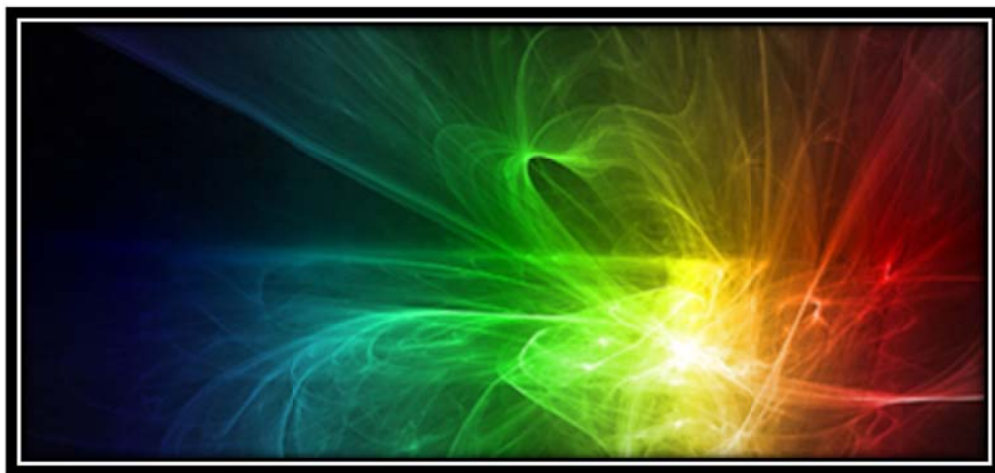


LIGHT 1

PARENT/TEACHER'S GUIDE

Learn about refraction, reflection, beam scattering, optical density, transmission, and absorption! Students investigate the electromagnetic spectrum by using lenses, mirrors and more as they build several projects including an eye-balloon, pinhole camera, optical kaleidoscope as well as experiments in splitting shadows into a rainbow, going on a black light treasure hunt, getting colors from black and white, investigating chemiluminescence by mixing cold light, and making a beaker totally disappear.



Created by Aurora Lipper, Supercharged Science

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This curriculum is aligned with the California State Standards and STEM for Science.

Introduction

Greetings and welcome to the unit on the electromagnetic spectrum! I hope you will find this helpful in preparing to teach your students, exhaustively thorough in content and a whole lot of fun, because that's when students and teachers do their best work.

This curriculum course has been prepared to be completed over several weeks, completing 1-2 lessons per week. You will find that there are 18 lessons outlined to take you from an introduction of light on through several advanced experiments complex enough to win a prize at the science fair. If you complete this course and send your kids off, you'll find their high school teachers entirely blown away by their mastery of the subject, and then will really be able to fly with them. Each lesson has a Teacher Page and a Student Worksheet.

The following features on each set of the Teacher Pages:

- Overview: this is the main goal of the lesson
- Suggested Time: make sure you have enough for completing this lesson
- Objectives : these are the core principles covered with this lesson
- Materials: Gather these before you start
- Lab Preparation: This outlines any preparation you need to do ahead of time
- Lesson: This outlines how to present the topic to the students, stirs up interest and gets the students motivated to learn the topic
- Lab Time & Worksheets: This includes activities, experiments, and projects that reinforce the concepts and really brings them to life. You'll also find worksheets that make up their Scientific Journal.
- Background Lesson Reading: This is optional additional reading material you can utilize ahead of time to help you feel confident when the students ask questions during the Lab Time. I don't recommend giving this reading to the kids beforehand. If you must share it with them, then do so *after* the students have gotten a chance to roll around with the activities. By doing this, it teaches kids to ask their own questions by getting curious about the concepts through the experiments, the way real scientists do in the real world.
- Exercises & Answer Key: How well did you teach? How well did they learn? Time to find out.
- Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Immediately following the Teacher Pages are "Student Worksheets" for each of the activities. Each set of student worksheets has the following sections:

- Overview
- What to Learn
- Materials
- Lab Time & Worksheets
- Exercises

In addition to the lessons, we have also prepared the following items you'll find useful:

- Scientific Method Guide
- Master Materials and Equipment List
- Lab Safety Sheet
- Written Quiz (with Answer Key)
- Lab Practical Test (with Answer Key)

Master Materials List for All Labs

This is a brief list of the materials that you will need to do *all* of the activities, experiments and projects in each section. The set of materials listed below is just for one lab group. If you have a class of ten lab groups, you'll need to get ten sets of the materials listed below. For ten lab groups, an easy way to keep track of your materials is to give each group a number from one to ten, and make up ten separate lab kits using small plastic tubs or baskets. Put one number on each item and fill each tub with the materials listed below. Label the tubs with the section name, like *Light Study Kit* and you will have an easy way to keep track of the materials and build accountability into the program for the kids. Copy these lists and stick them in the bin for easy tracking. Feel free to reuse items between lessons and unit sections. Most materials are reusable year after year.

- 12" fishing line
- 12" string
- 12" thread
- 12" yarn
- 8 index cards
- sliced cheese (individually wrapped)
- baby oil
- ball
- biconvex plastic lens
- book of matches
- box
- calculator
- CD or DVD
- chocolate bar (extra-large bars work best)
- chocolate chips
- clear tape
- crayons OR markers
- dark evening inside your house
- dark room
- diffraction grating
- disposable cups (6)
- dollar bill
- feather
- fingernail polish (red, yellow, green, blue)
- fire extinguisher
- flashlight
- glass jar (2)
- gloves
- glue stick
- goggles
- handheld magnifying lenses (2)
- index cards
- laser (optional)
- meter stick (2)
- microwave (only one for entire class)
- milk or flour
- mini marshmallows
- nail
- paper
- paper plates
- paperclip
- pencil
- penny
- razor or scissors
- red, green, and blue true-color light sticks
- round balloon, white, 9 inches
- rubbing alcohol
- scrap piece of cardboard
- strainer, such as a coffee filter
- tack
- tape
- tracing paper
- UV black fluorescent light
- votive candle
- water

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Unit Prep

This is a short list of things that you may want to consider as you prepare for this unit.

Student Lab Books: If you're the kind of teacher who likes to prepare lab books for your kids, now is a good time to do this. You can copy the *Introduction for Kids* and the *Student Worksheets* for each of the experiments, 3-hole punch them, and stick it in a binder. You'll want one binder per student.

Science Journals: One of the best things you can do with your students is to teach them how to take notes in a journal as you go along. This is the same way scientists document their own findings, and it's a lot of fun to look back at the splattered pages later on and see how far you've come. I always jot down my questions that didn't get answered with the experiment across the top of the page so I can research these topics more.

Master Set of Materials: If you plan on doing all the labs in this unit, you'll want to start gathering your materials together. There's a master materials list so you'll have everything you need when you need it.

Test Copies: Students will take two tests at the end of each section. There are quizzes and lab practical tests you can copy and stash away for when you need them.

Classroom Design: As you progress through the units, you'll be making demos of the experiments and kids will be making posters. You can hang these up on your bulletin boards, string them from the ceiling, or display them in a unique way. I always like to snap photos of the kids doing their experiments and hang those up along with their best labs so they can see their progress as we go along.

Lab Safety

Goggles: These should be worn when working with chemicals, heat, fire, or projectiles. These protect your eyes from chemical splatter, explosions, and tiny fast-moving objects aimed at the eyes. If you wear glasses, you can find goggles that fit over them. Don't substitute eyeglasses for goggles, because of the lack of side protection. Eyeglasses don't provide this important side eye protection.

Clean up Messes: Your lab area should be neat, organized, and spotless before you start, during your experiment, and when you leave. Scientists waste more time hunting for lost papers, pieces of an experiment, and trying to reposition sensitive equipment... all of which could have easily been avoided had they been taught organizational skills from the start.

Dispose of Poisons: If a poisonous substance was used, created, or produced during your experiment, you must follow the proper handling procedures for disposal. You'll find details for this in the experiments as needed.

Special Notes on Batteries: Do not use alkaline batteries with your experiments. Find the super-cheap kind of batteries (usually labeled "Heavy Duty" or "Super Heavy Duty") because these types of batteries have a carbon-zinc core, which does not contain the acid that alkaline batteries have. This means when you wire up circuits incorrectly (which you should expect to do because you are learning), the circuits will not overheat or leak. If you use alkaline batteries (like Energizer and Duracell) and your students short a circuit, their wires and components will get super-hot and leak acid, which is very dangerous.

No Eating or Drinking in the Lab: All foods and drinks are banned from your classroom during science experimentation. When you eat or drink, you run the very real risk of ingesting part of your experiment. For electricity and magnetism labs, always wash your hands after the lab is over to rinse off the lead from the electrical components.

No Horse Play: When you goof around, accidents happen, which means chemicals spill, circuits short, and all kinds of hazards can occur that you weren't expecting. Never throw anything to another person and be careful where you put your hands – it could be in the middle of a sensitive experiment, especially with magnetism and electricity. You don't want to run the risk of getting shocked or electrified when it's not part of your experiment.

Fire: If you think there's a fire in the room (even if you're not sure), let your teacher know right away. If they are not around (they always should be), smother the fire with a fire blanket or use a fire extinguisher and send someone to find an adult. Stop, drop, and roll!

Questions: If you're not sure about something stop and ask, no matter what it's about. If you don't know how to properly handle a chemical, do part of an experiment, ask! If you're not comfortable doing part of the experiment, then don't do it.

Teaching Science Right

These activities and experiments will give you a taste of how science can be totally cool AND educational. But teaching science isn't always easy. There's a lot more to it than most traditional science books and programs accomplish. If your students don't remember the science they learned last year, you have a problem.

What do kids really need to know when it comes to science? Kids who have a solid science and technology background are better equipped to go to college, and will have many more choices once they get out into the real world.

Learning science isn't just a matter of memorizing facts and theories. On the contrary, it's developing a deep curiosity about the world around us, AND having a set of tools that lets kids explore that curiosity to answer their questions. Teaching science in this kind of way isn't just a matter of putting together a textbook with a few science experiments and kits.

Science education is a three-step process (and I mean teaching science in a way that your students will really understand and remember).

Here are the steps:

1. Get kids genuinely interested and excited about a topic.
2. Give them hands-on activities and experiments to make the topic meaningful.
3. Teach the supporting academics and theory.

Most science books and curriculum just focus on the third step and may throw in an experiment or two as an afterthought. This just isn't how students learn. When you provide your students with these three keys (in order), you can give your students the kind of science education that not only excites them, but that they remember for many years to come.

So what do you do? First, don't worry. It's not something that takes years and years to do. It just takes commitment.

What if you don't have time? What I'm about to describe can take a bit of time as a teacher, but it doesn't have to. There is a way to shortcut the process and get the same results! But I'll tell you more about that in a minute. First, let me tell you how to do it the right way:

Putting It into Action

Step one: Get students genuinely interested and excited about a topic. Start by deciding what topic you want your students to learn. Then, you're going to get them really interested in it. For example, suppose I want my fifth-grade students to learn about aerodynamics. I'll arrange for them to watch a video of what it's like to go up in a small plane, or even find someone who is a pilot and can come talk with the kids. This is the kind of experience that will really excite them.

Step two: Give your students hands-on activities and experiments to make the topic meaningful. This is where I take that excitement and let them explore it. I have flying lesson videos, airplane books, and real pilots interact with my students. I'll also show videos on how pilots plan for a flight. My students will learn about navigation, figuring out how much fuel is needed for the flight, how the weight the plane carries affects the aerodynamics of it, and so much more. (And did I just see a spot for a future math lesson also?) I'll use pilot training videos to help us

figure this out (short of a live demo, a video is incredibly powerful for learning when used correctly).

My students are incredibly excited at this point about anything that has to do with airplanes and flying. They are all positive they want to be pilots someday and are already wanting flying lessons (remember - they are only fifth-graders!).

Step three: Teach the supporting academics and theory. Now, it's time to introduce academics. Honestly, I have my pick of so many topics, because flying includes so many different fields. I mean my students use angles and math in flight planning, mechanics and energy in how the engine works, electricity in all the equipment on board the plane, and of course, aerodynamics in keeping the plane in the air (to name just a few).

I'm going to use this as the foundation to teach the academic side of all the topics that are appropriate. We start with aerodynamics. They learn about lift and drag, make paper and balsa-wood gliders and experiment by changing different parts. They calculate how big the wings need to be to carry more weight (jelly beans) and then try their models with bigger wings. Then we move on to the geometry used in navigation. Instead of drawing angles on a blank sheet of paper, our workspace is made of airplane maps (free from the airport). We're actually planning part of the next flight my students will "take" during their geography lesson. Suddenly, angles are a lot more interesting. In fact, it turns out that we need a bit of trigonometry to figure out some things.

Of course, a 10-year old can't do trigonometry, right? Wrong! They have no idea that it's usually for high school and learn about cosines and tangents. Throughout this, I'm giving them chances to talk with the pilot in class, share what they've learned with each other, and even plan a real flight. How cool is that to a kid?

The key is to focus on building interest and excitement first, and then the academics are easy to get students to learn. Try starting with the academics and...well, we've all had the experience of trying to get kids do something they don't really want to do.

The Shortcut: Okay, so this might sound like it's time-intensive. If you're thinking "I just don't have the time to do this!" Or maybe "I just don't understand science well enough myself to teach it to my students at that level." If this is you, you're not alone.

The good news is, you don't have to. The shortcut is to find someone who already specializes in the area you want your students to learn about and expose them to the excitement that the person gets from the field. Then, instead of you being the one to invent an entirely new curriculum of hands-on activities and academics, use a solid science program or curriculum (live videos, not cartoons). This will provide them with both the hands-on experiments and the academic background they need.

If you use a program that is self-guided (that is, it guides you and your students through it step-by-step), you don't need to be hassled with the preparation. That's what this unit is intended to do for you and your students. This program uses these components and matches your educational goals set by state standards.

This unit implements the three key steps we just talked about and does this all for you. My hope is that you now have some new tools in your teaching toolbox to give your students the best start you can. I know it's like a wild roller coaster ride some days, but I also know it's worth it. Have no doubt that that the caring and attention you give to your students' education today will pay off manifold in the future.

Educational Goals for Light 1

Scientists are still trying to make heads or tails of this thing called light, and near as they can tell, it sometimes interacts like a particle (like a marble) and other times like a wave (like on the ocean), and you really can't separate the two because they actually complement each other.

Energy can take one of two forms: matter and light (called electromagnetic radiation). Light is energy in the form of either a particle or a wave that can travel through space and some kinds of matter, like glass. We're going to investigate the wild world of the photon that has baffled scientists for over a century. Low electromagnetic radiation (called radio waves) can have wavelengths longer than a football field, while high-energy gamma rays can destroy living tissue.

Here are the scientific concepts:

- Light has a source and travels in a direction.
- Sunlight can be blocked to create shadows.
- Light is reflected from mirrors and other surfaces.
- The color of light striking an object affects how our eyes see it.
- We see objects when light traveling from an object enters our eye.
- Light can travel through a vacuum, like space.
- Light can change speeds, but the maximum speed is through a vacuum (186,000 miles per second).
- The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light.
- Prisms un-mix light into its colors or wavelengths.
- Light changes speeds when it passes through a different material.
- Lenses work to bend light in a certain direction, called refraction.
- Concave lenses work to make objects smaller and convex lenses make them larger.

