Name: ____ **Period:** ___________

Can I Believe My Eyes?

Physical Science 1

Light waves, their role in sight and interactions with matter

Investigating and Questioning
Our World through Science
and Technology
(IQWST)

Name: ____ **Period:** __________

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Vocabulary	Definitions/Images

Evidence Gained	What did we learn?

Scientific Principles

Design 1 – How do I design a solar cooker?

Summary

We will follow the ***design process*** to create a solar cooker.

Design Process:

Empathize: Learn about the audience (research, interviews, etc.)	Why is it important to design a cheap, do-it-yourself solar cooker?
Define: Explain the objective (goal), the key requirements, and constraints	What are the key requirements? What are your constraints? (*materials)*
Research: Research online and find ideas - what information will help you?	

Solar Oven Part	Why is it important?

Ideate:
-Draw at least 1 idea
-Share with your group- all are worthy
-“Yes and…”
-Prioritize (which design do you think is the best one to start with?)

Stamp of approval

Your idea (draw with labels!)

Explain why it would it work.

Explain what you’re not sure about.

Draw the design you are going to start with. Include labels!

<—Discuss with the teacher and get a stamp to begin gathering materials and building a prototype

Prototype and Redesign: -Build an example -Fail fast -Rebuild quickly *If you need more data tables, get a piece of paper and create more	Procedure for testing your prototype:

Procedure for testing your prototype:

- [ ] If indoors, place about 3 feet away from the lamp.
- [ ] If outdoors, make sure you are within sight of the teacher
- [ ] Collect data to answer these two questions: What is the maximum temperature? How quickly can it reach that temperature?

Prototype 1

Time (min)	Temperature (°C)
0	
2	
4	
6	
8	
10	

Time (min)	Temperature (°C)
12	
14	
16	
18	
20	

Prototype 2

Time (min)	Temperature (°C)
0	

Time (min)	Temperature (°C)

Prototype 3

Time (min)	Temperature (°C)
0	

Time (min)	Temperature (°C)

Test:
-Final design (for now)
-We will complete this together at the same time

Time (min)	Temperature (°C)
0	

Time (min)	Temperature (°C)

Evaluate:

1. How much did your solar cooker heat up in the final test? (Take the final temperature and subtract the initial temperature)

2. How did your solar cooker compare to others in your class?

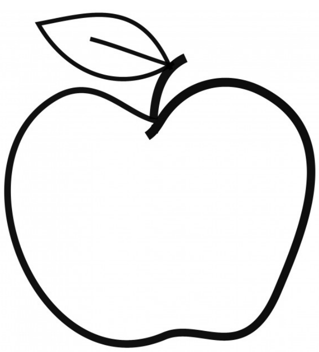
3. If you could redesign for another prototype, what would you keep? Why?

4. What would you change? Why?

Pre-assessment

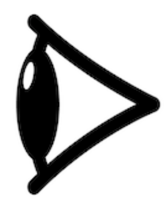
Instructions

This assessment is a way to show what you already know and it does not affect your grade or proficiency score at all. Just try your best! If you are unsure or don't know, please explain what you do not understand.



1.Create a model to show what happens when light reaches an object. You may draw and/or use words to explain. Remember, your teacher has to be able to understand your thinking.

A.Clear plastic



B. Black paper

C. Wrinkled aluminum foil

2. Complete the model below to explain why the red apple appears red.

Lesson 2 – What Do We Need to See an Object?

Investigation 2.1 – Seeing objects around the room.

Summary (What will we do?)

We will explore some of the things humans need in order to see an object

Procedure

- ☐ Look at the image your teacher projects. Think-pair-share: Why can the girl see the tree?

- ☐ Look at the next image projected. Think-pair-share: Why doesn't the girl see the car?

- ☐ Pretend you have been hit by a *freeze* ray. It is important that you keep your body and your head in the same position so you can collect fair data. As your teacher names objects in the room, record them in the data table. Then put a check mark (✓) in the appropriate column. You will not be able to see everything your teacher names..

Data (Qualitative or quantitative)

Objects around the Classroom	I Can See	I Cannot See

Analysis and Interpretation

1. What patterns do you notice about who could and could not see the different objects?

2. What factors affected whether a person could see an object or not?

Investigation 2.2 – The Light Box.

Summary (What will we do?)

We will gather evidence about what needs to happen in order for people to see an object.

Materials

- ☐ Lightbox

Safety/Responsibility

- ☐ Please be gentle with the flap and box. Rotating or slamming the light box may cause damage.

Procedure

- ☐ Look into the light box. Keep the lid and the flap closed. In the data table, draw what you see.
- ☐ While keeping the light box lid closed, open the side flap. Look into the light box. In Table 1, draw what you see.
- ☐ Your teacher will add a divider to your light box. Keep the box lid closed and the side flap open. Draw what you see in Table 2. Include as much detail as you can.

Data (Qualitative or quantitative)

Table 1

	Lid and Flap Closed	Lid Closed and Flap Open
Observations		

Table 2

Observations	

Analysis and Interpretation

1. Describe the differences (compare) between your observations in Table 1. Why are the observations different?

2. Compare your drawing with other students' drawings. How can you explain the differences?

3. List the conditions that need to be met in order for people to see an object. This list should be agreed upon by the whole class.

Reading 2.2 – Picture This!

Getting Ready

Look closely at the picture. Hold the paper close to your face. Now, set your book down and look at the picture from across the room.

Why do the small pictures you can see up close look like one big picture from across the room?

In this reading, you will learn how a similar idea makes the pictures that you see on TV.

How Do People See Objects around Them?

In class, you learned about things that affect what people see. You learned that the girl in the image your teacher projected can see the tree because light travels from the sun, bounces off the tree, and enters her eye.

In the second image your teacher projected, something different happens. Light from the sun bounces off the car, but this time the girl cannot see the car. Some of the light travels toward her, but it cannot enter her eye, because the wall blocks its path. If the light bouncing off the car does not enter her eye, the girl cannot see the car.

Image 1

Image 2

Do you think the girl in Image 1 can see the sun? Why? (Be sure to write about the path the light might take.)

Do you think the girl in Image 2 can see the sun? Explain your ideas. (Be sure to write about the path the light might take.)

In Lesson 2, you looked for objects around the room. You learned that you could only see some of the objects from your seat. You could not see other objects, even though some of your classmates could see them. You also looked into the end of a light box and learned that sometimes you could see what was inside, and sometimes you could not.

Your class used these activities to develop a list of conditions that need to be met in order for humans to see an object. As you read, think about these conditions and how they affect what you see on a television.

A Different Experience with Seeing: How Do I See Objects on Television?

If you have a television in your home, turn it on. What do you see on the screen? You probably see a person, some objects, or a scene indoors or outdoors. However, there is a difference between seeing the actual object and seeing the object on television. To see the object—like a chair—in real life, you need a source to provide light, and you need the light to bounce off the chair to your eye. To see a chair on television, you do not need an additional source of light to bounce off of the chair.

The television is the light source. The television produces light that goes directly to your eyes. An image on television is both an object and a light source at the same time. That is why you can see objects on television even in a room with no lights.

Review the class' list of conditions (Q3, p17) from investigation 2.2 of factors people need to see. Using the list, explain what is different about seeing an object in a room and seeing an image on television.

The difference between seeing an object and an image on television is that an object must have a light source that is bouncing light off of it for us to see it. When we see an image on the television, the image is both the object and the light source. This true for any light source. If you look at a light bulb, it is both the object and the light source.

How Is an Image on Television Similar to the Picture at the Beginning of This Reading?

When you see objects on television, you are really seeing many tiny dots. Together, the dots create an image that looks like something real. These dots are called pixels. On some televisions, especially old ones, you may be able to see the pixels if you look at the screen closely. Even if you can see the pixels up close, they are too small to be seen as individual dots when you stand far away. Instead, your brain will put them together to make an image. This is the same way that the picture in the Getting Ready section works. If you stand far enough away, the tiny pictures look like pixels, and your brain puts them together to make a larger image.

An Example of Pixels

When you see an image on your television or on a movie screen, you are actually seeing millions of tiny dots that all together look like the object or person. Your brain puts the dots together so that you see a single image.

Your television screen is a collection of tiny dots that join together to make the big picture you see. Each little dot acts like a light source and an object. The light moves along a straight path to your eyes. Your brain does not see a bunch of little objects, because it puts them together to see the image on the television.

Two More Examples: Newspapers and Artwork

Dot patterns are not only used for television images. Dots are also used in computer and newspaper images and in paintings. If you have a newspaper at home, look at it very closely. If you have a magnifying glass, use it to look at the newspaper up close. Can you see the tiny dots that make up the pictures and the words?

Many things in the world today use pixels to make images. Long ago, artists in France painted in a style called pointillism (see image below). Images using pointillism are created by painting many tiny dots or points. The colors of the paint are not mixed together using a brush. Instead, the different colored dots are placed very close together. When you look at the painting from far away, the light from the room bounces off the dots on the painting and then enters your eye. Your brain blends the dots together to form a larger image.

Sunday Afternoon on the Island of La Grande Jatte,
Georges Seurat

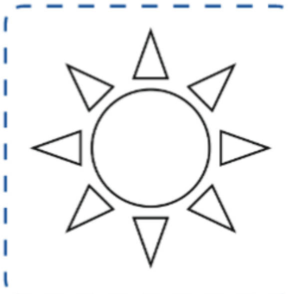
Compare the dots used in pointillism with the dots created on a television screen. Be sure that your comparison describes what is alike and what is different.

Lesson 3 – Constructing Models of How People See

Activity 3.1 – What makes a good model?

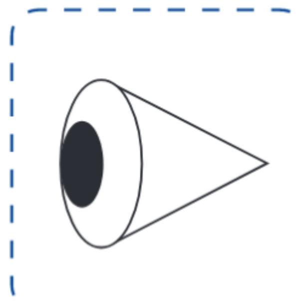
Summary (What will we do?)

We will construct physical models of how people see. Our models will represent the key components and relationships that we have learned so far.



Part A: Introducing models

A model is a way to explain how a phenomenon works. A model can be good or not-so- good, depending on what it is being used for. When you use a model to explain an idea to someone, the best model is usually a simple one. A good model for explaining something includes all the key components and the relationships between them. It is important that a model only includes those things and not extra parts that do not help explain something. It is also important that your model is accurate.



