. Summarize the commission’s findings and recommendations in two or three paragraphs.