By the end of the labs in this unit, students will be able to:

- Design and build a simple refractor telescope using lenses.
- Know how to demonstrate how compound microscopes work.
- Understand how to determine how to measure the speed of light.
- Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.
- Formulate and justify predictions based on cause-and-effect relationships.
- Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
- Construct and interpret graphs from measurements.
- Follow a set of written instructions for a scientific investigation.

Lesson #1: Rainbow Shadows

Teacher Section

Overview: Imagine you're a painter. What three colors do you need to make up any color in the universe? (You should be thinking: red, yellow, and blue.) Here's a trick question – can you make the color “yellow” with only red, green, and blue as your color palette? If you're a scientist, it's not a problem. But if you're an artist, you're in trouble already. The key is mixing light, not paint.

Suggested Time: 30-45 minutes

Objectives: The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light. Sunlight can be blocked to make shadows.

Materials

- flashlights (3)
- fingernail polish (red, green, and blue)
- clear tape (NOT translucent)
- a white wall (or another large white surface)

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Make sure the flashlights are bright enough to really illuminate the wall.
5. Double check the room ahead of time to be sure you're able to get it dark enough in order for the colors to really show up on your wall.
6. Depending on materials and time, you may assign each group a single flashlight and one color, or let each group have a full set of three flashlights.

Background Lesson Reading

The universe is made of matter and energy. Matter is anything that has mass, and all ordinary matter exists in four states, which we cover in our *Chemistry* unit. Electromagnetic radiation (EM) is energy in the form of waves or particles that are emitted from a source and travel through space and even through certain kinds of matter.

Visible light is a form of energy that we can see with our eyes, and the organelles (called cones and rods) collect light from images that we see and transmit these to the brain. Visible light makes up a tiny part of the electromagnetic spectrum. This energy can be measured and specified by its intensity (how bright), frequency (wavelength), polarization (the direction of the electric field), and phase (time shift).

White light makes up all the colors of the rainbow: red, orange, yellow, green, blue, and purple. Prisms can un-mix light into the individual colors by bending the light by different amounts. The red, green, and blue are the primary colors of light that mix together to form every other color we see.

When light strikes a surface, it can travel through the surface completely, partially, or be entirely reflected back, depending on the surface it strikes. Light can also enter a material and get completely trapped inside by internal reflections. In some cases, light can be absorbed, and when this happens, the absorbing material can heat up, change color, change state, or re-transmit the light at a completely different wavelength.

Light can be filtered and dissected into a special signature that allows scientists to identify the patterns and be able to tell which element generated the light in the first place. These patterns, or light signatures, are used extensively by astronomers and chemists to determine the properties of the light and the chemical reactions required to generate the light.

Most light isn't detectable by the human eye, which makes studying light more like investigating a crime scene. You'll quickly be puzzling the pieces together to explain why pencils break in a glass of water, how to focus light energy to fry eggs, and how lenses bend light to distort and magnify images in telescopes.

Mixing the three primary colors of light gives white light. If you took three light bulbs (red, green, and blue) and shined them on the ceiling, you'd see white. And if you could magically un-mix the white colors, you'd get the rainbow (which is exactly what prisms do).

If you're thinking yellow should be a primary color – it *is* a primary color, but only in the artist's world. Yellow paint is a primary color for painters, but yellow light is actually made from red and green light.

Troubleshooting: This experiment has a few things to be aware of. If you're not getting the colored shadows, check to be sure that the flashlight is bright enough to illuminate a wall in the dark. Be sure to shut the doors, shades, windows, and drapes. In the dark, when you shine your red flashlight on the wall, the wall should glow red. Beware of using off-color nail polish – make sure it's really red, not hot pink. Alternately, you could use brightly-colored cellophane.

If you still need help making this experiment work, you can visit your local hardware store and find three flood lamp holders (the cheap clamp-style ones made from aluminum work well – you'll need three) and screw in colored "party lights" (make one red, one green, and one blue), which are colored incandescent bulbs. These will provide a lot more light! You can also add a fourth yellow light to further illustrate how yellow light isn't a primary color. Try using only red, yellow, and blue... you'll quickly find that you can't obtain all the colors as you could with the original red-green-blue lights.

Lesson

1. Ask the students which colors they would need to make up any color in the universe.
2. Now, ask if it's possible to make the color yellow using only red, green and blue. Maybe not with paint, but how about with *light*?
3. In the art world, yellow, blue, and red are primary, but when we mix light we have a different set of primary colors: red, blue, and green.

Lab Time

1. Hand each group their materials and give them time to perform their experiment and write down their observations.
2. Make your room as *dark* as possible for this experiment to work.
3. Cover each flashlight lens completely with the clear tape. Be sure to get the edges and around the rim.
4. Paint one flashlight's tape layer red, one blue, and one green. Make sure there are no unpainted spots.
5. Allow the nail polish to dry.
6. Turn off all the lights.
7. Shine the flashlights together onto a white wall. What color is the wall? Record it on your chart.
8. Now turn off the red flashlight. What color do you see now? Record your observation.
9. Place your hand, a pencil, or another object in front of the flashlight. Wave it around a bit. What color shadows do you see on the wall?
10. Experiment with the different color combinations while filling out the chart with your observations.

Exercises

1. What are the three primary colors of light? (red, blue, and green)
2. What color do you get when mixing the primary colors of light? (white)
3. How do you mix the primary colors of light to get yellow? (green and red light make yellow light)
4. Use crayons or colored pencils to draw what you saw when all three lights were shining on the wall and you waved your hand in front of the light.

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #1: Rainbow Shadows

Student Worksheet

Name _____

Overview: Imagine you're a painter. What three colors do you need to make up any color in the universe? (You should be thinking: red, yellow, and blue.) Here's a trick question – can you make the color “yellow” with only red, green, and blue as your color palette? If you're a scientist, it's not a problem. But if you're an artist, you're in trouble already. The key is mixing light, not paint.

What to Learn: The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light. Sunlight can be blocked to make shadows.

Materials

- flashlights (3)
- fingernail polish (red, green, and blue)
- clear tape (NOT translucent)
- a white wall (or another large white surface)

Lab Time

1. Make your room as *dark* as possible for this experiment to work.
2. Cover each flashlight lens completely with the clear tape. Be sure to get the edges and around the rim.
3. Paint one flashlight's tape layer red, one blue, and one green. Make sure there are no unpainted spots.
4. Allow the nail polish to dry.
5. Turn off all the lights.
6. Shine the flashlights together onto a white wall. What color is the wall? Record it on your chart
7. Now turn off the red flashlight. What color do you see now? Record your observation.
8. Place your hand, a pencil, or another object in front of the flashlight. Wave it around a bit. What color shadows do you see on the wall?
9. Experiment with the different color combinations while filling out the chart with your observations.

Rainbow Shadows Data Table

Lens #1 Color	Lens #2 Color	Shadow Color

Exercises Answer the questions below:

1. What are the three primary colors of light?
2. What color do you get when mixing the primary colors of light?
3. How do you mix the primary colors of light to get yellow?
4. Use crayons or colored pencils to draw what you saw when all three lights were shining on the wall and you waved your hand in front of the light.

Lesson #2: Kaleidoscopes

Teacher Section

Overview: The first kaleidoscopes were constructed in 1816 by a scientist while studying polarization (you'll learn more about polarization in a future lesson). Kaleidoscopes were quickly picked up as an amusement gadget by the public and have stayed with us ever since. Today you will be making your very own kaleidoscope. In a simple sense, a kaleidoscope is a tube lined with mirrors. Whether you leave the end opened or tape on a bag of beads is up to you, but the main idea is to provide enough of an optical illusion to wow your friends.

Suggested Time: 30-45 minutes

Objectives: Kaleidoscopes are an example of using light reflectors, which don't give off any light, but still bounce light back to your eyes. Light is reflected from mirrors and other surfaces.

Materials (per lab group)

Mirror Kaleidoscope

- 4-5 mirrors, all the same size
- tape
- scissors

Mylar Kaleidoscope

- Mylar
- index card or piece of cardboard
- hot glue gun
- scissors

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Prepare some interesting things for your students to inspect with their kaleidoscopes: a tray of beads, lava lamp, or even just a colorful image are some examples.
5. Prepare one kaleidoscope in advance so you can demonstrate it before you start the lab.

Background Lesson Reading

A candle is a light source (or source of light waves). So are a campfire, a light bulb, and the sun. An apple, however, reflects light. It doesn't give off any light on its own, but you can see it because light bounces off the apple into your eye. If you shut off the light, you can't see the apple. In this same way, the sun is a light source, and the moon is a light reflector.

Light can be reflected off the surface of different materials. The incident angle of the light (the angle the light hits the material) is always the same as the reflected angle of light. We're going to build a kaleidoscope that uses mirrors to reflect light.

Kaleidoscopes use light from a source, such as the lights in your room or the sun in the sky, and reflect the light back to our eyes. The reflections bouncing all around on the mirrors or Mylar make interesting shapes for our eyes to see.

There are many variations for this experiment. You can do both the mirror and Mylar kaleidoscopes, or simply choose one that works best with the materials you're able to find.

For the Mirror Kaleidoscope, you'll find that if you use only two mirrors, you'll get a solid background. Add a third mirror and tilt together into a triangle (as shown in the video) and you'll get the entire field filled with the pattern. You can place transparent objects at the end (like marbles floating in water or mineral oil) or just leave it open and point at the night stars.

By changing the size and shape of the mirrors, you can change the dimensional effect you see. Just be sure to look at the mirror surface, not the opening. You can also make mirrors wider at the bottom and narrower at the top (this is easier to do with the Mylar-cardboard mirrors). Use four or five mirrors instead of three in different combinations to get different effects. You can also change the length of the mirrors or use curved mirrors instead of flat by lining the inside of an oatmeal box with Mylar.

Lesson

1. Explain to the students the difference between a light source (a source of light waves) such as the sun, and a light reflector – one that doesn't give off any light of its own, but that you can still see because light bounces off of it – like the moon.
2. Ask the students to name some other surfaces that can reflect light (water, mirrors, etc.)
3. Tell the students that multiple light reflectors can be used to create interesting patterns for our eyes to enjoy. Kaleidoscopes are a good example of the use of multiple light reflectors.
4. Ask for a volunteer, and hand them the demo kaleidoscope. Ask the student to:
 - a. Hold the scope up to their eye and close their other eye. Make sure that they are seeing multiple images of everything they are looking at.
 - b. Walk around the room while holding the scope to their eye.
 - c. Hand them a sheet of paper and pencil and ask them to write their name.
 - d. Toss them a lightweight ball or balloon and have them catch it.
 - e. Dribble a soccer ball (I would have kids try to play soccer with their scopes after everyone built them, but this might be a little crazier than you're comfortable with.)

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.

Mirror Kaleidoscope

1. Lay out a strip of tape, sticky side up.
2. Center one mirror on the tape with its reflective side pointing up.
3. Attach the second and third mirrors close to the first at 90-degree angles. One will be on the left; the other will be on the right.
4. Rip the excess tape off of one end and then carefully tape together the three identical mirrors, forming a triangular shape. Make sure that the reflective surface is on the inside.
5. Tape all the rough edges very well and peek through the opening as you walk around.
6. Look at the images the mirrors make on the inside while pointing it at various objects.

Mylar Kaleidoscope

1. Fold the index card into three equal pieces in order to make it a triangular tube.
2. Make sure your Mylar is the same size as each fold of the tube. Trim as needed.
3. Glue the Mylar down to the cardboard.
4. Fold your tube again, just making sure that the edges are as crisp as possible.
5. Tape lengthwise along the top edge of your triangular tube.
6. If you are making both kaleidoscopes, compare the reflections you see in this longer tube with those you saw in the mirror kaleidoscope.

Exercises

1. What is a light source? Please give an example. (a source of light waves – the sun, light bulbs, fire, etc. are all examples)
2. What is a light reflector? Please give an example. (A reflector does not emit light. Instead it bounces light off of it and reflects the light back to our eyes. Water, mirrors, the moon are all examples.)
3. Sketch an image of something interesting that you were able to see as the light reflected from the multiple surfaces of the kaleidoscope to your eyes.

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #2: Kaleidoscopes

Student Worksheet

Name _____

Overview: In the simplest sense, a kaleidoscope is a tube lined with mirrors. Whether you leave the end open or tape on a bag of beads is up to you, but the main idea is to provide enough of an optical illusion to wow your friends. Kaleidoscopes are an example of using light reflectors, which don't give off any light, but still bounce light back to your eyes.

The first kaleidoscopes were constructed in 1816 by a scientist while studying polarization (you'll learn more about polarization in a future lesson). Kaleidoscopes were quickly picked up as an amusement gadget by the public and have stayed with us ever since. Today you will be making your very own kaleidoscope.

What to Learn: Kaleidoscopes are an example of using light reflectors, which don't give off any light, but still bounce light back to your eyes. Light is reflected from mirrors and other surfaces.

Materials

Mirror Kaleidoscope

- 4-5 mirrors, all the same size
- tape
- scissors

Mylar Kaleidoscope

- Mylar
- index card or piece of cardboard
- hot glue gun
- scissors

Lab Time

Mirror Kaleidoscope

1. Lay out a strip of tape, sticky side up.
2. Center one mirror on the tape with its reflective side pointing up.
3. Attach the second and third mirrors close to the first at 90-degree angles. One will be on the left; the other will be on the right.
4. Rip the excess tape off of one end and then carefully tape together the three identical mirrors, forming a triangular shape. Make sure that the reflective surface is on the inside.
5. Tape all the rough edges very well and peek through the opening as you walk around.
6. Look at the images the mirrors make on the inside while pointing it at various objects.

Mylar Kaleidoscope

1. Fold the index card into three equal pieces in order to make it a triangular tube.
2. Make sure your Mylar is the same size as each fold of the tube. Trim as needed.
3. Glue the Mylar down to the cardboard.
4. Fold your tube again, just making sure that the edges are as crisp as possible.
5. Tape lengthwise along the top edge of your triangular tube.
6. If you are making both kaleidoscopes, compare the reflections you see in this longer tube with those you saw in the mirror kaleidoscope.

Kaleidoscope Data Table

Number of Mirrors Used	Type of Mirror (Mylar or Glass, Flat or Curved, Shape and Size)	How were the Mirrors Arranged? (Triangle, Square...)	Effect on Image (What did it look like?)

Exercises Answer the questions below:

1. What is a light source?
2. What is a light reflector?

3. Sketch an image of something interesting that you were able to see as the light reflected from the multiple surfaces of the kaleidoscope to your eyes:

Lesson #3: Liquid Prism

Teacher Section

Overview: A prism un-mixes light back into its original colors of red, green, and blue. In this experiment, water is our prism. You can make prisms out of glass, plastic, water, oil, or anything else you can think of that allows light to zip through.

Suggested Time: 30-45 minutes

Objectives: Water acts like a prism, and today we're going to learn about the refractive characteristics of water.

Materials (per lab group)

- mirror
- shallow baking dish
- sunlight
- index card

You'll also have one of the following:

- plain water
- baby oil or mineral oil
- water with one tablespoon of salt mixed in
- distilled white vinegar
- isopropyl rubbing alcohol
- clear liquid soap (do not mix with water)

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Each lab group will be mixing up a different batch of clear liquid to use. Students will rotate from one lab team's setup to the next when they fill out their data table. You might want to pre-assemble the different liquid trays if you've got a rowdy crowd or a younger group of students.