Your teacher will show you two different models of light.

Model A: A 3D model with a styrofoam ball as a light bulb and some toy cars

Model B: A 2D drawing of a light bulb with light rays

	hs	Limitations
Model B		

1. Explain which model you think explains the phenomenon of light the best. Why?
2. Fill out the chart below by describing the strengths and limitations for each model (Guiding questions: What does model A explain well that model B does not? What does model B show that model A does not? What do they both show well? What do they both <u>not</u> show well?)

Part B: Develop Your Model

3. A model needs to be consistent with all the evidence. In Lesson 2, you gathered evidence that a model of seeing needs to include four key components: a light source, an object, an eye, and paths between the light, the object, and the eye. Draw your model below.

Part C: Evaluating Different Models

No model is perfect. Every model has strengths and weaknesses. Follow your teacher's directions in examining and analyzing the different models.

1. Choose a model that you think best explains the phenomenon of how people see. What are the strengths of this model?

2. Choose a model that you think had many limitations in explaining the phenomenon of how people see. Describe those limitations.

3. What are the strengths and weaknesses of your model?

Part D: Developing a Consensus Model

A model is an explanation of a phenomenon (written description, 2D drawing, 3D construct, mathematical equation, computer simulation, etc.). Consensus means everyone agrees.

4. Define “consensus model”:

5. After class discussion, draw the consensus model below.

Reading 3.1 – Modeling

Why Do Scientists Use Models?

When you hear the word model, you might think of fashion models or model airplanes or model cars. Scientists use the word model in a special way. In science, a model is a way to represent an idea, process, or system in order to describe, explain, or predict something.

Models help to explain things that are difficult to understand or difficult to observe. For instance, you cannot see your heart, but you can use a model of a heart to explain how it pumps blood through your body. Models can also represent things that are too big or too small to observe. People cannot observe the whole Earth at once, but they can use maps and globes as models to help them explain phenomena. People on television use maps to help them explain weather or earthquakes. Globes can help explain why it is day and night at different times in different parts of the world.

In class, you have been developing a model of how light makes it possible for people to see objects. Your model helps you understand, and it can also help you explain it to other people. Scientists use models to communicate. As you learn more about light, you might decide that you need a different model than the one you made today. Scientists revise their models as they learn new things. It is OK if your model of how people see gets revised, too.

Models help scientists think about possible answers to their questions about phenomena.

Is It OK that My Friend's Model Is Different from Mine?

You and your classmates may have constructed different models of how people see. Different models can be helpful because they may show

Write a GIST summary of the reading (40 words or less) different information about the same phenomenon. All models have strengths and limitations. Even good models can often be made better. You will learn how to evaluate models to decide what is good and what needs to be changed.

Scientists evaluate their own models and revise them when necessary. For example, new data make scientists think about a phenomenon in a new way. Data is a word you will use over and over again in science. When scientists make observations, they take careful notes while they are observing something with their senses or measuring it with instruments. The notes they write or record are called data. When they use data to support an idea, they are using the data as evidence. You will do the same thing in science class. Your data may come from your own observations and measurements, or it may come from a table or graph that someone else made. When you use data to explain an idea, you are using the data as evidence. When scientists—or you—develop a model, the model needs to be consistent with all the relevant evidence.

An Example of Scientists Revising Their Models

Scientists revise a model when it does not work very well for explaining something. For example, you probably know that sailors once explored the world by sailing across oceans. They drew maps of the oceans and land to show what the world looked like. These drawings were similar to the flat maps we use today. Maps are one kind of model that is drawn. A flat model helped early scientists understand most things about the world around them.

However, as people made observations and tried to answer new questions, they found that a flat model of Earth did not work for everything. For example, sailors could see the tops of masts as ships approached them over the horizon. If Earth was flat, that would not make sense. They would not see the tops of masts first and then gradually see the rest of the ship. They also wondered why the sun changes its position in the sky throughout the year. A flat model of Earth was not consistent with the data they observed.

Scientists began to consider a new model. They began to use a round model of Earth—like a ball. A round Earth model can explain why the tops of ships' masts are visible first. A globe model can explain the positions of the sun in the sky, and it can explain seasons.

Later, photographs taken from space showed the shape of Earth. Before scientists knew for sure, they had to keep testing their model to see whether it worked to explain their observations. Today, a globe serves as a good model for many things scientists want to explain. A flat map is good for showing how to get from one place to another. However, it is not good for explaining how the sun rises and sets or how a ship can sail around the world. Every model has strengths and limitations (or advantages and disadvantages).

A model that explains what you know today about how light helps people see might not be a good model for what you will try to explain later in the unit. You might revise your model as you gather more data. Scientists revise

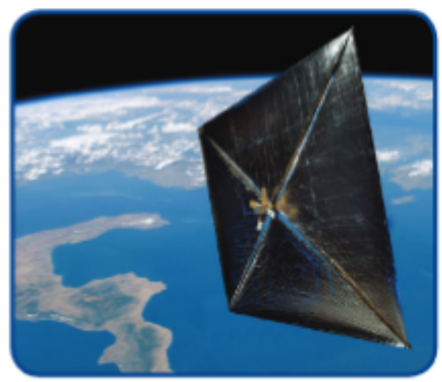
Reading 3.2 – Faster than a Speeding Bullet

Getting Ready

In this reading, you will learn about how fast light moves. Before you read, think of some of the fastest things you have heard about. Fill in the chart with your ideas.

Moving Object	How Fast does it go?
Fastest human runner	
Fastest bicycle rider	
Fastest animal	
Fastest Car	
Fastest man-made object	

When people say that turning on a light switch lights up the room, what do they mean? In class, you constructed a model that shows what is needed for people to see objects in a room. The key components in your model were an object, an eye, a light source, and the key relationship between these was the straight paths between them. When you turn on a light bulb, light travels from the bulb outward in all directions and hits objects in the room. You see the objects because light travels from the light bulb, bounces off the objects, and then enters your eye.



If light has to travel back and forth across the room before you can see an object, why do you see things in a room as soon as you turn on a light switch? The answer has to do with the speed of light. Light is very fast.

What Do We Know about the Speed of Light Today?

Today, humans can send objects much farther away. In 1969, the United States sent astronauts to the moon. The moon is about 240,000 miles (365,000 km) away from Earth. This is like traveling around the whole Earth 10 times. Think about how long it would take you to drive around the earth in a car. During the mission to the moon, scientists noticed that it took about one second for light from Earth to reach the astronauts on the moon.

Light can travel around Earth 10 times in just one second. Nothing else can travel that fast. The sun is much farther away than the moon. Traveling to the sun would be like taking 37,000 trips around Earth. Even though Earth is a huge distance from the sun, it only takes light from the sun about eight minutes to get to Earth. This means that when you see the sun, you are seeing how it looked eight minutes ago.

How Does the Speed of Light Compare to Other Fast Things?

In the beginning of this reading, you thought about some fast things. The world's fastest people can run at about 25 miles per hour. A cheetah can run 70 miles per hour. The fastest animal is the peregrine falcon. It can fly over 200 miles per hour.

Humans have made machines that can move extremely fast. The fastest a person has ever made a bicycle go is 167 miles per hour. A Thrust SSC, the world's fastest car, can go 760 miles per hour. The fastest human-made objects travel in space. A spacecraft called the Helios traveled at 150,000 miles per hour (or 241,400 km per hour). At this speed, it would take about a month to travel from Earth to the sun.

It only takes light eight minutes to travel from the sun to the earth because light moves much faster than anything humans have ever made. Light moves through space at 670,000,000 miles per hour. This means that it would take a jet airplane 25 days to travel the same distance that light can travel in one second. When you flip on a light switch, it seems that light hits your eye instantly because light moves so fast. It moves back and forth across the room so fast that you do not even notice it moving.

How Can the Speed of Light Help People Move Faster?

One way that the speed of light matters to scientists is when they think about space travel. Right now, if people could travel to Mars with the space shuttle, it would take nine months to get to Mars. It would take another nine months to get back to Earth. Scientists at NASA are studying how to use new spaceships called solar sails. This is a photo of a solar sail. These ships could travel thousands of times faster than the space shuttle. The space shuttle is pushed by burning rocket fuel, but solar sails are pushed by light. That means they would be much faster. Experimenting with solar sails is one of the ways that scientists use their understanding of light to create something new.

As you have learned, light moves extremely fast, and it will be able to help people do things even faster. In Lesson 4, you will learn about what happens to the light that enters your eye.

Lesson 4 – The Eye as a Light Sensor

Investigation 4.1 – How does the Eye Work?

Summary (What will we do?)

We will learn about how our eyes act like a light sensor.

Materials

1 Light sensor

1 iPad

1 Light Sensor Connection Sheet

Safety and Responsibility

Be aware of your surroundings.

Do not drop the light sensor or iPad.

Procedure

- ☐ Your teacher will project a representation of the eye. Use the following space to draw or write notes about what your teacher reviews in class.

- [ ] Use the Light Sensor Probe Connection sheet to connect your iPad to the light sensor. You are going to go on a hunt using a light sensor. The sensor only detects light that comes from objects directly in front of it. The light has to bounce off the object or come from a light source and travel straight into the sensor.
- [ ] Use the light sensor to measure light in different places in the room. Record the location, the measurement, and the units in the data table.

Data

Location	Amount of light (lux)

Analysis and Interpretation

1. Where are the brightest parts of the room? What are the least bright parts of the room?

2. If no light is coming from any object into your eye, then what will you see? What evidence from a classroom activity supports your answer?

3. Does a light sensor detect an object, or does it detect the light coming from an object?

4. Why does it make a difference in which direction you point the light sensor?

5. Why does it make a difference how far away the light sensor is from the object at which it is pointing?

6. Like the light sensor, the eye acts as a sensor of light. Light has to come into the light sensor and into your eye from outside. How can you use the consensus model of light to explain why parts of the room are the brightest (or the least bright) to the eyes?

Reading 4.1 – Eyes in the Animal Kingdom

Getting Ready

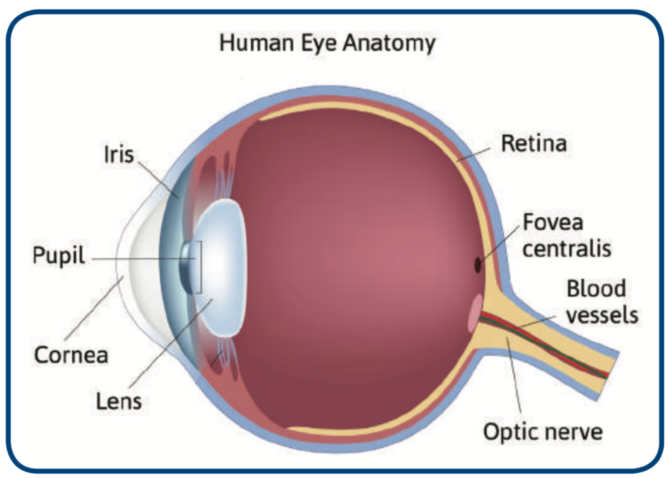
Try this at home. Go into a small room with a mirror, like a bathroom. Look closely in the mirror at your eyes; then turn off the light and make the room as dark as possible. If you cannot make the room dark, shut your eyes and cover them with your hands. Wait for several seconds, and then turn the lights on as you continue to look at your eyes in the mirror.

What changes do you notice in your eyes immediately after you turn the light on? Why do you think this change happens?

Do you think the same change happens to animals' eyes? In this reading, you will learn why your eyes look different depending on whether the lights are on or off. You will also learn whether animals' eyes do something similar or different.

How Do My Eyes Sense Light?

In class, you learned how the human eye works as a light sensor. When you see an object in a room, the light is bouncing off of that object and going straight into your eye. How does your eye help you see?



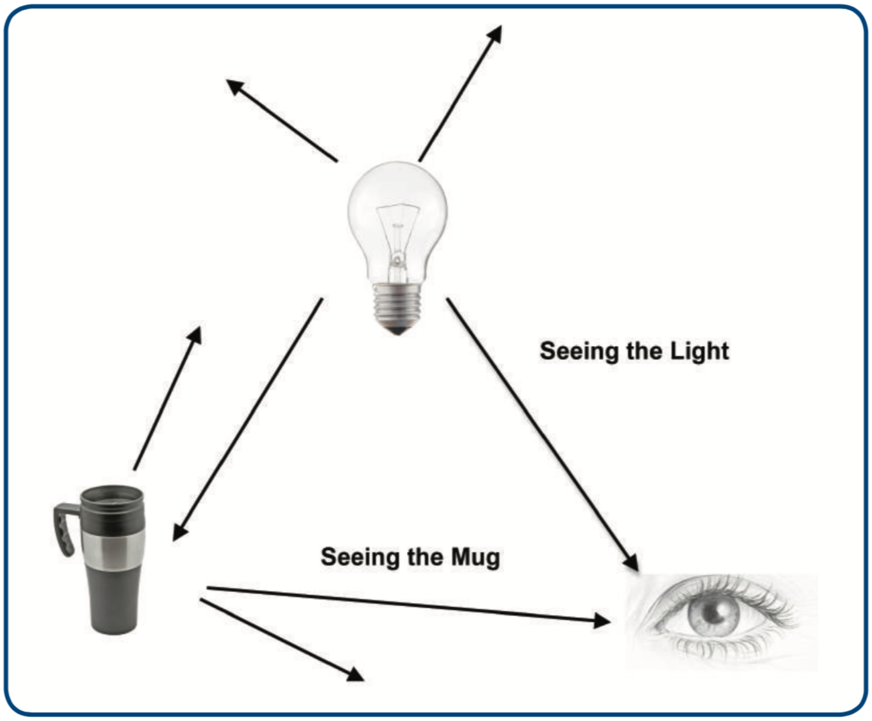
The eye has several important parts. The opening in the center is called the pupil. In the picture, the pupil is labeled. It looks black, but it is really just like a clear window that lets light into the eye.

The cornea is a protective covering over the whole eye. It keeps the eye from getting scratched. The lens in the eye is like the lens in eyeglasses or in a camera. The lens focuses the light coming into the eye.

The lens focuses light onto the back of the eyeball on an area called the retina. Sensors in the retina detect the light that reaches them. Those sensors send a signal to the brain through the optic nerve.

How Do the Parts of the Eye Work Together?

When you see a light bulb, several things happen. First, some of the light coming from the bulb enters your eye and reaches your retina. Second, your retina sends a signal to your brain. Third, your brain recognizes that the signal is a light from a light bulb.



Look at the diagram. If a coffee mug were in the room so that you could see it, then some of the light from the light bulb would be bouncing off of the mug. Some of the light bouncing off of the mug would enter your eye and reach the retina. A signal would go to your brain, and recognize it as the image of a mug. A lot has to happen for you to see something; but it happens very quickly.

Using Equipment as a Light Sensor

Your eye is a sensor. Special equipment also can act as a sensor. The light sensors that you used in this lesson are one example. When you pointed the sensor at an object, it detected the light coming from that object. Just like with your eyes or with cameras, light had to enter the sensor in order to be detected. Instead of sending a signal that your brain recognizes as an image, the light sensor sends a signal to a small computer. This computer receives the signal and displays a number that tells how much light is entering the sensor. When you saw an object in the room that looked bright to your eyes, the light sensor showed a very high number on its display. You may have gotten a high number when you pointed the sensor at the lights or at a window. When you saw an object that looked dim to your eyes, the sensor showed a low number on its display. You may have gotten low numbers when you pointed the sensor under tables or desks. When light enters a sensor, a computer gives information. When light enters your eye, your brain gives you information.

Do Animal Eyes Work like Human Eyes?

Just like human eyes, animals' eyes work by detecting light. However, there are some differences between human eyes and some animals' eyes. In this reading, you will learn about three animals that have eyes with special characteristics.

Polar Bears

Have you ever played outside in the snow on a sunny day or played on a white sand beach on a sunny day? If you have, you know how bright it is when the sun's light bounces off of the white snow or the white sand. You also may have noticed that it is difficult to see in bright light without squinting. Why do people squint?

People squint so that their eyelids squeeze together and cover part of the iris. When the iris is partially covered, the path of some of the light going into the eyes gets blocked. Polar bears live outside in the snow. Because polar bears have to hunt for food in intense sunlight, their eyes have to allow them to see in very bright light. Polar bear eyes have a protective, clear cover over their eyeballs. The bears can see through this covering to hunt. The covering protects their eyes from bright sunlight and the light that bounces off the snow. It is kind of like having built-in sunglasses. This protective cover also helps protect a bear's eyes when it swims under water.

Cats

Cats also have eyes adapted to their environment. As natural hunters, cats need to have keen senses in order to stalk their prey. Cats can see almost as well as humans during the daytime, but their nighttime vision is much better. Although cats cannot see in complete darkness, they can see much better than humans in environments that appear dark to us. In fact, cats can see six times better than humans in places with low light. There are several reasons for this. Cat retinas are more sensitive than human retinas. During the day, a cat’s pupil looks like a slit. This slit decreases the amount of light entering the eyes and prevents the cat from having to squint. A round pupil, like in a human eye, would let in too much light. At night, or when cats are in dark places, their pupils can open three times wider than those of humans. The wider opening lets in much more light. Like polar bears, they have a transparent protective cover over their eyes that allow them to see well in bright daylight. You may have seen a cat’s eyes appear to glow in the dark when light is shined on them, as in the photo. The transparent cover causes cats’ eyes to appear to glow at night. You may have also noticed this on dogs.

Giant Sea Squid

Giant sea squids are known to have the largest eyes of any animal in the animal kingdom. Even though many animals are larger than the sea squid, none have such big eyes. Some giant sea squids have eyes about the size of your head. Their huge eyes have very large

Lesson 5 – Examining Shadows

Investigation 5.1 – How are shadows created?

Summary (What will we do?)

We will explore shadows and use our light model to explain our observations.

Materials

Flashlight

Blank white paper

Object (hand, pencil, etc.)

Procedure

- ☐ The teacher will dim the lights in the classroom.
- ☐ Put a piece of white paper on your desk.
- ☐ Use your object and a flashlight to create a shadow on the paper.
- ☐ Explore what happens to the shadow in three conditions:
  - ☐ moving the object
  - ☐ moving the flashlight
  - ☐ moving the paper
- ☐ Record your observations in the data table.
- ☐ Discuss the following questions with your group:
  - ☐ How does the shape of the shadow compare to the shape of the object?
  - ☐ How can you change the size of the shadow?
  - ☐ How can you change the location of the shadow?

Data

	Observations of the shadow
Moving the object	
Moving the flashlight	
Moving the paper	

Analysis and Interpretation

1. How does the light model help you explain that the shape of the shadow is like the shape of the object?

2. How does the light model help you explain how you can change the location of the shadow?

3. Use the consensus model to explain how shadows are created and why we can see a shadow. Use the observable components: Light source, eye, object, shadow, and surface.

4. Models can be useful not only to understand and explain but also to predict something before experiencing it. Using your model, predict what a light detector would detect when pointing toward the shadowed area on the surface. Explain.

Reading 5.2 – A Midnight Crime

We will read a story about a crime that took place on a dark night. We will use what we have learned about light and shadows to answer questions and solve the crime.

A Midnight Crime

Halloween was perfect, with a clear and dark sky. Many people came to the Diaz's Halloween party. Everyone had a great time, and some people stayed until dawn. After everyone left, the Diazs discovered that some expensive jewelry was missing. They called the police. The police asked everyone who had been at the party to answer a few questions.

A police officer listened carefully to each person's story. Mr. Jones said, "I left the Diaz's party around midnight, and I walked to my car. It was cold, but the sky was clear with no clouds. It was totally dark outside. When I got in my car to leave, I saw someone walking out of the house holding a decorated wooden box. I turned on the car lights, and the person immediately turned around and walked away from me. They walked directly toward the wall next to the house. I could see the shadow on the wall getting larger and larger until the person disappeared around the corner. At that time, I did not suspect anything, so I just drove away." The police officer thought for a minute and said, "You are under arrest on suspicion of stealing the Diaz's jewelry. Your statement includes too many impossible details. I suspect you know something about the disappearance of the jewelry collection."