Background Lesson Reading

What is a prism? Think of a beam of light. It zooms fast on a straight path, until it hits something, like a water drop. As the light goes through the water drop, it changes speed. This is called *refraction*, which we will discuss more in a future lesson. The speed change depends on the angle at which the light hits the water, and what the drop is made of. If it was a drop of mineral oil, the light would slow down a bit more because the fluid has more optical density. So when white light passes through a prism, like that water drop, it changes speed, which we can see with our eyes because it also turns colors.

Prisms un-mix light into its different wavelengths. When light hits the prism, most of it passes through, although a small bit of light does get reflected off the surface, but when it passes through it changes speed. Since the sunlight is made up of many different wavelengths (colors), each color gets bent by different amounts, and you see a

rainbow out the other side. As long as the light travels at the same speed (like through the air), it's white. But as soon as the light hits the water and bends at different angles, the wavelengths separate and spread out, making the rainbow you see.

Troubleshooting: This is one of the easiest experiments to do, and the most beautiful. The trouble is, you don't know where the water shadow will show up, so make sure you point the mirror to the sky and play with the angle of the mirror until you find the wavering rainbow. Because the shadow is constantly moving, you can snap a few pictures when you've got it so you can look over the finer details later. If this project still eludes you, take a large sheet and use it instead of the tiny index card.

Lesson

1. Begin the lesson discussion by asking your students, "What is a prism?"
2. To explain a prism, have students imagine a beam of light. It zooms fast on a straight path, until it hits something, like a water drop. As the light goes through the water drop, it changes speed.
3. The speed change depends on the angle that the light hits the water, and what the drop is made of. If it was a drop of mineral oil, the light would slow down a bit more. (We'll discuss this idea of refraction more in a future lesson.)
4. When white light passes through a prism, like that water drop, it changes speed, and turns colors. Prisms actually un-mix the light into its different wavelengths by bending each color by different amounts, giving you a rainbow on the other side.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Set a tray of liquid in sunlight. If you're using water, then fill your tray with water. If you're using salt, mix in a tablespoon of salt into the water and then set it in sunlight. If you're using anything else, fill it with your liquid and set it outside.
4. Lean a mirror against the inside edge of the tray and adjust it so that a rainbow appears.
5. Use the index card (or another white surface) so that you can clearly see the reflection from your prism.
6. You can also use a light bulb as an alternate light source by shining it through a slit in a flat cardboard surface. However, you'll find that sunlight is much more effective and will make a brighter, more complete rainbow.

Exercises

1. What serves as the prism in this experiment? (water or other clear liquid)
2. What property can help make something a good prism material? (transparency: a material that allows light to pass through it)
3. What are some other items that could be used as prisms? (glass, oil, clear plastic)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #3: Liquid Prism

Student Worksheet

Name _____

Overview: A prism un-mixes light back into its original colors of red, green, and blue. In this experiment, water is our prism. You can make prisms out of glass, plastic, water, oil, or anything else you can think of that allows light to zip through.

What to Learn: Today you're going to play with splitting apart white light into its primary colors. The color of light striking an object affects how our eyes see it.

Materials

- mirror
- shallow baking dish
- sunlight
- index card

You'll also have one of the following:

- plain water
- baby oil or mineral oil
- water with one tablespoon of salt mixed in
- distilled white vinegar
- isopropyl rubbing alcohol
- clear liquid soap (do not mix with water)

Lab Time

1. Set a tray of liquid in sunlight. If you're using water, then fill your tray with water. If you're using salt, mix a tablespoon of salt into the water and then set it in sunlight. If you're using anything else, fill it with your liquid and set it outside.
2. Lean a mirror against the inside edge of the tray and adjust it so that a rainbow appears.
3. Use the index card (or another white surface) so that you can clearly see the reflection from your prism.
4. You can also use a light bulb as an alternate light source by shining it through a slit in a flat cardboard surface. However, you'll find that sunlight is much more effective and will make a brighter, more complete rainbow.
5. Troubleshooting: This is one of the easiest experiments to do, and the most beautiful. The trouble is, you don't know where the water shadow will show up, so make sure you point the mirror to the sky and play with the angle of the mirror until you find the wavering rainbow. If you still have trouble, use a large sheet of white paper instead of the tiny index card.

Liquid Prism Data Table

Type of Liquid for the Prism	What did you observe?

Exercises Answer the questions below:

1. What serves as the prism in this experiment?
2. What property can help make something a good prism material?
3. What are some other items that could be used as prisms?

Lesson #4: Lunar Phases

Teacher Section

Overview: The Moon appears to change in the sky. One moment it's a big white circle, and next week it's shaped like a sideways bike helmet. There's even one day where it disappears altogether. So what gives? That's what this lab is all about.

Suggested Time: 30-45 minutes

Objectives: Sunlight can be blocked to create shadows.

Materials (per lab group)

- ball
- flashlight

Lab Preparation

1. This lab works best if your room is very *dark*. Button down those shades and make it as dark as you can.
2. Print out copies of the student worksheets.
3. Read over the Background Lesson Reading before teaching this class.
4. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

The sun illuminates half of the Moon all the time. Imagine shining a flashlight on a beach ball. The half that faces the light is lit up. There's no light on the far side, right? So for the Moon, *which* half is lit up depends on the rotation of the Moon. And which part of the illuminated side we can see depends on where we are when looking at the Moon. Sound complicated? This lab will straighten everything out so it makes sense.

One question you'll hear is: *Why don't we have eclipses every month when there's a new Moon?* Good question. The Moon's orbit around the Earth is not in the same plane as the Earth's orbit around the sun (called the ecliptic). It's actually off by about 5° . In fact, only twice per month does the Moon pass through the ecliptic.

The lunar cycle is approximately 28 days. To be exact, it takes on average 29.53 days (29 days, 12 hours, 44 minutes) between two full moons. The average calendar month is $1/12$ of a year, which is 30.44 days. Since the Moon's phases repeat every 29.53 days, they don't quite match up. That's why on Moon phase calendars, you'll see a skipped day to account for the mismatch.

A second full Moon in the same month is called a *blue Moon*. It's also a *blue Moon* if it's the third full Moon out of four in a three-month season, which happens once every two or three years.

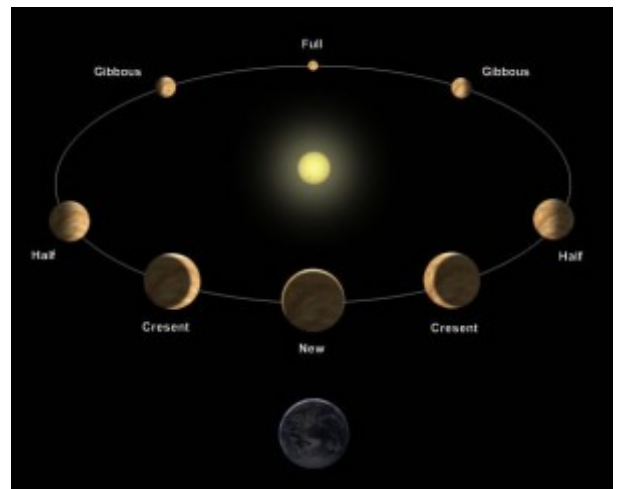
The Moon isn't the only object that has phases. Mercury and Venus undergo phases because they are closer to the sun than the Earth. If we lived on Mars, then the Earth would also have phases.

Lesson

1. If you prefer, you can run this lab as a demonstration where you are the ball-holder (Moon) and a volunteer holds a strong light (for the sun), with the kids all seated in a big pile at the center (Earth). Have the kids record their observations as you create the different phases of the Moon.
2. Go over the different phases of the Moon with the kids by asking them to come up and draw you a picture of the Earth in the middle of the board.
3. Ask kids to come up and draw a full Moon (at the 9 o'clock position), first quarter (12 o'clock position), third quarter (6 o'clock position), and new Moon (3 o'clock position) on the board. Leave plenty of space between so you can add labels and additional phases.
4. Which Moon is waxing (first quarter) and which is waning (third quarter)? Label each Moon.
5. Draw a waxing crescent Moon between the first quarter and the new Moon and label it.
6. Ask the kids where the waning crescent should be. (Between the third quarter and the new Moon.)
7. Ask the kids where the waxing gibbous Moon should be. (Between the full and the first quarter.)
8. Draw the waning gibbous Moon between the full and third quarter.
9. Now ask the kids where the sunlight is coming from (to the right of the board). Draw arrows toward the new Moon to show the direction of the sunlight.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups. You need at least three per group.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Assign one person to be the sun and hand them the flashlight. Stay standing up about four feet away from the group. The sun doesn't move at all for this activity.
4. Assign one person to be the Moon and hand them the ball. Stay standing up, as you'll be circling the Earth.
5. The rest of the people are the Earth, and they stand or sit right in the middle (so they don't get a flashlight in their eyes as the Moon orbits).
6. Start with a new Moon. Shine the flashlight above the heads of the Earth. Move the Moon (ball) into position so that the ball blocks all the light from the flashlight. Ask the Earth kids how much light they can see on their side of the Moon (should be none). Which phase of the Moon is this?
7. Now the Moon moves around to the opposite side of the Earth so that the Earth kids can see the entire half of the ball lit up by the flashlight. Ask the Earth kids how much light they can see on their side of the Moon (should be half the ball). Which phase of the Moon is this?
8. Now find the positions for first quarter. Where does the Moon need to stand so that the Earth kids can see the first quarter Moon?
9. Continue around in a complete circle and fill out the diagram below. Color in the circles to indicate the dark half of the Moon. For example, the new Moon should be completely darkened.
10. Now it's time to investigate why Venus and Mercury have phases. Put the sun in the center and assign a student to be Venus. Venus gets the ball.
11. Venus should be walking slowly around the sun. The sun is going to have to rotate to always face Venus, since the sun normally gives off light in every direction.



12. The Earth kids need to move further out from the sun than Venus, so they will be watching Venus orbit the sun from a distance of a couple of feet.
13. Earth kids: what do you notice about how the sun lights up Venus from your point of view? Are there times when you get to see Venus completely illuminated, and other times when it's completely dark? Draw a diagram below of what's going on, labeling Venus's full phase, new phase, half phases, crescent, and gibbous phases. Label the sun, Earth, and 8 phases of Venus like we did on the board for the Moon at the beginning of this lesson.

Exercises

1. Does the sun always light up half the Moon? (Yes. We don't always get to see it, which is because the Moon has phases.)
2. How many phases does the Moon have? (eight)
3. What is it called when the Moon appears to grow? (waxing)
4. What is it called when you see more light than dark on the Moon? (gibbous)
5. How long does it take for a complete lunar cycle? (about 29 ½ days)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #4: Lunar Phases

Student Worksheet

Name _____

Overview: The Moon appears to change in the sky. One moment it's a big white circle, and next week it's shaped like a sideways bike helmet. There's even a day where it disappears altogether. So what gives?

What to Learn: The sun illuminates half of the Moon all the time. Imagine shining a flashlight on a beach ball. The half that faces the light is lit up. There's no light on the far side, right? For the Moon, *which* half is lit up depends on the rotation of the Moon. And which part of the illuminated side we can see depends on where we are when looking at the Moon. Sound complicated? This lab will straighten everything out so it makes sense.

Materials

- ball
- flashlight

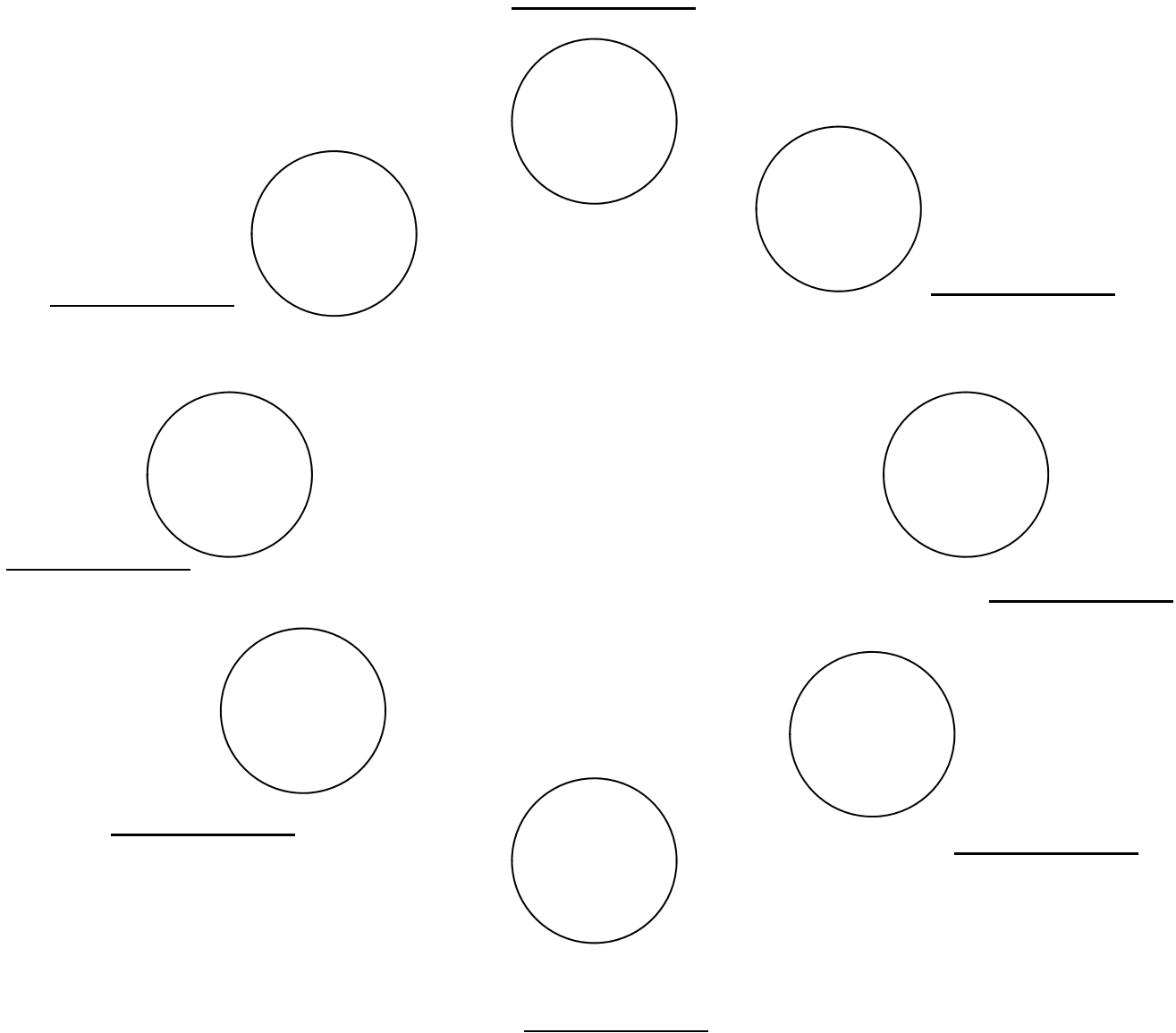
Lab Time

1. Assign one person to be the sun and hand them the flashlight. Stay standing up about four feet away from the group. The sun doesn't move at all for this activity.
2. Assign one person to be the Moon and hand them the ball. Stay standing up, as you'll be circling the Earth.
3. The rest of the people are the Earth, and they sit right in the middle (so they don't get a flashlight in their eyes as the Moon orbits).
4. Start with a new Moon. Shine the flashlight above the heads of the Earth. Move the Moon (ball) into position so that the ball blocks all the light from the flashlight. Ask the Earth kids how much light they can see on their side of the Moon (should be none). Which phase of the Moon is this?