Follow Up Questions

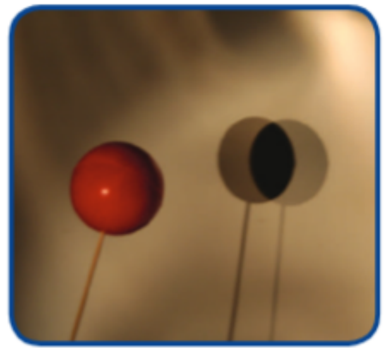
1. What are the impossible details in Mr. Jones's statement to the police? Explain why these details are impossible.

Detail in the Statement	Why is That Impossible?

2. Construct a drawn model that helps explain how Mr. Jones would have really seen a person's shadow.

3. If Mr. Jones had not turned on his car lights, would he have been able to see the person? Would he have been able to see the person's shadow? Explain.

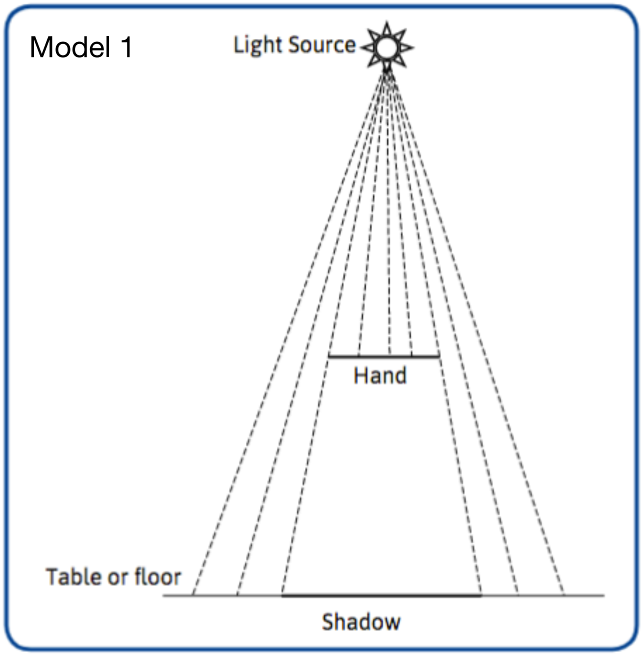
4. Explain why light is necessary to see an object.



Investigation 5.2 – How are fuzzy shadows created?

Summary (What will we do?)

We will explore how to make fuzzy shadows and use the consensus model to help us explain.



Materials

Flashlight

Blank white paper

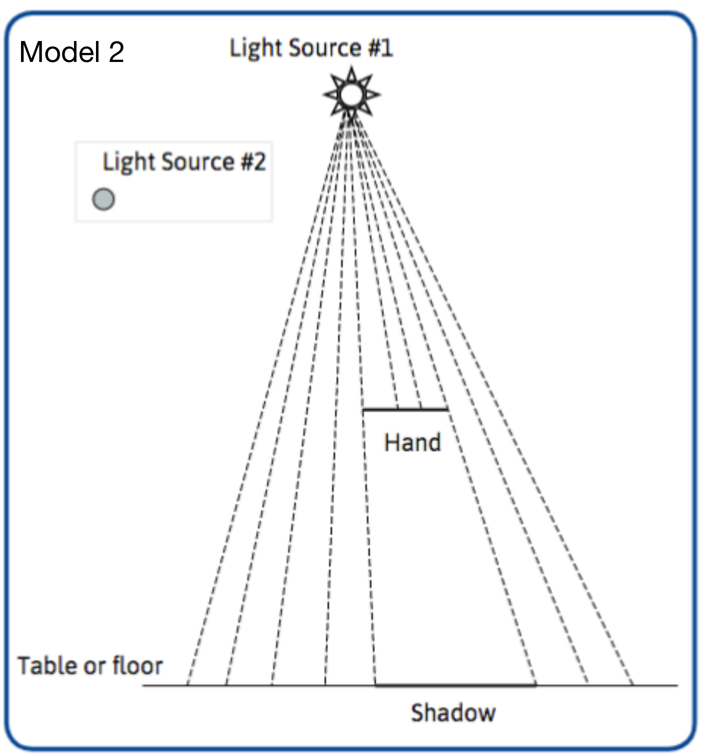
Object (hand, pencil, etc.)

Procedure

- ☐ The teacher will dim the lights in the classroom.
- ☐ Put a piece of white paper on your desk.
- ☐ Use your materials to try to make clear shadows, fuzzy shadows, and multiple shadows (Hint: Join a group and share materials)

Data

1.What materials and methods helped you make a clear shadow?



2.What materials and methods helped you make a fuzzy shadow?

3.Were you able to create multiple shadows? How?

Analysis and Interpretation

1. Model 1 shows how shadows are created from one light source. Describe what the model is explaining.

2. Complete Model 2 to show why fuzzy/multiple shadows are formed.

Lesson 6 – Light and Matter

Investigation 6.1 – What happens when light reaches an object?

Summary (What will we do?)

Today you will investigate what happens to light when it reaches an object, provide evidence to support your ideas, and connect what you have discovered to your solar cooker design.

Prediction

Look at the different objects your teachers shows you. What does light do when it reaches each of these objects?

Materials

Objects:

Black paper	flashlight
Clear plastic	light sensor
Mirror	temperature probe
White Paper	iPad
Aluminum foil	angle sheet
Cellophane (variety of colors)	

Safety/Responsibility

Follow the handouts to connect the light sensor and temperature probes to the iPad
Do not crumple or damage any of the objects
Keep light away from other people's eyes
The flashlights will roll off the table - always place them in the bin

Procedure

- [ ] The teacher will dim the lights in the classroom.
- [ ] Experiment with the materials to answer the guiding question and collect data
- [ ] Tips to getting started:
    - Remember: In order to see an object, you need a light source, object, and a light sensor/eye.
    - The light sensor and temperature probe can be used to measure the amount of light and the temperature of an object (quantitative data). You can also use observations (qualitative data) to answer the guiding question. Remember, your eye is also a light sensor.
    - Place the light sensor in different places around the object
    - The temperature probe
- [ ] Collect and record your data (quantitative and/or qualitative)
- [ ] Record any questions you may still have below:

Data

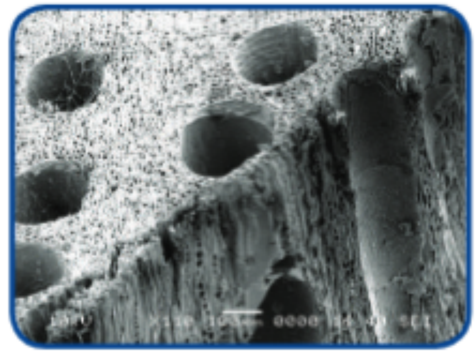
Object	Observations and/or Measurements
mirror	
black paper	
white paper	
aluminum foil	
clear plastic	
__________ color plastic	

Analysis and Interpretation

1. What did your investigation show about light when it reached an object? What evidence supports your claim?

2. (Wait for the class discussion before answering). What did another group share that
    1. Added to your idea(s)
    2. Confirmed your idea(s)
    3. Disagreed with your idea(s)

3. Draw models to communicate what you think is happening to each object.



Reading 6.3 – Polishing Objects

Getting Ready

Look at this photograph. It is a photo of something magnified many times. When something is magnified, it appears much larger than your eye sees it by just looking at it. People sometimes refer to using your eyes with no magnifying glass or microscope as “seeing with the naked eye.” Before you read the hints, take a guess: What do you think this photo is?

Here are four hints:

1. You can keep clothes in something made of it.
2. 2. You may be sitting on it right now.
3. Baseball players use it.
4. It grows outdoors.

Did you figure out that this is a picture of wood? When wood is magnified many times, it looks like tiny tubes. Sometimes the surface of wood is coated so that it looks shiny. A baseball bat might have a shiny surface. Maybe you have a table at home or in school with a surface that shines, but you cannot see your reflection in wood as well as you can in a mirror.

Why does your reflection in a mirror look different from your reflection in wood?

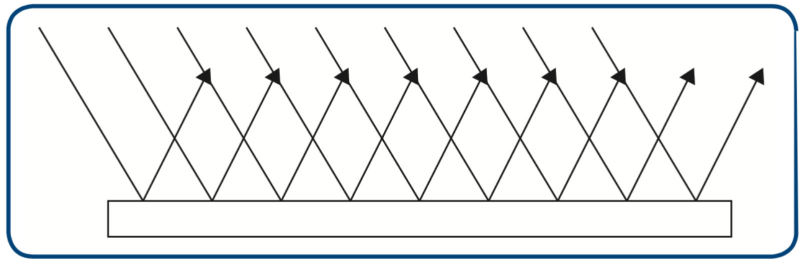
Why Can I See My Reflection in Some Objects but Not in Others?

In class, you did an investigation using a light sensor to track light from a flashlight. You compared what the light did as it bounced off a mirror and off a sheet of paper. When light reaches a surface, it can be reflected or it can be scattered.

Reflection is what happens when light bounces off of a surface that is very smooth. A mirror has a very smooth surface.

Look at the following two models. They show two different ways that light interacts with a surface.

The model on the top shows light reflecting off of a smooth surface, like a mirror. See how all of the arrows point in about the same direction? Now, look at the model on the bottom. The arrows in this model point in many directions. This is what happens when light bounces off of paper. Paper seems smooth, but if you magnify the surface, like the



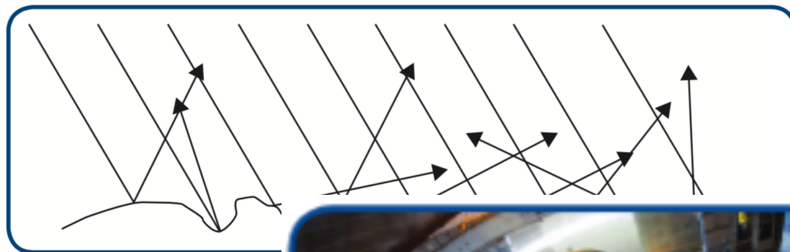
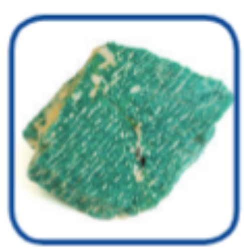


photo of wood at the beginning of this reading, you can see that the surface is bumpy. Light bouncing off of a bumpy surface is scattered.

Scattering is what occurs when light bounces off of surfaces that are not smooth. Many objects that scatter light feel smooth when you touch them. A sheet of paper and a wooden baseball bat feel smooth. However, if you could look at them with a powerful microscope, you would see that their surfaces are bumpy.

If you could take an object that scatters light, like a piece of wood, and smooth out all the bumps and ridges, then the object would reflect more light and scatter less light. The process of smoothing the microscopic bumps and ridges on a surface is called polishing.

How Does a Mirror Really Work?



In a mirror, all of the light rays are reflected from a mirror so they bounce back to your eyes, and they look like they are coming from an object on the other side of the mirror. If the surface of the mirror is scratched, it will scatter more of the light that hits it. If the mirror is too scratched or uneven, so much light will be scattered that you can no longer see a clear image in the mirror.

Using Mirrors to See the Stars

Astronomers are one type of scientists who use mirrors. Astronomers use telescopes to produce images of stars and planets that are very far away. Telescopes use specially curved mirrors to reflect light from stars toward a sensor. The sensor uses this light to produce a picture of the stars.

Many objects in the sky do not appear very bright because they are so far away. This means that very little of the light that comes from them actually reaches Earth. In order to get the best pictures, astronomers must use a big mirror that reflects a lot of light, so it helps to see even very faint objects. A smooth mirror produces a clear image because it reflects almost all the light to the sensor, scattering very little.

Polishing a Giant Telescope

The Hale telescope at the Mount Palomar Observatory in California was the largest telescope in the world for more than 50 years. The main mirror in the Hale telescope is 200 inches across. An average 12-year-old is less than 60 inches tall. The mirror is about as big as three adults standing on top of each other. The mirror is very smooth. If you could magnify it so that it was as wide as the Atlantic Ocean, the biggest bump you could see on its surface would be smaller than 5 centimeters high. It is very difficult to make a mirror so smooth. It took about 11 years for people to polish this mirror by hand.

Other Things People Polish to Reflect More Light

Polished mirrors are important to astronomers. You probably use polished mirrors, too. People polish other objects—like rocks—to make them look more shiny and pretty, as you can see in these photos.

A device called a rock tumbler was used to polish the rocks in the photographs. A rock tumbler has a small barrel filled with rocks, water, and coarse sand. The barrel rotates slowly so that the coarse sand rubs over the surface of the bumpy rocks. Coarse sand smoothes the large bumps on the rocks. Those are the bumps that you do not need a microscope to see. In the photo, it is easy to see the bumps on the stones on the left. After awhile, the coarse sand is replaced with finer sand. Sand that has a fine grain can smooth out smaller bumps that you cannot see or feel. After enough time in a rock tumbler, rocks and minerals appear much shinier than they were at first. Why? The polished rocks are smoother, so they reflect much more of the light that hits them.

What Makes Wood Look Shiny?

Wood is polished in a different way. To polish wood, the surface is covered with a clear substance, like wax. The wax fills all the tiny holes in the wood. After the holes are filled, the wood has a smooth surface that reflects light much better. The following pictures show the difference between a wood floor with wax and one without wax.

Why Do People Polish Things?

People polish surfaces for different reasons. They polish wood, rocks, and minerals because they like the way the finished objects look and feel. Materials like gold and diamonds are not very shiny before they are polished. The diamond and gold jewelry people wear has been polished. In science, polishing is an important part of making instruments like telescopes work properly. Instruments like these can help people learn more about the universe in which they live.

1. To polish leather shoes, people use shoe polish. What does this tell you about the surface of leather?

2. Most objects that can be polished still scatter some light; no object can have pure reflection without any scattering. Why?

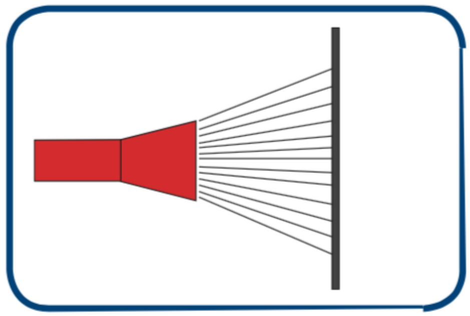
Assessment 7.3 – Light Interacting with Objects

Light from a flashlight is shown hitting two different objects below.

1. Complete each diagram, so that it shows how much light you think each object will transmit, absorb, and scatter/reflect.

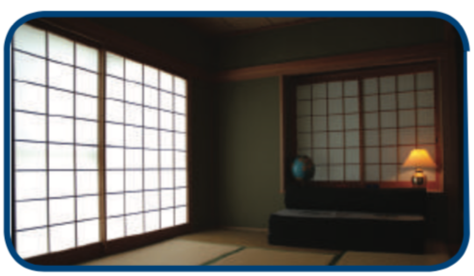
Reflective Sunglasses

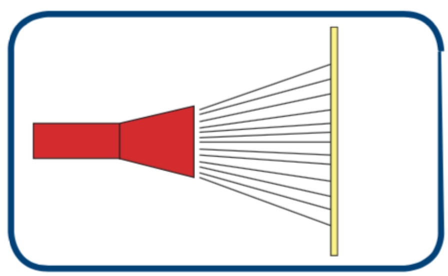
Some sunglasses have a reflective coating. The coating makes them look like a mirror, but it still allows the person to see.



Rice Paper

Rice paper is used in places like Japan to make doors that let light through. The picture shows a door made with rice paper.





Conclusion

1. After Eva cleaned the sliding glass door at her house, her friend came over and walked right into it. Why is it easier to see the glass when it is dirty than when it is clean?

Lesson 1 – Strange Images

Investigation 1.1 – Can I Believe My Eyes?

Summary (What will we do?)

We will observe two strange images.

Procedure

- ☐ Look at the first image your teacher projects. What do you see? Record your observations in the data table.
- ☐ Your teacher will project a second image. Which square appears darker to you: square A or square B? Record what you see in the data table.
- ☐ Your teacher will make some changes to the second image. Which square appears darker now: square A or square B? Record your observations.

Data

ESSENTIAL QUESTION:
How do the parts of the eye work together for a person to see?

Image	What I See
First image	
Second image	
Second Image with Additions	

Analysis and Interpretation

1. Why do you think that square A and square B looked different from the first time you looked at them than they did the second time you looked at them?

Lesson 7 – Anatomy of an Eye

Investigation 7.1 – How does the eye work so a person can see?

Summary (What will we do?)

We will learn about the parts of a mammalian eye and develop a written model for how we can see.

Elicit

Look at p30 to elicit (remember) what you learned before about the different parts of the eye.

Procedure

- ☐ Watch the video: How Your Eyes Work
- ☐ Take notes
- ☐ Use your notes to write a summary of how the eye works

Notes

SUMMARY: Write in complete sentence form, answering the essential question (or addressing another prompt/ question, if one is given by the teacher). This should be a paragraph and include details.

____

____

____

____

____

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____

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____

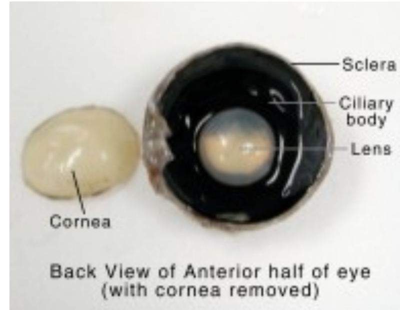
NOTES:

- Parts of the eye and its function (include description and drawings)
  - Pupil
  - Iris
  - Eyelid
  - Lens
  - Ciliary muscle
  - Retina
    - Rods
    - Cones
  - Optic Nerve

Investigation 7.2– What are the different parts of the eye?

Summary (What will we do?)

We will dissect a mammalian eye and identify the different parts

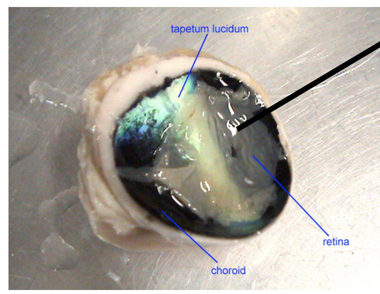


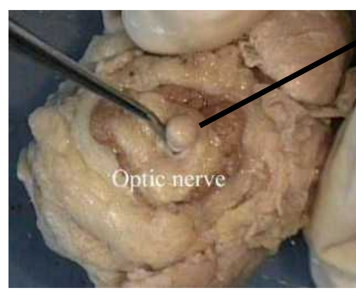
Materials

- ☐ Gloves
- ☐ Safety Goggles
- ☐ Scissors
- ☐ Forceps
- ☐ Aluminum pan
- ☐ Damp towel to keep the parts from drying out
- ☐ Magnifying glass
- ☐ Eye diagram sheet

Safety/Responsibility:

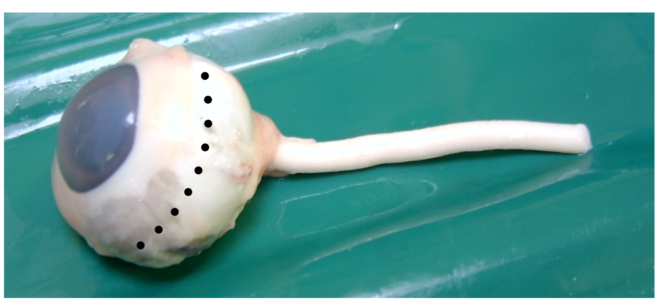
- If you are unsure about the next step, ask your group and read the directions. If you still have questions, raise your hand for the teacher to help.
- Keep your gloves and safety goggles on until everyone is cleaned up - the eyes are preserved in a toxic chemical.
- Wash your hands properly at the end of the investigation