5. Now the Moon moves around to the opposite side of the Earth so that the Earth kids can see the entire half of the ball lit up by the flashlight. Ask the Earth kids how much light they can see on their side of the Moon (should be half the ball). Which phase of the Moon is this?

6. Now find the positions for first quarter. Where does the Moon need to stand so that the Earth kids can see the first quarter Moon?
7. Continue around in a complete circle and fill out the diagram below. Color in the circles to indicate the dark half of the Moon. For example, the new Moon should be completely darkened.

Lunar Phases Data Observations



1. Now it's time to investigate why Venus and Mercury have phases. Put the sun in the center and assign a student to be Venus. Venus gets the ball.
2. Venus should be walking slowly around the sun. The sun is going to have to rotate to always face Venus, since the sun normally gives off light in every direction.
3. The Earth kids need to move further out from the sun than Venus, so they will be watching Venus orbit the sun from a distance of a couple of feet.

4. Earth kids: what do you notice about how the sun lights up Venus from your point of view? Is there a time when you get to see Venus completely illuminated, and other times when it's completely dark?
5. Draw a diagram below of what's going on, labeling Venus's full phase, new phase, half phases, crescent, and gibbous phases. Label the sun, Earth, and all 8 phases of Venus like we did on the board for the Earth at the beginning of this lesson:

Exercises Answer the questions below:

1. Does the sun always light up half the Moon?

1. How many phases does the Moon have?

2. What is it called when the Moon appears to grow?

3. What is it called when you see more light than dark on the Moon?

4. How long does it take for a complete lunar cycle?

Lesson #5: Sky in a Jar

Teacher Section

Overview: Why is the sky blue? Why is the sunset red? This lab will answer those questions by showing how light is scattered by the atmosphere.

Suggested Time: 30-45 minutes

Objectives: Particles in the atmosphere determine the color of the planet and the colors we see on its surface. The color of light striking an object affects how our eyes see it.

Materials (per lab group)

- glass jar
- flashlight
- fingernail polish (red, yellow, green, blue)
- clear tape
- water
- dark room
- few drops of milk

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

Why is the sunset red? The colors you see in the sky depend on how light bounces around. The red/orange colors of sunset and sunrise happen because of the low angle the sun makes with the atmosphere, skipping the light off dust and dirt (not to mention solid aerosols, soot, and smog). Sunsets are usually more spectacular than sunrises, as more “stuff” floats around at the end of the day (there are less particles present in the mornings). Sometimes just after sunset, a green flash can be seen ejecting from the setting sun.



The Earth appears blue to the astronauts in space because the shorter, faster wavelengths are reflected off the upper atmosphere. The sunsets appear red because the slower, longer wavelengths bounce off the clouds.

Sunsets on other planets are different because they are farther (or closer) to the sun, and also because they have a different atmosphere than planet Earth. The image shown here is a sunset on Mars.

Lesson

1. The Earth appears blue to the astronauts in space because the shorter, faster wavelengths are reflected off the upper atmosphere. The sunsets appear red because the slower, longer wavelengths bounce off the clouds.
2. Uranus and Neptune appear blue because the methane in the upper atmosphere reflects the sun's light and the methane absorbs the red light, allowing blue to bounce back out.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Make your room as *dark* as possible for this experiment to work.
4. Make sure your label is removed from the glass jar or you won't be able to see what's going on.
5. Fill the clear glass jar with water.
6. Add a teaspoon or two of milk (or cornstarch) and swirl.
7. Shine the flashlight down from the top and look from the side – the water should have a bluish hue. The small milk droplets scatter the light the same way our atmosphere dust particles scatter sunlight.
8. Try shining the light up from the base – where do you need to look in order to see a faint red/pink tint? If not, it's because you are looking for hues that match our real atmosphere, and the jar just isn't that big, nor is your flashlight strong enough! Instead, look for a very *slight* color shift. If you do this experiment after being in the dark for about 10 minutes (letting your eyes adjust to the lack of light), it is easier to see the subtle color changes. Just be careful that you don't let the brilliant flashlight ruin your newly acquired night-vision, or you'll have to start the 10 minutes all over again.
9. If you are still having trouble seeing the color changes, shine your light through the jar and onto an index card on the other side. You should see slight color changes on the white card.
10. Cover the flashlight lens with clear tape.
11. Paint on the tape (not the lens) the fingernail polish you need to complete the table below.
12. Repeat steps 7-9 and record your data.

Exercises

1. What colors does the sunset go through? (The sunset goes through the colors of the rainbow as the sun sets lower in the sky, starting with yellow, then orange, and then red as it sets.)
2. Does the color of the light source matter? (Yes. White light gives the best results.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #5: Sky in a Jar

Student Worksheet

Name _____

Overview: Have you ever wondered why the sky is blue? Or why the sunset is red? Or what color our sunset would be if we had a blue giant instead of a white star? This lab will answer those questions by showing how light is scattered by the atmosphere.

What to Learn: Particles in the atmosphere determine the color of the planet and the colors we see on its surface. The color of the star also affects the color of the sunset and of the planet. The color of light striking an object affects how our eyes see it.

Materials

- glass jar
- flashlight
- fingernail polish (red, yellow, green, blue)
- clear tape
- water
- dark room
- few drops of milk

Lab Time

1. Make your room as *dark* as possible for this experiment to work.
2. Make sure your label is removed from the glass jar or you won't be able to see what's going on.
3. Fill the clear glass jar with water.
4. Add a teaspoon or two of milk (or cornstarch) and swirl.
5. Shine the flashlight down from the top and look from the side – the water should have a bluish hue. The small milk droplets scatter the light the same way our atmosphere's dust particles scatter sunlight.
6. Try shining the light up from the base – where do you need to look in order to see a faint red/pink tint? If not, it's because you are looking for hues that match our real atmosphere, and the jar just isn't that big, nor is your flashlight strong enough! Instead, look for a very *slight* color shift. If you do this experiment after being in the dark for about 10 minutes (letting your eyes adjust to the lack of light), it is easier to see the subtle color changes. Just be careful that you don't let the brilliant flashlight ruin your newly acquired night-vision, or you'll have to start the 10 minutes all over again.
7. If you are still having trouble seeing the color changes, shine your light through the jar and onto an index card on the other side. You should see slight color changes on the white card.
8. Cover the flashlight lens with clear tape.
9. Paint on the tape (not the lens) the fingernail polish you need to complete the table below.
10. Repeat steps 7-9 and record your data.

Sky in a Jar Data Table

Flashlight Color	Location	Color(s)
<i>White</i>	<i>Side of jar</i>	
<i>White</i>	<i>Bottom of Jar</i>	
<i>Red</i>	<i>Side of jar</i>	
<i>Red</i>	<i>Bottom of Jar</i>	
<i>Yellow</i>	<i>Side of jar</i>	
<i>Yellow</i>	<i>Bottom of Jar</i>	
<i>Green</i>	<i>Side of jar</i>	
<i>Green</i>	<i>Bottom of Jar</i>	
<i>Blue</i>	<i>Side of jar</i>	
<i>Blue</i>	<i>Bottom of Jar</i>	

Exercises Answer the questions below:

1. What colors does the sunset go through?

2. Does the color of the light source matter?

Lesson #6: Light Tricks

Teacher Section

Overview: When light rays strikes a surface, part of the beam passes through the surface and the rest reflects back, like a ball bouncing on the ground. The amount that reflects back depends on how the light initially hits the surface, just like how a ball bounces back to you depends on how you throw the ball.

Suggested Time: 30-45 minutes

Objectives: Students will learn how light striking an object affects how our eyes see it.

Materials (per lab group)

- glass jar
- penny
- laser (optional)
- flashlight
- milk or flour

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

Have you ever broken a pencil by sticking it into a glass of water? The pencil isn't really broken, but it sure looks like it! What's going on?

Light can be bent when it passes through materials. The amount that the light bends is called the *index of refraction*. How much light bends depends on the material it's passing through. This quality is measured for each individual material and is called the *optical density*. The more dense the substance, the slower the light travels through it, and the more the light bends.

To be exact, when a beam of light hits a different substance (like moving from air to water), the wavelength changes because the speed of the light changes.

If you're thinking that the speed of light is always constant, you're right... in outer space, light travels at 186,000 miles per second. But the Earth is covered with an atmosphere, and as soon as the light passes into this thick cloud of nitrogen and oxygen gas, it slows down a bit.

The speed of light changes whenever it passes from one material to another, like when it moves from water to ice, or to sunglasses, smoke, fog, or windows. How much the light speed slows down depends on what the material is made of. Mineral oil and window glass will slow light down more than water, but not as much as diamonds do.



Lesson

1. Have you ever looked at a pool of clear, still water and seen your own face? The surface of the water acts like a mirror so that you can see your own reflection. In fact, before mirrors were invented, this was the only way people had to look at themselves! If you were swimming below the surface, you'd still see your own face – the mirror effect works both ways.
2. In optics, refraction happens when light waves travel from one medium with a certain refractive index (air, for example) to another medium which has a different refractive index (like water).
3. Demonstrate the pencil illusion. Since the kids are probably sitting all around the glass, each kid is going to see something slightly different about the pencil as you do this exercise, so encourage them to walk around the glass until they can see the effect the best.
 - a. Hold an empty water glass in front of the kids and place a pencil in it (as shown in the image). Ask the kids to draw what they see and label their image as "Empty Water Glass".
 - b. Fill the glass halfway with water and ask the kids to draw what they see and label their image as "Half-Full Water Glass".
 - c. Fill the glass completely with water (make sure some of the pencil is still sticking out) and ask the kids to draw what they see and label their image as "Full Water Glass".
 - d. What do you notice about the three images? What's going on? (Refer to background reading for explanation.)
4. Demonstrate the lab with the group first by doing the following:
 - a. Hold an empty glass in front of the students and place a penny at the bottom.
 - b. Ask the students to slowly back away from the glass until the penny disappears from view, then stop.
 - c. Slowly pour water into the glass and ask them to tell you what they notice. (They should see a virtual image of the penny once the water level is high enough.)
 - d. Explanation: in the first case with the empty cup, the image of the penny is reflected straight up into the air since there's nothing to bend the light, and if you're too far away from the cup, you won't see the image. In the second case, the light from the penny is slowed down until it hits the surface of the water and crosses into the air, when it bends and increases speed. Because the light bends, you can now see the penny.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Record your observations on the data sheet and in the exercises as you go.
4. Toss one coin into a water glass and fill with an inch of water. Hold the glass up and find where you need to look to see TWO coins.
5. Look through the top of the glass – how many coins are there now? What about when you look from the side?
6. Toss in a second coin – now how many are there?
7. Remove the coins turn and out the lights. Shine a flashlight beam through the glass onto a nearby wall. (Hint – if this doesn't work, try using a square clear container.) Stick a piece of paper on the wall where your light beam is and outline the beam with a pencil.
8. Shine the light at an angle up through the water so that it bounces off the surface of the water from underneath. Trace your new outline and compare... are they both the same shape?

9. Add a teaspoon of milk and stir gently. (No milk? Try sprinkling in a bit of white flour.) Now shine your flashlight through the container as you did in steps 4 and 5 and notice how the beam looks.
10. *Optional:* Use a round container instead of square... what's the difference?

Exercises

1. When one coin is in the water, you can actually see two: Are the coins both the same size? Which one is the original coin? (the smaller coin is the reflection)
2. In step 2 of the experiment: How many coins are there when viewed from the top of the glass? What about when you look from the side? (one coin when looking from above, two when looking through the side)
3. What happened when you tossed in a second coin? (There were four.)
4. How did your outlines compare? (The first was a circle, the second was an oval.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #6: Light Tricks

Student Worksheet

Name _____

Overview: Today you get to see the science behind the illusion by learning how light striking an object affects how our eyes see it.

What to Learn: Light can be bent when it passes through materials. The amount that the light bends is called the *index of refraction*. How much light bends depends on the material it's passing through. This quality is measured for each individual material and is called the *optical density*. The more dense the substance, the slower the light travels through it, and the more the light bends.

Materials

- glass jar
- penny
- laser (optional)
- flashlight
- milk or flour

Light Tricks Data Table

When your teacher demonstrates the pencil illusion trick, record your observations below.

Water Level:	Water Level:	Water Level:

Lab Time

1. Record your observations on the data sheet and in the exercises as you go.
2. Toss one coin into a water glass and fill with an inch of water. Hold the glass up and find where you need to look to see TWO coins.
3. Look through the top of the glass – how many coins are there now? What about when you look from the side?
4. Toss in a second coin – now how many are there?
5. Remove the coins and turn out the lights. Shine a flashlight beam through the glass onto a nearby wall. (Hint – if this doesn't work, try using a square clear container.) Stick a piece of paper on the wall where your light beam is and outline the beam with a pencil.
6. Shine the light at an angle up through the water so that it bounces off the surface of the water from underneath. Trace your new outline and compare... are they both the same shape?
7. Add a teaspoon of milk and stir gently. (No milk? Try sprinkling in a bit of white flour.) Now shine your flashlight through the container as you did in steps 4 and 5 and notice how the beam looks.
8. Use a round container instead of square... what's the difference?

Exercises Answer the questions below:

1. When one coin is in the water, you can actually see two: Are the coins both the same size? Which one is the original coin?
2. In step 2 of the experiment: How many coins are there when viewed from the top of the glass? What about when you look from the side?
3. What happened when you tossed in a second coin?
4. How did your outlines compare?

Lesson #7: Black Light Treasure Hunt

Teacher Section

This is a homework lab for your students, unless you can get your room very, very dark. Start the lab in class with an overview, and have the kids take home their student worksheets so they can bring them back the next day for discussion.

Overview: Ever notice how BRIGHT your white T-shirt looks in direct sun? That's because mom washed with fluorescent laundry soap (no kidding!). The soap manufacturers put in dyes that glow white under a UV light, which make your clothes appear whiter than they really are.

Suggested Time: Overview: 10 minutes; Homework Lab time: 20 minutes; Discussion: 10 minutes.

Objectives: Light can be absorbed and retransmitted in a different color, depending on how the light strikes the object and the amount of energy the light initially has.

Materials (per lab group)

- UV black fluorescent light
- dark evening inside your house

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. When you purchase your UV fluorescent "black lights," be sure to get the LONG WAVE version (short wave UV is the kind that causes permanent damage to living things – that's how they kill the bacteria in water). UV fluorescent *lamps* work better than the UV *LEDs* that are currently on the market, which are usually sold as "UV Flashlights". I have tried both, and the stuff shone brighter with the fluorescent lamps, *not* flashlights with LEDs.

Background Lesson Reading

Light bulbs use *incandescence*, which means that the little wire (which is made from the element *tungsten*) gets so hot when you switch it on that it gives off heat and light. Unfortunately, these bulbs give off a lot of heat, which you'll notice if you bring your hand close to it after it's been on for a while. Incandescence happens when your electric stove glows cherry red-hot and you can visibly see the light energy. Our sun gives off energy through incandescence also – a lot of it.