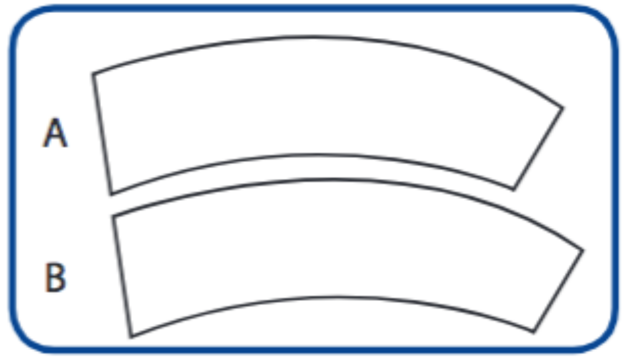


Procedure

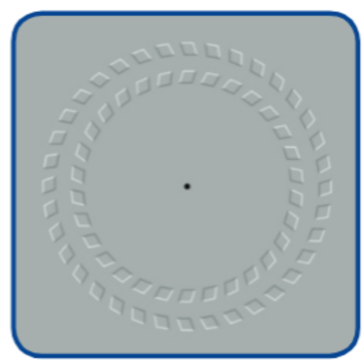
- ☐ Tip: Use your notes from Investigation 7.1 (p54-55) to help identify the function of each part of the eye.
- ☐ Get an Eye Dissection sheet from the teacher and follow those directions.
- ☐ Check to make sure you have all your materials
- ☐ Use the scissors to cut away the **muscles** until you can see the sclera and cornea
- ☐ Place muscles in the muscles section of your diagram
- ☐ Use the scissors to cut through the **sclera** between the iris and the optic nerve all the way around



- ☐ Carefully remove the **vitreous humor** come out and place it on your diagram
- ☐ Place damp towel over the back half of the eye



- ☐ Front half of the eye
    - ☐ Use your fingers and/or forceps to remove the **lens** and place it on your diagram. Examine with the magnifying glass.
    - ☐ Use your fingers and/or forceps to peel and separate the **iris** and place it on your diagram. Be careful to keep the iris intact as much as possible. Examine with the magnifying glass.
    - ☐ Use the scissors to cut the **cornea** out and place it on your diagram.
    - ☐ Cut the cornea in half to examine its thickness. Examine with the magnifying glass.
    - ☐ Place the remaining sclera on your diagram
- ☐ Pick up the back half of the eye
    - ☐ Examine the **retina** using the magnifying glass (white film on the back of the eye).
    - ☐ Notice where it is attached to the back of the eye. This is called the blind spot.
    - ☐ The dark, metallic-looking tissue behind the retina is called the choroid.
    - ☐ Remove the retina and place it on your diagram
    - ☐ If you haven't done so already, remove the muscles to expose the **optic nerve**
    - ☐ Pinch the optic nerve with your forceps or fingers to separate the fibers of the nerve and examine them with your magnifying glass.
    - ☐ Use scissors to remove the optic nerve and place it on your diagram
    - ☐ Place the remaining sclera on your diagram

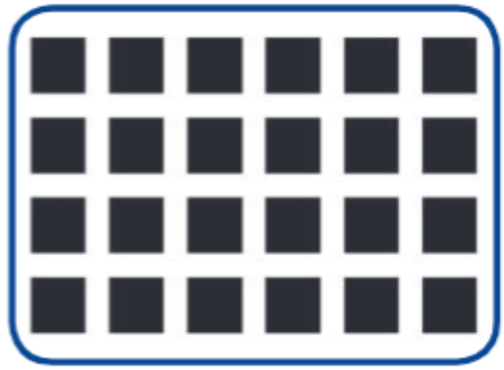


- ☐ Clean Up
    - ☐ Place all pig eye parts and paper in the designated waste bag
    - ☐ Rinse and return tools to aluminum pan
    - ☐ Return pan to counter
    - ☐ Use disinfecting spray and paper towels to clean tables

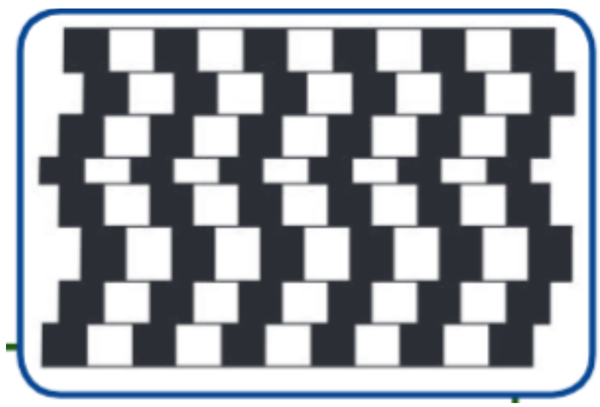
Reading 1.1 – Look at This!

Getting Ready

The picture shows two bent rectangles. Which bent rectangle is longer? Now use a ruler to measure the size of the two bent rectangles. Were you correct? To most people, B looks longer than A.



When you measured, you might have learned that your guess was wrong. In this reading, you will learn how your brain can get confused by what your eyes see. You will be able to compare the figures in this reading to what you saw in class.



To compare means to think about what is alike and what is different. As you read, think about what is similar and different about the optical illusions you saw in class and the pictures in this reading.

What Are Optical Illusions?

Look at this picture. Stare at the small dot in the center of the circles. Now move the picture closer to you while you keep looking at the dot. What happens?

Tricks like these are called *optical illusions*. Optical is a word related to your sense of sight. Many other words start with the prefix opt- . An optometrist is an eye doctor. If you need glasses, an optician may have helped you choose your glasses.

You may have seen magicians who perform illusions. Magicians do not really make things disappear. But they do know how to fool your brain so you think things disappear. Optical illusions can be fun because they fool you. Optical illusions are a kind of trick. Your eyes play an important role in seeing. But your eyes and your brain work together. Your brain is the organ that makes sense of what you see. In the picture in the Getting Ready section, your eyes see two identical bent rectangles. Your eyes see the right thing, but your brain interprets it incorrectly. When your brain gets it wrong, this is called an illusion. Optical illusions and magician's tricks are not real. Your brain is just fooled.

Another Optical Illusion

Look at these small dark squares. If you look closely for a few seconds, you will see light gray circles in between the squares. Are the gray circles really there, or do they just seem to be there? This is another example of an illusion. Your brain is being fooled again.

Can You Figure This Out?

Here is one more interesting image. Look at the lines separating the rows of black and white squares.

Do you think what you are seeing is an illusion? Are the lines actually parallel and your brain is being fooled, or are the lines really at angles?

Were the Images in Class Optical Illusions?

In class, you saw strange images. The first looked like a bunch of spinning circles. The second image looked like a checkerboard with a square marked A being clearly darker than another square marked B. Finally, your teacher added black rectangles to the second image and it became apparent that squares A and B had actually identical darkness. These images succeeded in fooling your brain. They were illusions. You observed a real phenomenon. What you saw depended on how your brain interpreted parts of the image. A phenomenon is an event that happens in the real world and that occurs over and over again.

Sometimes you can observe things that appear very strange but are actually real. Hold the tips of your thumb and index finger next to each other so that they are just about touching. Hold them up so that they are next to your eye and look between them at a bright white background. You should just barely feel your thumb touching your finger. You should see one or more small black lines between your fingers. From where did these lines come? This is a real thing you are seeing, not an illusion. Your brain is not getting anything wrong. This goal in this unit is to figure out what happens to make people see things, whether they are real or illusions.

Investigating phenomena will help you learn how light affects what you see. In science class, you will observe different phenomena almost every day. By the end of the unit, you may be able to explain the two optical illusions you saw in class.

Observing the Two Illusions in Class
An important part of science is making observations. An observation is the act of paying careful attention to events that happen in the world. This is what you did in class. You paid close attention to what you could see when you looked at the two images. Making good observations, plus learning the science that goes with them, will help you to explain things that happen around you.

What Questions Do You Have?
List questions you have about light, seeing, or about the two images from class now that you have finished reading.

Why Is Light Important?
You already know that light helps you see. But did you know that if you understand the behavior of light, you can also understand how cell phones and microwave ovens work? The scientific ideas that explain the behavior of light also explain how computers, televisions, satellites, GPS, and many other systems work. In fact, many scientific discoveries from the last 100 years are based on the same principles that explain the behavior of light. You will not study all of these in class, but you will learn about many of them. You might also decide to investigate other uses of light on your own. You may be surprised to learn that light plays an important role in just about everything around you.

Lesson 9 – What is the opposite of white light?

Investigation 9.1 – Mixing light

Summary (What will we do?)

We will explore light and color and different colors of light.

Prediction

What do you think will happen if you mix red and green light together? Red and blue? Green and blue? Red, green and blue?

Materials

Red lamp
Green lamp
Blue lamp
Blank white paper

Safety/Responsibility

- The lamps are top heavy. Hold carefully to make sure it does not fall and break the bulbs.
- The light bulbs will get very hot. Do not touch them directly.

Procedure

- ☐ Turn on the red lamp and shine it on the paper.
- ☐ Turn on the green lamp. Adjust its distance from the paper until you see a different color.
- ☐ Record your observations
- ☐ Continue combining different color lights. Can you make yellow? Purple? Teal? White?
- ☐ Done? Put an object (like a pencil) in the middle of the paper

Data

Original colors	Resulting color
Red + Green	

Analysis and Interpretation

1. When you mix different colors of light, the new color you see is brighter than the original colors you mixed. Explain why you think this happens.

2. Watch the teacher put different color filters in front of the projector light. What happened? Explain why you think this happens.

Investigation 9.2 – Mixing colors of light on a computer

What will we do?

We will use technology to investigate how much red, green, and blue light should be mixed to create white, black, and shades of gray.

Materials

iPad or computer

Procedure

- ☐ Go to the following website: http://web.stanford.edu/class/cs101/image-rgb-explorer.html (or do a web search for "stanford rgb explorer").
- ☐ Adjust the amount of each color by moving the slider along the bar.
- ☐ Make sure each person in your group has at least one opportunity to operate the app.
- ☐ Students who are not operating the app should make suggestions about how to get the desired color.
- ☐ Manipulate the computer until you succeed in making white light and record the amounts of red, green and blue.
- ☐ Manipulate the computer until you succeed in making black light and record.
- ☐ Manipulate the computer until you succeed in making light gray light and record.
- ☐ Manipulate the computer until you succeed in making dark gray light and record.
- ☐ Continue exploring by making other colors. Record the amounts of red, green and blue.

Data

Color	Amount of Red	Amount of Green	Amount of Blue
White light			
Black light			
Light gray			
Dark gray			

Analysis and Interpretation

1. Examine the computer screen the teacher provides with a magnifying glass. Notice it only has red, green, and blue pixels. Yet, your computer screen shows a picture with green grass, a blue sky, a yellow sun, and a brown house. How do you think the screen makes these different colors?

Lesson 10 – How do objects change the color of light?

Investigation 10.1 – Analyzing color composition

Summary (What will we do?)

We will learn how to analyze light to determine out of which other colors of light it is composed.