On the other end of things, *cold light* refers to the light from a glow stick, called *luminescence*. A chemical reaction (chemiluminescence) starts between two liquids, and the energy is released in the form of light. On the atomic scale, the energy from the reaction bumps the electron to a higher shell, and when it relaxes back down it emits a photon of light.

Phosphorescent light is the glow-in-the-dark kind of light you see after you charge up a glow toy with a bright light source. This delayed afterglow happens because when you charged the object with light, the light actually hits the atom's electron and whacks it into a higher energy state. When the electron relaxes back down its lower energy

state, it emits a light particle of (usually) a different wavelength (color). That's why glow-in-the-dark toys are often a different color than the light they emit after charged up. Since light is a form of energy, then in order for things to glow in the dark, you have to add energy first.

Triboluminescence is the spark you see when you smack two quartz crystals together in the dark. Other minerals spark when struck together, but you don't have to be a rock hound to see this one in action – just take a Wint-O-Green Lifesaver in a dark closet with a mirror and you'll get your own spark show. If you chew the candy with your mouth open, you'll be able to see the sparks in your mouth with a mirror. The spark is basically light from friction.

Fluorescence is similar to phosphorescence, except that it requires a continual light source in order to glow. These types of paints are popular with dark amusement-park rides. If you look carefully, you'll see UV lights hidden all around to make the images glow as you speed through the ride. In nature, you'll find fluorescence in certain rocks, plants and animals. Fluorescent objects absorb the UV light and reemit a completely different color. Like with phosphorescence, the light strikes the electron and bumps it up a level, and when the electron relaxed back down, emits a photon (light particle) of a different wavelength.

Lesson

1. Read over the Background Reading first, and find as many of these to demonstrate as you can. Here are some ideas:
2. Ask: "Can anyone tell me what an incandescent light bulb is?" It's the older kind of light bulb that uses a tungsten wire which gets hot. It gives out light, but it makes heat, which makes them less energy-efficient than fluorescent lights.
3. Fluorescent lights give out less heat, but more light. Since they don't lose as much energy to heat, they are more energy-efficient. I will usually hold up an incandescent bulb and a fluorescent bulb and ask the students how each makes light. A fluorescent tube is lined with white stuff called phosphor, which gives off light whenever it's struck by UV rays. The tube is filled with a gas that gives off UV rays when placed in an electrical field. When the bulb is turned on, electrons rip through the tube and go out the other side. As they go through, they smack into the gas vapor which releases light rays (UV in a fluorescent tube) that hit the phosphor on the inside of the tube, which then emits light. Fluorescent lights, or any tube of gas from the noble gases column on the periodic table, like neon, will also glow in an electrically charged field.
4. Phosphorescence is a type of fluorescence like you find in glow sticks and other glow-in-the-dark items.
5. Triboluminescence is a type of fluorescent light that comes from friction, like when striking two quartz crystals together. (You can hand out Wint-O-Green Lifesavers as part of their homework for the day and have them record their results in their lab.)

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups, if you are doing the lab during class time. Otherwise, let them know when it's due (like tomorrow).
2. Hand each group their materials. If you are doing this during class time, give them time to perform their experiment and write down their observations. If not, loan the kids the materials so they can perform their experiments at home.
3. If they are doing this lab for homework, demonstrate their lab by doing the following:
 - a. Turn off all the lights and turn on your UV black light.
 - b. Find things that glow.

c. Here are some things to try

- i. white paper (although paper made pre-1950 doesn't, which is how investigators tell the difference between originals and fakes)
- ii. club soda or tonic water (it's the quinine that glows blue)
- iii. body fluids (yes, blood, urine, and more are all fluorescent, though you may not want to demonstrate this with a younger audience)
- iv. Vitamins (Vitamin A, B, B-12 (crush and dissolve in vinegar first), thiamine, niacin, and riboflavin are strongly fluorescent)
- v. chlorophyll (grind spinach in a small amount of alcohol (like vodka or ethanol) and pour it through a coffee filter to get the extract (keep the solids in the filter, not the liquid))
- vi. antifreeze
- vii. laundry detergents
- viii. tooth whiteners
- ix. postage stamps
- x. driver's license
- xi. jellyfish
- xii. certain rocks (like fluorite, calcite, gypsum, ruby, talc, opal, agate, quartz, amber)
- xiii. show the image of the Hope Diamond (which is blue in regular light, but glows red)



Exercises

1. Why are incandescent lights less energy-efficient than fluorescent lights? (Incandescent light give off more heat and less light – they lose energy to heat and fluorescent lights do not.)
2. What are the two types of fluorescent light? (Phosphorescence and triboluminescence)
3. What kinds of things did you find that glow on your treasure hunt? Give at least five examples. (answers vary)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #7: Black Light Treasure Hunt

Student Worksheet

Name _____

Overview: Ever notice how BRIGHT your white T-shirt looks in direct sun? That's because mom washed with fluorescent laundry soap (no kidding!). The soap manufacturers put in dyes that glow white under a UV light, which make your clothes appear whiter than they really are.

What to Learn: Light can be absorbed and retransmitted in a different color, depending on how the light strikes the object and the amount of energy the light initially has.

Materials

- UV black fluorescent light
- dark evening inside your house

Lab Time

1. Turn off all the lights in your house and turn on your UV black light.
2. Find things that glow both inside and outside the house.
3. What fluoresces in your house? Here are some things to try: white paper (although paper made pre-1950 doesn't, which is how investigators tell the difference between originals and fakes), club soda or tonic water (it's the quinine that glows blue), body fluids (yes, blood, urine, and more are all fluorescent), Vitamins (Vitamin A, B, B-12 (crush and dissolve in vinegar first), thiamine, niacin, and riboflavin are strongly fluorescent), chlorophyll (grind spinach in a small amount of alcohol (like ethyl alcohol) and pour it through a coffee filter to get the extract (keep the solids in the filter, not the liquid)), antifreeze, laundry detergents, tooth whiteners, postage stamps, driver's license, jellyfish, and certain rocks (fluorite, calcite, gypsum, ruby, talc, opal, agate, quartz, amber) and the Hope Diamond (which is blue in regular light, but glows red).
4. Complete the data table.

Exercises Answer the questions below

1. Why are incandescent lights less energy-efficient than fluorescent lights?
2. What are the two types of fluorescent lights?
3. What kinds of things did you find that glow on your treasure hunt? Give at least five examples.

Black Light Treasure Hunt Data Table

Item/Object	What color did it glow?

Lesson #8: Benham's Disk

Teacher Section

Overview: Charles Benham (1895) created a toy top painted with a specific pattern. When you spin the black and white pattern, surprising arcs of color (called “pattern induced flicker colors”) show up; and here’s the odd part: Different people see different colors!

Suggested Time: 30-45 minutes

Objectives: Students will learn how the color of light striking an object affects how our eyes see it. They will also learn that the cones and rods inside our eyes collect images that are transmitted to the brain.

Materials (per lab group)

- Benham's Disks (included in this lesson)
- 8 index cards
- glue stick

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Special note for the experiment and exercises: Different people see different colors and/or intensities in this experiment. The answer to experiment questions may vary depending on what your students perceive.
5. If you have younger students, print out and cut out the disks ahead of time (in the Student Worksheet Section).
6. Make a demo by cutting out one of the disks and finding a way to spin it. The faster you spin it, the better it works. You can stick a pencil through the center and spin it like a top, or thread string through it and pull it like a button spinner to rotate the disk, or attach the pencil poked through the disk to a drill or hand mixer, or poke a small hobby motor shaft through the disk and engage the power. Which works best?

Background Lesson Reading

We can't really say why this effect with Benham's Disk happens, but there are a few interesting theories. The retina at the back of your eye has a bunch of light-sensitive cells called cones and rods. Your eyeball has two different ways of seeing light: cones and rods. Cones are used for color vision and for seeing bright light, and there are three types of cones (red, green, and blue). Rods are important for seeing in low light and they sense black, white, and gray shades. Together, they turn the light that enters your eye into an image.

One possibility of how this experiment works is how the human eye is tuned for different colors. Your eyeballs respond at different rates to red, green, and blue colors. The spinning disk triggers different parts of the retina. This alternating response may cause some type of interaction within the nervous system that generates colors.

Another theory is that certain cones take longer to react, and thus stay active, for longer amounts of time (though we're still talking milliseconds, here). To put it another way, the white color activates all three cones, but then the black deactivates them in a certain sequence, causing your brain to get mixed and unbalanced signals. Your brain

does the best it can to figure it out the information it's getting, and "creates" the colors you see in order to make sense of it all.

Neither of these theories fully explains why we see the different colors on the disk, so the reason behind the illusion remains unsolved. Maybe you can help?

Lesson

1. Hand the students a copy of the Benham's disk (from the Student Worksheet section). Ask how we can make these black and white disks appear colored without using markers, paints, crayons, or anything other than movement. Is this even possible?
2. It is when you're using a Benham's Disk! If you spin it fast enough, arcs of color actually appear on the disk.
3. How does this happen? Well, scientists don't really know exactly how. (Refer to Background Reading section.)
4. Can you help out these baffled scientists? Let's try the experiment and see what you think.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Cut out the Benham's Disks.
4. Glue the disks to index cards for stability. Regular paper tends to flop around when you spin it quickly.
5. Label each disk with a number from 1 to 6 on the back side so you can record your observations in the data table later.
6. Spin the disks with your chosen method (you'll want to demonstrate this for the kids).
7. Play with this a bit before you take data so you can get comfortable with how to do the experiment.
8. When you are ready, record your observations in the data table.

Exercises

1. What colors were you able to see when the disks were spinning? (answers vary)
2. How did the different patterns look when they were spun? (answers vary)
3. How did speed and direction affect what you saw? (answers vary)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #8: Benham's Disk

Student Worksheet

Name _____

Overview: Charles Benham (1895) created a toy top painted with a specific pattern. When you spin the black and white pattern, surprising arcs of color (called “pattern induced flicker colors”) show up; and here’s the odd part: Different people see different colors!

What to Learn: The color of light striking an object affects how our eyes see it. The cones and rods inside our eyes collect images that are transmitted to the brain.

Materials

- Benham's Disk sheet
- string (about 3 feet)
- 8 index cards
- glue stick

Lab Time

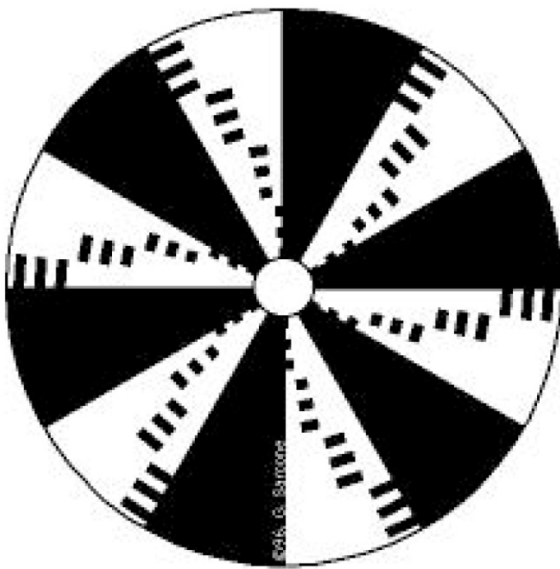
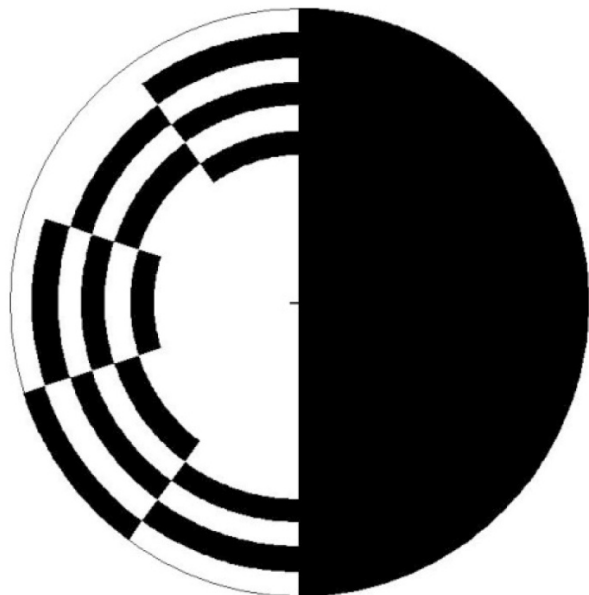
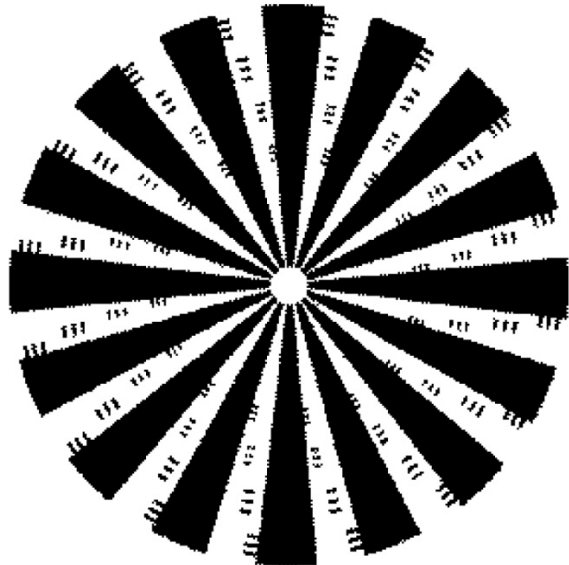
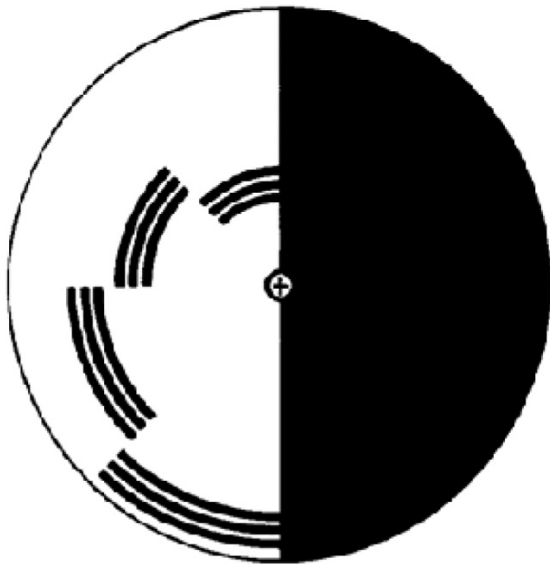
1. Cut out the Benham's Disks.
2. Glue the disks to index cards for stability. Regular paper tends to flop around when you spin it quickly.
3. Label each disk with a number from 1 to 6 on the back side so you can record your observations in the data table later.
4. Spin the disks using the method chosen by your teacher. Play with this a bit before you take data so you can get comfortable with how to do the experiment.
5. When you are ready, record your observations in the data table.

Benham's Disk Data Table

Disk #	What Colors Did You See?
1	
2	
3	
4	
5	
6	
Your Own Design #1	
Your Own Design #2	

Exercises Answer the questions below:

1. What colors were you able to see when the disks were spinning?
2. How did the different patterns look when they were spun?
3. How did speed and direction affect what you saw?



Benham's Disks

Lesson #9: Eye Balloon

Teacher Section

Overview: In this lab, we are going to make an eyeball model using a balloon. This experiment should give you a better idea of how your eyes work. The way your brain actually sees things is still a mystery, but using the balloon we can get a good working model of how light gets to your brain.

Suggested Time: 30-45 minutes

Objectives: Students will learn that we see objects when light traveling from an object enters our eye.

Materials (per lab group)

- biconvex plastic lens
- round balloon, white, 9 inches
- assistant
- votive candle
- black marker
- book of matches
- metric ruler
- **Adult Supervision!**

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

First, we'll discuss the parts of the balloon that relate to parts of your eye. The white portion of the balloon represents your sclera, which you may have already guessed is also the white part of your eye. It is actually a coating made of protein that covers the various muscles in your eye and holds everything together.

Of course, the lens you inserted represents the actual lens in your eye. The muscles surrounding the lens are called ciliary muscles and they are represented by the rubber neck of your balloon. The ciliary muscles help to control the amount of light entering your eyes.

The retina is in the back of your eye, which is represented by the inside back of your balloon. The retina supports your rods and cones. They collect information about light and color and send it to your brain.

Lesson

1. Did you know your eyes are similar to a camera? It's true. Both have lenses, and both use a series of interconnected parts which work together in order to produce an image.
2. In this experiment, we're going to make a balloon eye using a convex lens that mimics the lens in your eye.
3. We'll also mimic the conditions of near-sightedness and far-sightedness by gently changing the shape of the balloon.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Blow up the balloon until it is about the size of a grapefruit. If it's difficult to inflate, stretch the material a few times or ask an adult to help you.
4. You will need an extra set of hands for this portion. Ask your partner to hold the neck of the balloon closed to keep the air in while you insert the lens into the opening. The lens will need to be inserted perpendicular to the balloon's neck. It will prevent any air from escaping once it's in place. Like your eye, light will enter through the lens and travel toward the back of the balloon.
5. Hold the balloon so that the lens is pointing toward you. Take the lens between your thumb and index finger. Look into the lens into the balloon. You should have a clear view of the inside. Start to twist the balloon a little and notice that the neck gets smaller like your pupils do when exposed to light. Practice opening and closing the balloon's "pupil."
6. Help the kids put the candle on the table and light it. Turn out the lights.
7. Put the balloon about 20 to 30 centimeters away from the candle with the lens pointed toward it. The balloon should be between you and the candle. You should see a projection of the candle's flame on the back of the balloon's surface. Move the balloon back and forth in order to better focus the image on the back of the balloon and then proceed with data collection.
8. Describe the image you see on the back of the balloon. How is it different from the flame you see with your eyes? Draw a picture of how the flame looks.
9. The focal length is the distance from the flame to the image on the balloon. Measure this distance and record it.
10. What happens if you lightly push down on the top of the balloon? Does this affect the image? You are experimenting with the affect caused by near-sightedness.
11. To approximate a farsighted eye, gently push in the front and back of the balloon to make it taller. How does this change what you see?

Exercises

1. How does your eye work like a camera? (Both have lenses, both produce images with lots of components working together.)
2. How can you tell if a lens is double convex? (When you run your fingers across it, you feel two bumps on each side.)
3. What is the difference between convex and concave? (A concave surface curves inward, while a convex surface bulges out.)

4. Can you give an example of an everyday object that has both a convex and a concave side? (spoon)
5. How can you change the balloon to make it near-sighted? (lightly push down on the top)
6. How can you change the balloon to make it far-sighted? (gently push in front and back of the balloon to make it taller)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #9: Eye Balloon

Student Worksheet

Name _____

Overview: In this lab, we are going to make an eyeball model using a balloon. This experiment should give you a better idea of how your eyes work. The way your brain actually sees things is still a mystery, but using the balloon we can get a good working model of how light gets to your brain.

What to Learn: We see objects when light traveling from an object enters our eye.

Materials

- biconvex plastic lens
- round balloon, white, 9 inches
- assistant
- votive candle
- black marker
- book of matches
- metric ruler
- **Adult Supervision!**

Lab Time

1. Blow up the balloon until it is about the size of a grapefruit. If it's difficult to inflate, stretch the material a few times or ask an adult to help you.
2. You will need an extra set of hands for this portion. Ask your partner to hold the neck of the balloon closed to keep the air in while you insert the lens into the opening. The lens will need to be inserted perpendicular to the balloon's neck. It will prevent any air from escaping once it's in place. Like your eye, light will enter through the lens and travel toward the back of the balloon.
3. Hold the balloon so that the lens is pointing toward you. Take the lens between your thumb and index finger. Look into the lens into the balloon. You should have a clear view of the inside. Start to twist the balloon a little and notice that the neck gets smaller like your pupils do when exposed to light. Practice opening and closing the balloon's "pupil."
4. Have an adult help you put the candle on the table and light it. Turn out the lights.
5. Put the balloon about 20 to 30 centimeters away from the candle with the lens pointed toward it. The balloon should be between you and the candle. You should see a projection of the candle's flame on the back of the balloon's surface. Move the balloon back and forth in order to better focus the image on the back of the balloon and then proceed with data collection.
6. Describe the image you see on the back of the balloon. How is it different from the flame you see with your eyes? Draw a picture of how the flame looks.
7. The focal length is the distance from the flame to the image on the balloon. Measure this distance and record it.

8. What happens if you lightly push down on the top of the balloon? Does this affect the image? You are experimenting with the affect caused by near-sightedness.
9. To approximate a farsighted eye, gently push in the front and back of the balloon to make it taller. How does this change what you see?

Eye Balloon Data Table

Draw a picture of how the flame looks to you.	
Record the focal length from flame to the image.	
What happens to the image when you push down on the top of the balloon?	
What do you see when you push on the front and back of the balloon to make it taller?	

Exercises Answer the questions below:

1. How does your eye work like a camera?
2. How can you tell if a lens is double convex?
3. What is the difference between convex and concave?
4. Can you give an example of an everyday object that has both a convex and a concave side?

5. How can you change the balloon to make it like a near-sighted eye?

6. How can you change the balloon to make it like a far-sighted eye?

Lesson #10: Disappearing Frog

Teacher Section

Overview: Your optic nerve can be thought of as a data cord that is plugged in to each eye and connects them to your brain. The area where the nerve connects to the back of your eye creates a blind spot. There are no receptors in this area at all, and if something is in that area, you won't be able to see it. This experiment locates your blind spot.

Suggested Time: 30-45 minutes

Objectives: Cones and rods turn the light that enters the eye into images that are transmitted to the brain. Our eyes have a blind spot where the optic nerve connects to the back of the eye because there are no light receptors there.

Materials (per lab group)

- frog and dot card
- meter stick
- scrap piece of cardboard

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

There are no light receptors in the area of your eye where the optic nerve attaches to your eyeball. This is your blind spot and if an image is in this spot, the light reflected off of it doesn't get perceived by your eye.

Lesson

1. This is a fun experiment to play with using different ages of people. As folks get older, the shape of the eye changes and the blind spot can actually change. Ask a few fellow adults to help you demonstrate the lab and measure the distance for the blind spot based on how old the adults are.
2. You can also test to see if different people with different vision have different blind spots. For example, is the blind spot the same for someone with 20/20 versus 20/40? Or with or without eyeglasses? Have fun with the different variations!

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.

2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Print out the frog and dot and remove the dotted portion. Attach it to the piece of cardboard, which should have a matching portion removed. You can place the paper and cardboard on the meter stick at the notched area.
4. Now to locate blind spots. First, close your left eye. Look at the frog with your right eye. Can you see the dot and the frog? You should be able to see both at this point, but concentrate on the frog. Now *slowly* move the stick toward you so that the frog is coming toward your eye. Pay attention and stop when the dot disappears from your peripheral vision. At this point, the light hitting the dot and reflecting back toward your eye is hitting the blind spot at the back of your right eyeball, so you can't see it. Record how far your eye is from the card for your right eye.
5. Continue to move the stick toward your face, and at some point you will notice that you are able to see the dot again. Keep moving the stick forward and back. What happens to the dot?
6. Repeat steps 2 and 3 with your left eye, keeping your right eye closed. This time, stare at the dot and watch for the frog to disappear. Move the paper on the stick back and forth *slowly* until you notice the frog disappears. You have found the blind spot for your left eye. Be sure to note the distance the paper is from your eye.

Exercises

1. What did you notice about the vision of the student and the blind spot that you measured? (answers vary)
2. Why do you think it's important to know where your blind spot is? (so you can expect it and work around it if you need to)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #10: Disappearing Frog

Student Worksheet

Name _____

Overview: Your optic nerve can be thought of as a data cord that is plugged in to each eye and connects them to your brain. The area where the nerve connects to the back of your eye creates a blind spot. There are no receptors in this area at all and if something is in that area, you won't be able to see it. This experiment locates your blind spot.

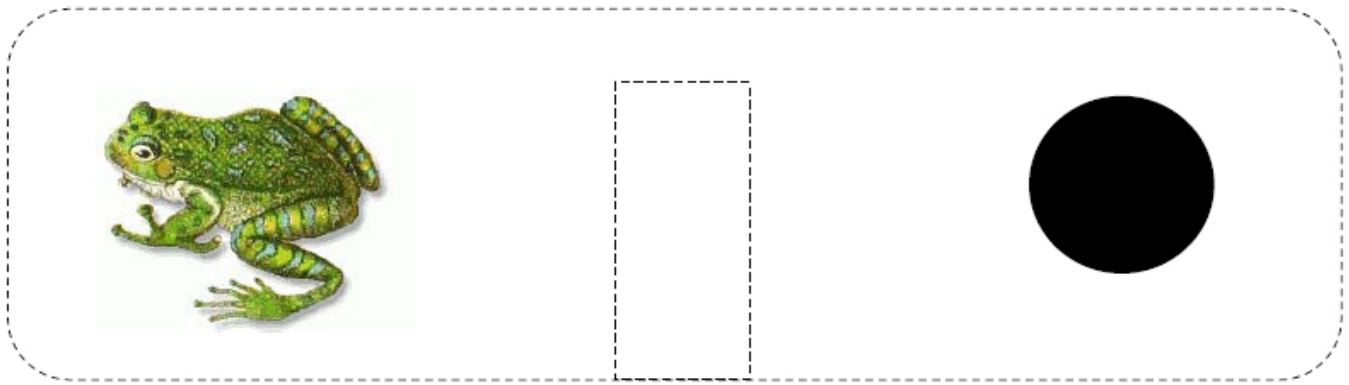
What to Learn: Cones and rods turn the light that enters the eye into images that are transmitted to the brain. Our eyes have a blind spot where the optic nerve connects to the back of the eye because there are no light receptors there.

Materials

- frog and dot printout
- meter stick
- scrap piece of cardboard

Lab Time

1. Print out the frog and dot and remove the dotted portion. Attach it to the piece of cardboard, which should have a matching portion removed. You can place the paper and cardboard on the meter stick at the notched area.
2. Now to locate blind spots. First, close your left eye. Look at the frog with your right eye. Can you see the dot and the frog? You should be able to see both at this point, but concentrate on the frog. Now *slowly* move the stick toward you so that the frog is coming toward your eye. Pay attention and stop when the dot disappears from your peripheral vision. At this point, the light hitting the dot and reflecting back toward your eye is hitting the blind spot at the back of your right eyeball, so you can't see it. Record how far your eye is from the card for your right eye.
3. Continue to move the stick toward your face, and at some point you will notice that you are able to see the dot again. Keep moving the stick forward and back. What happens to the dot?
4. Repeat steps 2 and 3 with your left eye, keeping your right eye closed. This time, stare at the dot and watch for the frog to disappear. Move the paper on the stick back and forth *slowly* until you notice the frog disappears. You have found the blind spot for your left eye. Be sure to note the distance the paper is from your eye.



Disappearing Frog Data Table

Student Name	Right or Left Eye?	Distance from Eye to Frog

Exercises Answer the questions below:

1. What did you notice about the vision of the student and the blind spot that you measured?
2. Why do you think it's important to know where your blind spot is?

Lesson #11: Pinhole Camera

Teacher Section

Overview: This is the simplest form of camera – no film, no batteries, and no moving parts that can break. This simple device will collect light and project it onto a screen.

Suggested Time: 30-45 minutes

Objectives: Students will learn that we are able to see objects when light traveling from an object enters our eye. Also, light can travel through a vacuum, like space.

Materials (per lab group)

- box
- tracing paper
- razor or scissors
- tape
- tack
- meter stick

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.

Background Lesson Reading

Light travels in a straight line; it comes through the window and into the hole in your camera. The rays of light cross as they enter the tiny hole, creating an inverted image that you see projected on the screen.

The biggest problem with this camera is that the inlet hole is so tiny that it lets in such a small amount of light and makes a faint image. If you make the hole larger, you get a brighter image, but it's much less focused. The more light rays coming through, the more they spread out the image and create a fuzzier picture. You'll need to play with the size of the hole to get the best image. You can also light a single candle in the middle of the room (instead of using a bright window) for the kids to use their camera. Just be careful they don't get too close – the cameras are flammable!

You can let your students go crazy taking actual photos with this camera by sticking on a piece of undeveloped black and white film (use a moderately fast ASA rating if you can still find it), but I recommend using tracing paper and a set of eyeballs to view your images.

OPTIONAL: You can hold up a magnifying glass in front of the pinhole to sharpen the image.

Lesson

1. Today, we're going to make a camera using just a box, some tape, and tracing paper. How do you think it will work?
2. Be sure to use lots of tape and make your box really lightproof!
3. Also, make a really tiny hole to let in the light. If you make the hole too big, you'll get a brighter image, but you'll lose focus as the light rays become more spread out and make your images fuzzy instead of sharp.
4. This camera works similarly to our eyes, with one main difference that you'll see when you're able to view an image through the camera.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Use a cardboard box that is light-proof (no leaks of light anywhere).
4. Seal light leaks with tape if you have to. Cut off one side of the box (Note – there's no need to do this if you're using a shoebox.)
5. Tape a piece of tracing paper over the cutout side, keeping it taut and smooth.
6. Make a pinhole in the box side opposite the tracing paper.
7. Point the pinhole at a sunny window and move toward or away from the window until you see its image in clear focus on the tracing paper.
8. If you have a magnifying glass, place it in front of the pinhole to help sharpen the image.

Exercises

1. How do the images appear when they're projected onto the paper inside your camera? (upside-down)
2. Why do you think it's important to make the box as light-proof as possible? (it allows only a small amount of light to pass through so that we can see the reflection better)
3. Is there a part of your body that works similarly to the pinhole? (our eyes)
4. Sketch a picture of something you saw through your pinhole camera.

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #11: Pinhole Camera

Student Worksheet

Name _____

Overview: Today you get to learn how to make a simple camera using equally simple materials. It's surprising how sharp the images appear when you do this experiment!

What to Learn: Although this might seem obvious, we see objects when light traveling from an object enters our eye. We can detect light in other ways (as you'll find out in a later lesson), but the eyes detect only visible light.