Materials

C-spectra sheet

iPad

Safety/Responsibility

Don't bend or wrinkle the C-spectra sheet or it will not work

Procedure

- ☐ Your teacher will project a white line on the screen. Discuss with your partner - why the line appears to be white?
- ☐ Choose one of two options:
  - ☐ Use the slideshow of different colored lines on the iPad (this will only show you colors from RGB)
  - ☐ Use the colored line projected on the whiteboard (this will show you many other colors)
- ☐ Put the C-Spectra sheet up to your eye and look at the colored line. In your data table, record the colors you see by putting a x each color you see. If it is a thick line, put a big X. If it is a thin line, put a little x. Every person in your group should have the opportunity to analyze at least one line.

Data

	Red	Orange	Yellow	Green	Blue	Violet
Red Line						
Orange Line						
Yellow Line						
Green Line						
Blue Line						
Violet Line						

Analysis and Interpretation

1. Explain why you think the different colored lines scatter different colors of light.

2. Why do you think the background color of the colored lines are on black paper rather than on white paper?

3. What color do you think you would have seen if the red stripe had been illuminated by red light? Explain your ideas.

4. What color do you think you would have seen if the red stripe had been illuminated by green light? Explain your ideas.

Materials (not every group will have everything at once. When you are done investigating, return it so other groups can use it)

light sensor and iPad
paper cups
paper clips
buttons
string
Amber rubber tubing
Red vacuum and pressure tubing
Tygon laboratory tubing
clear hanging wire (fiber optic)
electrical tape
laser pen
flashlight
mirror

Safety/Responsibility

DO NOT shine the laser or flashlight towards anyone, this can damage their eyes.

Getting Started

Investigation 10.2 – Modeling how we see color

Summary (What will we do?)

We use a model of how people see color to develop a model of how objects change the color of light.

Materials

iPad or computer

Whiteboard

Procedure and Data

- ☐ Go to https://phet.colorado.edu/sims/html/color-vision/latest/color-vision_en.html
- ☐ Click "Single Bulb".
- ☐ Press the red button on the 'flashlight' to turn on the 'light'. Record what color the 'person' sees.

- ☐ At the top under "Bulb Color", move the indicator along to bar to change the color of the light. How does this change what the 'person' sees?

- ☐ Set the bulb color to yellow
- ☐ Click the "Filter" tab to the on position. The default color of the filter should be yellow. Record what color the 'person' sees.

- ☐ Move the indicator along the bar to change the color of the filter. How does this change what the 'person' sees?

- ☐ Continue to change the color of the bulb and the filter. Record any patterns you notice below.

Analysis and Interpretation

1. Why does the color of the filter change the color the person sees? What happened to that color of light?

2. Use the model to explain why a red apple in white light appears red. With your group, use a whiteboard to draw a model to explain why we see the apple as red.

3. What color do you predict the red apple will be in green light?

Reading 11.2 – Rainbows

Getting Ready

Have you ever wondered why rainbows appear? You have probably noticed that rainbows have something to do with the weather. You have probably thought about the fact that the word rainbow has rain in it, and that is when you see rainbows. However, you do not see a rainbow every time it rains. This reading is about what makes rainbows appear in the sky.

Think of a time when you have seen a rainbow. Try to remember what the weather was like at the time. These three questions might help you:

- Was it still raining or had the rain stopped?
- Was the whole sky cloudy?
- Was it during the day or night?

You Can Make Your Own Rainbow

Before reading, here is an activity you can do to create your own rainbow. You need to do this on a sunny day. First, find a window where the sun is shining in. Second, pull a table close to the window. Third, place a full glass of water on the edge of the table where the sun is shining the brightest. Look at the following diagram to see how to set up your experiment. Once you place the glass on the table, look at the floor near the glass. You should see a rainbow on the floor. If it is not a sunny day, you can still try to make your own rainbow. Make a room as dark as possible and set up a full glass of water on the edge of a table. Instead of sunlight, you need a flashlight. Turn on the flashlight and point it at the glass, as if the flashlight were the sun. Keep the flashlight pointed at the glass, but move the flashlight a little at a time until you see a rainbow on the floor or on the wall. In this lesson, you will learn how drops of water and sunlight work together to form rainbows. In Lesson 9, you learned that white light is a mixture of all the different colors of light that you can see. Red, orange, yellow, green, blue, indigo, and violet (ROYGBIV) can all be found in white light. However, when you see white light, you do not usually see those colors. In order to be able to see all the colors that make up white light, you would have to break white light apart into its color components. That is what you did in Lesson 10, using C-Spectra.

Using a Prism

A prism is another way to break white light into its color components. A prism is a triangular piece of transparent glass or plastic. A beam of white light shining on one side of the prism will come out on the other side broken up into its color components. This figure shows how white light entering the prism comes out in the form of a rainbow.

Now you know that a prism separates white light into colors and you know that the colors look like a rainbow. You still do not know how a rainbow is formed. When light enters a prism, the prism causes the light to bend very slightly or to change directions just a little bit. This bending is called refraction. Not all light gets bent in the same way. Some colors of light get bent more than others. The color of light that gets bent the most is blue, while the color of light that gets bent the least is red. Look again at the figure of light being refracted by a prism. Can you see that blue gets bent more than red? Because the different colors of light bend differently, they come out of the prism at different places and move out of it in different directions. Because they move in different directions, they spread away from each other. That is why you can see them separately—the colors are no longer mixed together. What you see is an area in which the color of light changes gradually from one to another. It looks just like a rainbow.

How Are Real Rainbows Formed?

In a real rainbow, raindrops in the air act like very small prisms. Light enters the raindrops and gets bent by them. Each color of

A Special Phenomenon: Double Rainbows

Perhaps you have seen a double rainbow like in this photo. The brighter rainbow is called the primary rainbow. The fainter rainbow is called the secondary rainbow. The secondary rainbow is made when light is reflected twice inside the raindrop. Because of the double reflection, the light leaves the raindrop at a different angle, so you see the secondary rainbow higher up. If you look closely at the picture, you will also notice that the colors of the secondary rainbow are in the opposite order of the colors in the primary rainbow. The drops of rain have to be just the right size to create two reflections. This does not happen very often, so double rainbows are a rare sight to see.

How could you explain how rainbows are formed to someone who is not in your science class? For example, how could you explain rainbows to someone at home? Or how could you explain rainbows to someone younger than you? Think about that person as your audience, and explain how rainbows are formed in a way that person would understand. You might find it helpful to draw a model to explain.

Lesson 12 – Is There Light We Cannot See?

Investigation 12.1 – What is leaving the remote control?

Summary (What will we do?)

We will explore how a remote control works to see if there is light we cannot see.

Prediction:

Do you think that a remote control produces light? Explain why or why not.

Materials:

iPad with app ( ) or a digital camera

Procedure

☐ Observe the actions of your teacher and record your observation

Data

Action with remote	Describe what happens when your teacher does the action with the remote
Points at you and presses the on/off button	
Points at a TV or projector and presses the on/off button.	
Points at a digital camera or a doc cam and presses the on/off button	
Puts a piece of cardboard between the remote and the TV/ projector when pressing button	
Points the remote towards a mirror while pressing the button	
Puts a piece of clear plastic or glass between the remote and the TV/projector	

Analysis and Interpretation

1. Do your results support the idea that the remote is giving off light? Why or why not?

2. Point the camera at the remote. What do you see? Explain why you think that happened.

Investigation 12.2 – What is ultraviolet light and how do we protect ourselves from it?

Summary (What will we do?)

We will design an investigation to determine the effectiveness of sunscreen.

Elicit:

Why is it recommended that people wear sunscreen? What type of sunscreen should people wear?

Materials:

4 UV beads
Labeled containers (control, SPF 4, SPF 30, SPF 100)
Sunscreen spf 4, spf 30, spf 100

Safety/Responsibility

Tell your teacher if you have an allergy to mangos or sunscreen

Variables:

Independent Variable (IV): (What are you changing?)

Dependent Variable (DV): *(What changes with the IV?)*

Constants: (What needs to stay the same for it to be a fair experiment?)

Procedure

List step-by-step what you will do or draw your investigation

Data

Title:	
	Observations
Control	
SPF 4	
SPF 30	
SPF 100	

Analysis and Interpretation

1. Which sunscreen would you recommend using? Use evidence to support your recommendation.

Activity 12.3 – Introducing the Wave Model

What will we do?

We will do some activities to learn more about the differences between visible and nonvisible light. Then we will revise our model of light to account for new evidence.

Procedure

☐ As your teacher changes the pitch coming from the computer, raise your hand when you can no longer hear the sound.

Analysis and Interpretation

1. Are there sounds that you cannot hear? Explain.

2. Describe the wave model presented in class.

3. According to the wave model of light, what makes blue light different from green light?

4. Compare red light with the infrared light that comes from the remote. (Remember that compare means to describe what is similar and what is different.)

5. Describe how visible light is different from nonvisible light.

6. Based on your understanding of the wave model, explain why your eye could not detect the light coming from the remote but the camera could.

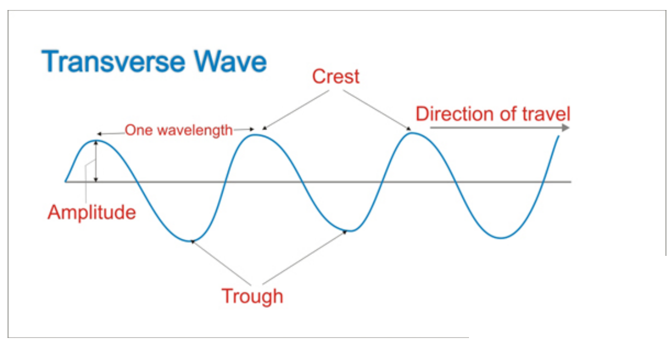


Figure 13.1

Lesson 13 – Wave Energy

Investigation 13.1 – How do Frequency, Amplitude and Wavelength of a Wave Affect its Energy?

Summary (What will we do?)

We will use a computer model of waves to investigate how frequency, amplitude and wavelength affects its energy.

Introduction

Energy can be transported by waves. There are many forms of waves that exist in the world. Mechanical waves, such as sound waves or water waves, must travel through a medium, or matter. For example, when you speak, you create a pressure disturbance in the air that travels as a wave through the air. You can also create a wave in a rope or string by moving one end from side to side. In each case, the wave travels through a medium, the air or the rope. Electromagnetic waves, such as radio, ultraviolet, and visible light waves, don't require a medium to travel.