Materials

- box
- tracing paper
- razor or scissors
- tape
- tack
- meter stick

Lab Time

1. Use a cardboard box that is light-proof (no leaks of light anywhere).
2. Seal light leaks with tape if you have to. Cut off one side of the box (Note – there's no need to do this if you're using a shoebox.)
3. Tape a piece of tracing paper over the cutout side, keeping it taut and smooth.
4. Make a pinhole in the box side opposite of the tracing paper.
5. Point the pinhole at a sunny window and move toward or away from the window until you see its image in clear focus on the tracing paper.
6. If you have a magnifying glass, place it in front of the pinhole to help sharpen the image.
7. Complete the data table below by measuring your camera with the meter stick.

Pinhole Camera Data Table

Measure:	Length (inches, feet, cm, or...?)
Box length (this is one dimension of the screen)	
Box width (this is the other screen dimension)	
Box height (this is the distance from the hole to the screen)	
Distance from hole to the window (or candle) when focused	

Draw a diagram of your experiment, labeling the different parts and distances measured from above:

Exercises Answer the questions below:

1. How do the images appear when they're projected onto the paper inside your camera?
2. Why do you think it's important to make the box as light-proof as possible?
3. Is there a part of your body that works similarly to the pinhole?
4. Sketch a picture of something you saw through your pinhole camera.

Lesson #12: Diffraction

Teacher Section

Overview: Students will play with diffraction gratings to learn about how they work, so they can make a *Spectroscope* in a later lesson.

Suggested Time: 30-45 minutes

Objectives: Scientists use diffraction gratings to split incoming light so they can figure out what fuels a distant star is burning. When hydrogen burns, it gives off light, but not in all the colors of the rainbow, only very specific colors in red and blue. It's like hydrogen's own personal fingerprint, or light signature. When each element burns, it gives off a different combination of colors.

Prisms un-mix light into its colors or wavelengths.

Materials (per lab group)

- feather
- CD or DVD
- diffraction grating
- Several light sources, such as a candle, laser pointer, neon light, sodium light, fluorescent light, incandescent light, glow stick, etc.

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Right before class, set up your various light sources around the room. Students will rotate between different stations and record their results.

Background Lesson Reading

Ever play with a prism? When sunlight strikes the prism, it gets split into a rainbow of colors. Prisms un-mix the light into its different wavelengths (which you see as different colors). Diffraction gratings are tiny prisms stacked together. The direction that the beam gets split and diffracted depends on the spacing of the diffraction grating and also the wavelength of the incoming light.

The feather works because there are tiny “hairs” on the feather that are acting like tiny prisms.

Diffraction gratings were first discovered by James Gregory, right around the time Newton performed his famous prism experiments with bird feathers. The first diffraction gratings took a long time to construct, as they were individual hairs strung between screws.

Lesson

1. A diffraction grating bends the light and splits it into different beams. You can see this very well when you use a monochromatic light source, like a laser, instead of a multi-wavelength light source.
2. Start everyone off viewing an incandescent light you have at the front of the room. Have the students each try looking through of the three diffraction gratings at the light sources, and recording the information in the data table. This is their first station. Now split them into groups and have one student lab group per light source.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Take a feather and put it over an eye.
4. Stare at a light source through the feather, like an incandescent light.
5. You should see two or three lights and a rainbow X.
6. Aim the CD so the light hits the CD and makes rainbows.
7. Look at the light source through the diffraction grating.
8. Draw what you see for all three. Were they the same?
9. Rotate around the room to a new station when your teacher calls the time to change. You'll find different light source areas your teacher has set out for you.
10. Complete the table below as you view the different light sources through your diffraction gratings.

Exercises

1. Which light source gave the most interesting results? (This varies with data.)
2. What happens when you aim a laser beam through the diffraction grating? (It splits into three beams of light, as shown in the second video.)
3. How is a CD different and the same as a diffraction grating? (A CD has a spiral of finely-spaced data tracks while the diffraction grating has a series of parallel lines. The CD splits the light the same way as the diffraction grating. The CD splits the beam into more than three beams.)
4. Why does the feather work? (There are tiny "hairs" on the feather that are acting like tiny prisms.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #12: Diffraction

Student Worksheet

Name _____

Overview: When light passes through diffraction gratings, it splits (diffracts) the light into several beams traveling at different directions. If you've ever seen the “iridescence” of a soap bubble, an insect shell, or on a pearl, you've seen nature's diffraction gratings.

What to Learn: Ever play with a prism? When sunlight strikes the prism, it gets split into a rainbow of colors. Prisms un-mix the light into its different wavelengths (which you see as different colors). Diffraction gratings are tiny prisms stacked together. The direction that the beam gets split and diffracted depends on the spacing of the diffraction grating and also the wavelength of the incoming light.

Materials

- feather
- CD or DVD
- diffraction grating

Lab Time

1. Take a feather and put it over an eye.
2. Stare at a light source through the feather, like an incandescent light.
3. You should see two or three lights and a rainbow X.
4. Aim the CD so the light hits the CD and makes rainbows.
5. Look at the light source through the diffraction grating.
6. Draw what you see for all three. Were they the same?
7. Rotate around the room to a new station when your teacher calls the time to change. You'll find different light source areas your teacher has set out for you.
8. Complete the table below as you view the different light sources through your diffraction gratings.

Diffraction Data Table

Light Source	Diffractive Object <i>(Feather, CD, or Grating?)</i>	Draw What You See:

Exercises Answer the questions below:

1. Which light source gave the most interesting results?
2. What happens when you aim a laser beam through the diffraction grating?
3. How is a CD different and the same as a diffraction grating?
4. Why does the feather work?

Lesson #13: Speed of Light

Teacher Section

Overview: One of the biggest challenges with measuring the speed of light is that the photons move *fast*, too fast to watch with our eyeballs. So instead, we're going to watch the effects of microwave light and base our measurements on the effects the light has on different kinds of food.

Suggested Time: 30-45 minutes

Objectives: Light can change speeds, but the maximum speed is through a vacuum (186,000 miles per second).

Materials (per lab group)

- chocolate bar (extra-large bars work best)
- mini marshmallows
- chocolate chips
- American sliced cheese (the kind that comes individually wrapped)
- paper plates
- ruler
- calculator
- pencil and paper
- microwave (You'll only need one of these for the entire group.)

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Run through this experiment, especially the calculations during lab time, to be sure you've got everything working correctly.
5. Pre-sort the candy onto plates so there's not a free-for-all when it's time to do the experiment (if you're letting the kids each heat their own materials).

Background Lesson Reading

When you warm up leftovers, have you ever wondered why the microwave heats the food and not the plate? (Well, some plates, anyway). It has to do with the way microwave ovens work.

Microwave ovens use dielectric heating (or high frequency heating) to heat your food. Basically, the microwave oven shoots light beams that are tuned to excite the water molecule. Foods that contain water will step up a notch in energy levels as heat. (The microwave radiation can also excite other polarized molecules in addition to the water molecule, which is why some plates also get hot.)

One of the biggest challenges with measuring the speed of light is that the photons move *fast*, too fast to watch with our eyeballs. So instead, we're going to watch the effects of microwave light and base our measurements on the effects the light has on different kinds of food. Microwaves use light with a wavelength of 0.01 to 10 cm (that's the

"microwave" part of the electromagnetic spectrum). When designing your experiment, you'll need to pay close attention to the finer details such as the frequency of your microwave oven (found inside the door), where you place your food inside the oven, and how long you leave it in for.

Lesson

1. Be sure to run your experiment a few times before taking actual data, to be sure you've got everything running smoothly.
2. You can run this experiment with only one chocolate bar for the entire class and have their lab be entirely a "paper lab" where they use the measurements from your demo experiment to calculate the speed of light. Or, my personal favorite is to hand out giant bars of chocolate to each group and have them nuke their own bars. That way, if a few don't work, the groups can work together to get the best results.

Lab Time

1. First, you'll need to find the "hot spots" in your microwave. Do this with the kids so they can see how to do their part of the experiment.
2. Remove the turntable from your microwave and place a naked bar of chocolate on a plate inside the microwave. (Make sure the chocolate bar is the BIG size – you'll need at least 7 inches of chocolate for this to work.)
3. Turn the microwave on and wait a few minutes until you see small parts of the chocolate bar start to bubble up, and then quickly open the door (it will start to smoke if you leave it in too long).
4. Look carefully at the chocolate bar without touching the surface... you are looking for TWO hotspots, not just one – they will look like small volcano eruptions on the surface of the bar.
5. If you don't have two, grab a fresh plate (you can reuse the chocolate bar) and try again, changing the location of the plate inside the microwave. You're looking for the place where the microwave light hits the chocolate bar in two spots so you can measure the distance between the spots.
6. Open up the door or look on the back of your microwave for the technical specifications. You're looking for a frequency in the 2,000-3,000 MHz range, usually about 2450 MHz. Write this number down on a sheet of paper – this tells you the microwave radiation frequency that the oven produces, and will be used for calculating the speed of light.
7. When you're ready to take a measurement, pop in the first food type on a plate (without the turntable!) into the best spot in the microwave, and turn it on. Remove when both hotspots form, and being careful not to touch the surface of the food, measure the center-to-center distance using your ruler in centimeters. TIP: If you're using mini-marshmallows or chocolate chips (or other smaller foods), you'll need to spread them out in an even layer on your plate so you don't miss a spot that could be your hotspot!
8. Note that when you measure the distance between the hotspots, you are only measuring the peak-to-peak distance of the wave... which means you're only measuring *half* of the wave. We'll multiply this **number by two** to get the actual length of the wave (wavelength). If you're using centimeters, you'll also need to convert those to meters by dividing by 100.
9. So, if you measure 6.2 cm between your hotspots, and you want to calculate the speed of light and compare to the published value which is in meters per second, here's what you do:
2,450 MHz is really 2,450,000,000 Hz or 2,450,000,000 cycles per 1 second
10. Find the length of the wave (in cm): $2 * 6.2 \text{ cm} = (12.4 \text{ cm}) / (100 \text{ cm/m}) = 0.124 \text{ meters}$
11. Multiply the wavelength by the microwave oven frequency:
 $0.124 \text{ m} * 2,450,000,000 \text{ Hz} = \mathbf{303,800,000 \text{ m/s}}$

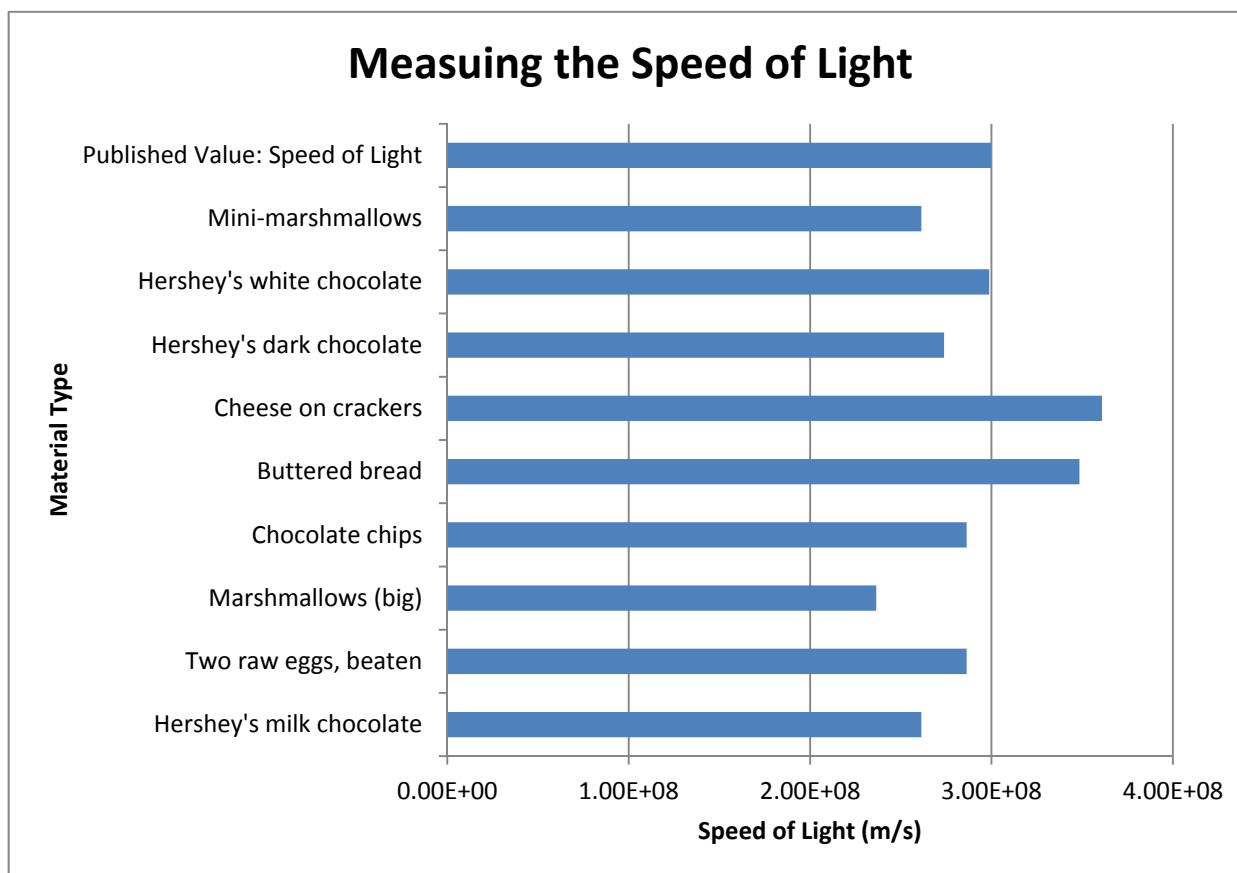
12. The published value for light speed is $299,792,458 \text{ m/s} = 186,000 \text{ miles/second} = 671,000,000 \text{ mph}$

13. For advanced students, show them how to calculate % Difference by using this simple formula:

$$\% \text{ Diff} = | \text{Measured Value} - \text{Published Value} | \div \text{Published Value} \times 100$$

Graphing:

1. Show the students how to graph their results using the sample graph below. You may not have quite as many different food types tested as I did, but do this for a couple of their results so they can see how to visualize their numbers to make more sense out of it.
2. Use the data from your table to make a graph of your results, putting the different types of food on the vertical axis and the measured (calculated) speed of light value on the horizontal axis. Refer to the sample below while you create your own. In the graph sample, note that “3.00 E+08” means 3 with eight zeros after it, or 300,000,000 meters per second.



Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #13: Speed of Light

Student Worksheet

Name _____

Overview: One of the biggest challenges with measuring the speed of light is that the photons move *fast*, too fast to watch with our eyeballs. So instead, we're going to watch the effects of microwave light and base our measurements on the effects the light has on different kinds of food.

What to Learn: Today you get to think and act like a real scientist by doing an experiment, taking measurements, using math to figure out an answer, and test different materials to see which gives you the best result.

Materials

- chocolate bar (extra-large bars work best)
- mini marshmallows
- chocolate chips
- American sliced cheese (the kind that comes individually wrapped)
- paper plates
- ruler
- calculator
- pencil and paper
- microwave (You'll only need one of these for the entire group.)