Although waves may travel differently, some waves can be represented by the same basic shape. A drawing of a wave is shown in Figure 13.1. The highest point of the wave is called the crest, and the lowest point is called the trough. The wavelength of the wave, a measure of how long the wave is, can be found by measuring the distance between the same point on a wave and the wave in front of or behind it. Usually, this is done by measuring crest to crest or trough to trough. The amplitude of a wave is the distance from the resting position (the horizontal line) to the crest or trough. The frequency of a wave is hard to show in a picture. A wave's frequency is a measure of how many times a wave passes a certain point in a certain amount of time. To measure frequency, scientists measure the number of wave cycles (trough to trough or crest to crest) that occur in 1 second, and they measure this value in hertz (Hz). One cycle per second ins 1 Hz, two per second is 2 Hz, and so on.

The properties of a wave contain information about the energy that wave is carrying and also determines its use. For example, electromagnetic radio waves are used to transmit the radio signals your car stereo picks up. Your favorite station numbers are actually measurements of the frequency at which that station broadcasts.

Your Task

Use what you know about waves and energy to design and carry out an investigation that will allow you to describe the relationship between a wave's energy and its amplitude, wavelength and frequency.

The guiding question of this investigation is, **How do frequency, amplitude, and wavelength of a wave affect its energy?**

Materials:

- iPad or computer with access to the simulation *Wave on a String* (https://phet.colorado.edu/sims/html/wave-on-a-string/latest/wave-on-a-string_en.html)
- Whiteboard + Dry Erase Markers
- Argumentation Session Notes

Getting Started
To answer the guiding question, you will need to design and carry out an experiment. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it. The *Wave on a String* simulation allows you to start (propagate) and manipulate a wave on a virtual rope. The rope is shown as a series of red circle, with every ninth circle colored green. This will make it easier for you to track and measure the properties of the various waves you create.

The upper-left-hand corner of the screen has a box with options for manual, oscillate, and pulse. These options allow you to choose how you will make the waves you will use for data. The "Manual" option requires that you move the wrench up and down to create a wave. The "Oscillate" option creates the wave for you, and you can adjust the frequency and amplitude of the waves using a slider that will appear at the bottom of the screen. Do not choose the "Pulse" option because it will not produce a wave that will be helpful for your investigation. You also have the option to use a rope with a fixed end, loose end, or no end. The simulation provides rulers, a timer, and a reference line for you to use. To activate these tools, simply check the box next to each option. You can move the rulers by clicking and dragging them to different locations. You may start and pause the simulation at any time by selecting the play/pause button at the bottom of the screen. You can also view the simulation in normal time or in slow motion.

You will need to design and carry out at least three different experiments using the *Wave on a String* simulation in order to determine the relationship between frequency, amplitude, wavelength and energy. You will need to conduct at least three different experiments, because you will need to be able to answer three specific questions before you will be able to develop an answer to the guiding question:

- How does changing the frequency affect the energy of the wave?
- How does changing the amplitude affect the energy of the wave?
- How does changing the wavelength affect the energy of the wave?

It will be important for you to determine what type of data you need to collect, how to collect the data you need, and how you will need to analyze your data for each experiment, because each experiment is slightly different.

To determine what type of data you need to collect, think about the following questions:

- What will serve as your independent variable in the investigation?
- What will serve as your dependent variable(s) in the investigation?
- How will you define and determine the amount of energy being put into the waves?
- How will you measure the various properties of the waves?

To determine how you will collect your data, think about the following questions:

- What simulation settings will you use to collect the data you need?
- How will you make sure your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine how you will analyze your data, think about the following questions:

- What type of calculations will you need to make?
- What type of table or graph could you create to help make sense of your data?
- How will you determine if there is a relationship between different variables?

With your group, complete your Investigation Proposal. Before moving on, explain your proposal your teacher and get their approval.

The Guiding Question...

Hypothesis 1

IF...

Hypothesis 2

IF...

Hypothesis 3

IF...

The Test

AND...

Procedure

What data will you collect?

How will you analyze the data?

What safety precautions will you follow?

Predicted Result if hypothesis 1 is valid

THEN...

Predicted Result if hypothesis 2 is valid

THEN...

Predicted Result if hypothesis 3 is valid

THEN...

I approve of this investigation.

Instructor's Signature

Date

Your Actual Data	AND…
Your Analysis of the Data	
The Claim you will Make	

Initial Argument
Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The claims is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard (see teacher for set up).

Argumentation Session
Get argumentation session notes from your teacher. The goal of this is to identify the flaws and weaknesses in each argument so you can fix it. All groups will share their arguments. One member of each group will stay at the station to share their group's argument, while the other members will go to other stations and listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so they can be fixed. If you are stuck on what to ask, ask your teacher for a list of possible questions.

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims. Remember, your goal at this stage is to develop the most acceptable and valid answer to the research question!

Reflective Discussion
1. How do frequency, amplitude and wavelength of a wave affect its energy?
2. What went will with your investigation? What did not go well?
3. How can we improve the designs of our investigations in the future? How can we make it more "scientific"?

Report
Prepare an investigation report. There are three sections:
1. What questions were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

This report should be two pages or less. It must be typed and include any diagrams, figures or tables. Be sure to write it in a persuasive style; you are trying to convince others that your claim is acceptable and valid!

When you are done, title it (Your Number)_WaveEnergy and share it with your teacher. Make sure you do not write your name on the document, it needs to be anonymous.

Lesson 14 – Information Transfer

Investigation 14.1 –How can we transfer information over long distances?

Introduction
Starting in the late 1940s, scientists and mathematicians began conducting experiments that led to a new field of study that today we call information theory. They focused on answering a few important questions: How can we transfer information from one place to another? For example, you might have watched a sporting event over the weekend and know who won the game, while your friend was unable to watch and does not know you won. If you tell your friend who won, that is transferring information from you to your friend. Although this is not a new question (humans have been transferring information for thousands of years), the formal study of the question is quite new. Telephones, fax machines, and the internet grew out of this research. Many of the cables that you connect to your TV or computer serve the purpose of transferring information from someplace to your TV, computer or smart device.

A second question that scientist and mathematicians ask is, what are the advantages and disadvantages of transferring information in different ways? For example, the oldest way to transfer information from one person to another is by talking to that person. The advantages of this type of information transfer are that (1) it happens very quickly and (2) you know who sent the message because you can see them in front of you. The disadvantage is that the message does not last very long and will be hard to communicate from long distances. A person could write a letter to transfer information. The advantage is that the letter lasts a long time and can be sent over a long distance. The disadvantage is that it takes a long time to mail a letter to a friend.

Scientists and mathematicians also ask, how can we get a message to another person in the least amount of time possible? Physicists (a type of scientist) have determined that light moves faster than anything else in the universe. Information scientists used this finding. If light is the fastest thing in the universe, then maybe light can be used to transfer information.

Finally, they also ask, how can we limit the loss of information when transferring it from one place to another? Information scientists have determined that all messages lose some information between being sent and being received. Sometimes this is not a problem; for example, if you write a letter to a friend, the letter will not transfer information about whether you wrote it while sitting inside or outside (unless you say so in the letter). Other times, loss of information is a problem. If you have ever had a phone call cut out or heard static, this is an example of information loss.

Your Task
Use what you know about light, tracking energy and matter, and the relationship between structure (what it looks like) and function (how it works) to design and carry out an investigation that will you allow you to determine the advantages and disadvantages of different types of information transfer. For this investigation, the information you will be transferring will be a simple sentence. Then you will write down a recommendation for the best way to communicate information.
The guiding question of this investigation is, What is the most effective way to transmit information?

To answer the guiding question, you will need to design and conduct an investigation to measure the effectiveness of information transfer. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it before you begin.

To determine what type of data you need to collect, think about the following questions:
- How will you determine what an effective information transfer will be? For example, is it distance? Time?
- How will you determine whether an effective information transfer has occurred?

To determine how you will collect your data, think about the following questions:
- What equipment will you need to collect the data you need?
- How will you make sure your data are of high quality (i.e., how will you reduce error)?
- Are there different ways you can measure the amount of information transferred?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine how you will analyze your data, think about the following questions:
- How will you determine the amount of information lost?
- What type of table or graph could you create to help make sense of your data?

With your group, complete your Investigation Proposal. Before moving on, explain your proposal your teacher and get their approval.

The Guiding Question...

What data will you collect?

How will you collect your data?

Your Procedure

What safety precaution will you follow?

How will you analyze your data?

I approve of this investigation. ______________________________ ______________

Instructor's Signature Date

Your Actual Data	
Your Analysis of the Data	
The Claim you will Make	

Initial Argument
Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to include a claim, evidence to support your claim, and a justification of the evidence. The claims is your group's answer to the guiding question. The evidence is an analysis and interpretation of your data. Finally, the justification of the evidence is why your group thinks the evidence matters. The justification of evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard (see teacher for set up).

Argumentation Session
Get argumentation session notes from your teacher. The goal of this is to identify the flaws and weaknesses in each argument so you can fix it. All groups will share their arguments. One member of each group will stay at the station to share their group's argument, while the other members will go to other stations and listen to and critique the arguments developed by their classmates. This is similar to how scientists present their arguments to other scientists at conferences. If you are responsible for critiquing your classmates' arguments, your goal is to look for mistakes so they can be fixed. If you are stuck on what to ask, ask your teacher for a list of possible questions.

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims. Remember, your goal at this stage is to develop the most acceptable and valid answer to the research question!

Reflective Discussion
1. What materials and methods were best in transferring information? What materials and methods had the least amount of information loss?
2. What went will with your investigation? What did not go well?
3. How can we improve the designs of our investigations in the future? How can we make it more "scientific"?

Report
Your teacher will give you an investigation report graphic organizer. Prepare an investigation report. There are three sections:

1. What questions were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

This report should be two pages or less. It must be typed and include any diagrams, figures or tables. Be sure to write it in a persuasive style; you are trying to convince others that your claim is acceptable and valid!

When you are done, title it (Your Number)_InformationTransfer and share it with your teacher. Make sure you <u>do not</u> write your name on the document, it needs to be anonymous.