Lab Time

1. First, you'll need to find the "hot spots" in your microwave. Your teacher will demonstrate this for you, but here are the steps:
2. Remove the turntable from your microwave and place a naked bar of chocolate on a plate inside the microwave. (Make sure the chocolate bar is the BIG size – you'll need at least 7 inches of chocolate for this to work.)
3. Turn the microwave on and wait a few minutes until you see small parts of the chocolate bar start to bubble up, and then quickly open the door (it will start to smoke if you leave it in too long).
4. Look carefully at the chocolate bar without touching the surface... you are looking for TWO hotspots, not just one – they will look like small volcano eruptions on the surface of the bar.
5. If you don't have two, grab a fresh plate (you can reuse the chocolate bar) and try again, changing the location of the plate inside the microwave. You're looking for the place where the microwave light hits the chocolate bar in two spots so you can measure the distance between the spots.
6. Open up the door or look on the back of your microwave for the technical specifications. You're looking for a frequency in the 2,000-3,000 MHz range, usually about 2450 MHz. Write this number down on a sheet of paper – this tells you the microwave radiation frequency that the oven produces, and will be used for calculating the speed of light.
7. When you're ready to take a measurement, pop in the first food type on a plate (without the turntable!) into the best spot in the microwave, and turn it on. Remove when both hotspots form, and being careful not to touch the surface of the food, measure the center-to-center distance using your ruler in centimeters. TIP: If you're using mini-marshmallows or chocolate chips (or other smaller foods), you'll need to spread them out in an even layer on your plate so you don't miss a spot that could be your hotspot!

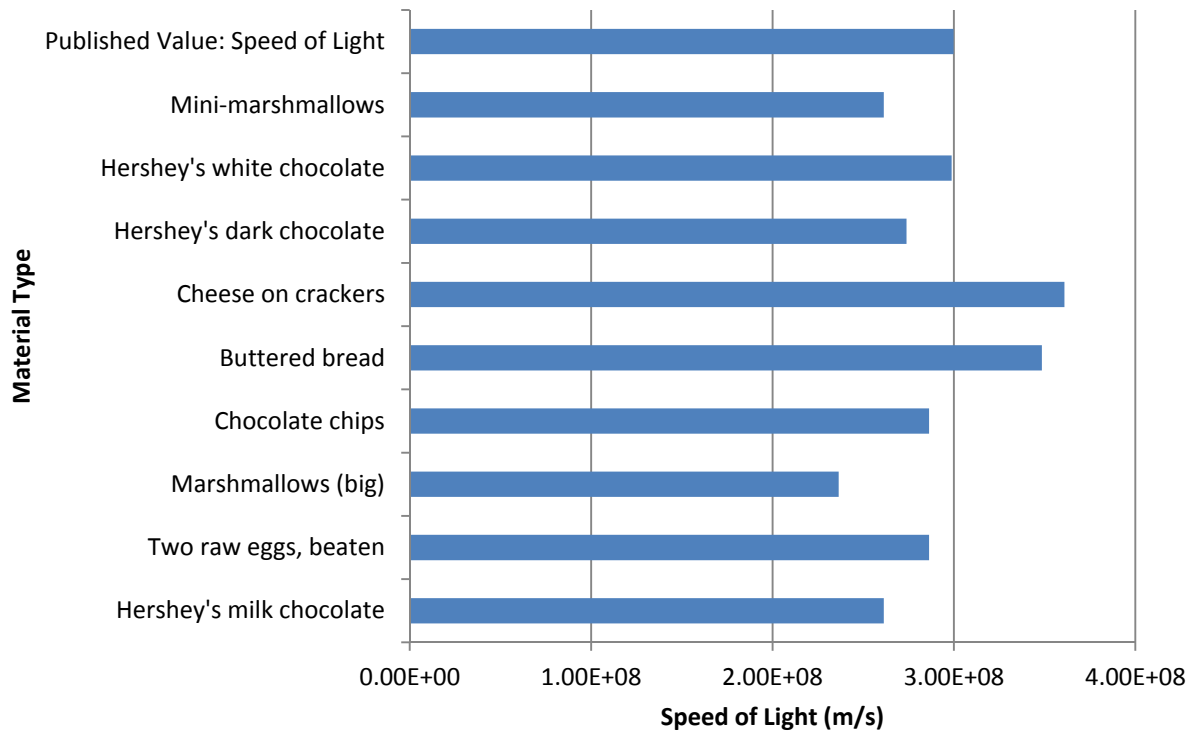
8. Note that when you measure the distance between the hotspots, you are only measuring the peak-to-peak distance of the wave... which means you're only measuring *half* of the wave. We'll multiply this **number by two** to get the actual length of the wave (wavelength). If you're using centimeters, you'll also need to convert those to meters by dividing by 100.
9. So, if you measure 6.2 cm between your hotspots, and you want to calculate the speed of light and compare to the published value which is in meters per second, here's what you do:
2,450 MHz is really 2,450,000,000 Hz or 2,450,000,000 cycles per 1 second
10. Find the length of the wave (in cm): $2 * 6.2 \text{ cm} = (12.4 \text{ cm}) / (100 \text{ cm/m}) = 0.124 \text{ meters}$
11. Multiply the wavelength by the microwave oven frequency:
 $0.124 \text{ m} * 2,450,000,000 \text{ Hz} = \mathbf{303,800,000 \text{ m/s}}$
12. The published value for light speed is $299,792,458 \text{ m/s} = 186,000 \text{ miles/second} = 671,000,000 \text{ mph}$
13. Calculate % Difference by using this simple formula:
 $\% \text{ Diff} = | \text{Measured Value} - \text{Published Value} | \div \text{Published Value} \times 100$

Speed of Light Data Table

Food Type	Hotspot Distance (cm)	Calculated Speed of Light (m/s)	% Difference

Graphing: Use the data from your table to make a graph of your results, putting the different types of food on the vertical axis and the measured (calculated) speed of light value on the horizontal axis. Refer to the sample below while you create your own. In the graph sample, note that "3.00 E+08" means 3 with eight zeros after it, or 300,000,000 meters per second.

Measuring the Speed of Light



Lesson #14: Mixing Colors

Teacher Section

Overview: There are two different sets of primary colors. The three primary colors of light are red, green, and blue. However, the three colors that artists use are red, *yellow*, and blue. What happens if you mix red, green, and blue paint? Paint and light are not the same!

Suggested Time: 30-45 minutes

Objectives: The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light.

Materials (per lab group)

- scissors
- crayons OR markers
- sharpened wood pencil OR skewer
- index cards
- cup
- drill (optional)

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Pre-cut the circles from the index cards if you have younger students, or want the lab to move along more quickly. You need circles about 3" in diameter.

Background Lesson Reading

Most kids understand how yellow paint and blue paint make green paint, but are totally stumped when red light and green light mix to make yellow light. The difference is that we're mixing *light*, not paint.

Lots of science textbooks still have this experiment listed under how to mix light: "*Stir together one of red water and one glass of green water (dyed with food coloring) to get a glass of yellow water.*" Hmmm... the result I get is a yucky greenish-brown color. What happened? The reason you can't mix green and red water to get yellow is that you're essentially still mixing paint, not light. But don't take our word for it – test it out for yourself with this super-fast light experiment on mixing colors.

Lesson

1. Ask students to name the primary colors.
2. How are the primary colors of light different from the primary colors in art?
3. What happens when mixing green and red light? Let's find out now.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Stack the index cards
4. Use the cup to trace a circle on the top card.
5. Keep the cards stacked while you cut out the circles. They don't have to be perfect, but make sure all the sharp corners are cut off.
6. Using different color markers, make different-colored slices (or pie pieces) on each circle. These are the colors that will blur together in your experiment.
7. Poke a hole through the center of the now-colorful circle with your pencil or skewer. Make sure the colored side is facing up toward you, not down toward the table.
8. To spin this like a top, make the "okay" symbol with your index finger and thumb. Put the skewer inside the circle your fingers make and spin it. Your hand will help to keep the top upright so that you are able to see how the colors blend together.
9. Optionally, an adult can help use a drill, handheld mixer, or electric screwdriver to spin the circle much faster.

Exercises

1. What do you see when blue and red are mixed on the spinner? (purple)
2. What do you see red and green are mixed on the spinner? (yellow)
3. What colors would you mix to get orange? (red and yellow)
4. What are the primary colors of light, and how do they differ from the primary colors we learn in art class? (Red, blue, and green are the primary colors of light – in art, the primary colors are red, yellow, and blue.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #14: Mixing Colors

Student Worksheet

Name _____

Overview: There are two different sets of primary colors. The three primary colors of light are red, green, and blue. However, the three colors that artists use are red, *yellow*, and blue. What happens if you mix red, green, and blue paint?

What to Learn: The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light.

Materials

- scissors
- crayons OR markers
- sharpened wood pencil OR skewer
- index cards
- cup
- drill (optional)

Lab Time

1. Stack the index cards
2. Use the cup to trace a circle on the top card.
3. Keep the cards stacked while you cut out the circles. They don't have to be perfect, but make sure all the sharp corners are cut off.
4. Using different color markers, make different colored slices (or pie pieces) on each circle. These are the colors that will blur together in your experiment.
5. Poke a hole through the center of the now-colorful circle with your pencil or skewer. Make sure the colored side is facing up toward you, not down toward the table.
6. To spin this like a top, make the "okay" symbol with your index finger and thumb. Put the skewer inside the circle your fingers make and spin it. Your hand will help to keep the top upright so that you are able to see how the colors blend together.
7. Optionally, an adult can help you use a drill, handheld mixer, or electric screwdriver to spin the circle much faster for a more noticeable effect.

Mixing Colors Data Table

Color and Percentage	Color and Percentage	Color and Percentage	Result
<i>Example:</i> blue 50%	<i>Example:</i> red 50%	<i>Example:</i> (nothing here - some cells may be blank)	<i>Example:</i> purple

Exercises Answer the questions below:

1. What happens when blue and red are mixed on the spinner?
2. What happens when red and green are mixed on the spinner?
3. What colors would you mix to get orange?
4. What are the primary colors of light, and how do they differ from the primary colors we learn in art class?

Lesson #15: Mixing Cold Light

Teacher Section

Overview: You can demonstrate how the primary colors of light mix together using glow sticks. The glow stick gives off its own light through a chemical reaction called chemiluminescence, which isn't the same as mixing paint together, since cups of paint are reflecting light, not generating it. It's like the difference between the sun (which gives off its own light) and the moon (which you see only when sunlight bounces off it to your eyeballs).

Suggested Time: 30-45 minutes

Objectives: The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light.

Materials (per lab group)

- disposable clear plastic cup or glass jar
- red, green, and blue true-color light sticks (one of each)
- scissors (with adult help)
- gloves
- goggles
- strainer, such as a coffee filter or bit of cheesecloth
- sink

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. This lab works well as a demonstration to the previous lab *Mixing Colors* if you prefer.
5. Be sure your light sticks are true-color. They will be housed in clear plastic and the liquid on the inside will have the color. You can order the true-color glow sticks here:
<http://www.teachersource.com/product/6-chemical-light-sticks-8-hour>

Background Lesson Reading

When we talk about light, its three primary colors are actually red, green, and blue. As a painter, you already know that mixing these three colors together would get a muddy brown. But as a scientist, when you mix together three cups of cold light, you will get something different.

The key is that we would be mixing light, not paint. Mixing the three primary colors of *light* gives white light. If you took three light bulbs (red, green, and blue) and shined them on the ceiling, you'd see white. And if you could magically un-mix the white colors, you'd get the rainbow (which is exactly what prisms do).

If you're thinking yellow should be a primary color – it *is* a primary color, but only in the artist's world. Yellow *paint* is a primary color for painters, but yellow *light* is actually made from red and green

light. (Easy way to remember this: think of Christmas colors – red and green merge to make the yellow star on top of the tree.)

As a painter, you know that when you mix three cups of red, green, and blue paint, you get a muddy brown. But as a scientist, when you mix together three cups of cold light, you get white. If you pass a beam of white light through a glass filled with water that's been dyed red, you've now got red light coming out the other side. The glass of red water is your filter. But what happens when you try to mix the different colors together?

The cold light is giving off its own light through a chemical reaction called chemiluminescence, whereas the cups of paint are only reflecting nearby light. It's like the difference between the sun (which gives off its own light) and the moon (which you see only when sunlight bounces off it to your eyeballs).

Lesson

1. Ask the class to name the three primary colors of art. How do they differ from the primary colors of light?
2. Remind students that yellow *is* a primary color, but only in the artist's world. Yellow *paint* is a primary color for painters, but yellow *light* is actually made from red and green light. (An easy way to remember this: think of Christmas colors – red and green merge to make the yellow star on top of the tree.)
3. In this experiment, the glow sticks are giving off cold light through a chemical reaction called chemiluminescence.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Bend the light sticks to break the glass inside the container (you'll hear a little "crack"). Do this for all three light sticks. This will activate the sticks.
4. Slap your gloves on your hands and goggles on your eyes. No exceptions.
5. Stand over a sink and carefully cut one end off of the light sticks. Get an adult to help, as the plastic can be stiff to cut through.
6. Carefully pour a tiny amount of one of the colors into your test tube. If bits of glass come out also, use the cheesecloth as a strainer to catch the pieces of glass from inside the tube.
7. Now add a second color and swirl gently to mix. Record your observations in the data table.
8. Repeat steps 4 and 5 for your data table.
9. Note: You may not need all of the red, due to its level of color concentration. Only add about half of the red and swirl until the colors are completely mixed. Add more red if needed to adjust the color.
10. When you are done with this lab, discard the bits of glass in the trash and flush the liquid down the sink with plenty of water.

Exercises

1. What color do you get when you mix blue and green liquid lights? (answers vary – green to blue)
2. What happens when you start to add the red light? (the color starts to pale)
3. What is your final color result when mixing red, blue, and green lights? (white)

4. How would your result differ if you instead mixed red, blue and green *paints*? (it would be a brown color)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #15: Mixing Cold Light

Student Worksheet

Name _____

Overview: You can demonstrate how the primary colors of light mix together using glow sticks. The glow stick gives off its own light through a chemical reaction called chemiluminescence, which isn't the same as mixing paint together, since cups of paint are reflecting light, not generating it. It's like the difference between the sun (which gives off its own light) and the moon (which you see only when sunlight bounces off it to your eyeballs).

What to Learn This

Materials

- disposable test tubes
- red, green, and blue true-color light sticks (one of each)
- scissors (with adult help)
- gloves
- goggles
- strainer, such as a coffee filter or bit of cheesecloth

Lab Time

1. Bend the light sticks to break the glass inside the container (you'll hear a little "crack"). Do this for all three light sticks. This will activate the sticks.
2. Slap your gloves on your hands and goggles on your eyes. No exceptions.
3. Stand over a sink and carefully cut one end off of the light sticks. Get an adult to help, as the plastic can be stiff to cut through.
4. Carefully pour a tiny amount of one of the colors into your test tube. If bits of glass come out also, use the cheesecloth as a strainer to catch the pieces of glass from inside the tube.
5. Now add a second color and swirl gently to mix. Record your observations in the data table.
6. Repeat steps 4 and 5 for your data table.
7. Note: You may not need all of the red, due to its level of color concentration. Only add about half of the red and swirl until the colors are completely mixed. Add more red if needed to adjust the color.
8. When you are done with this lab, discard the bits of glass in the trash and flush the liquid down the sink with plenty of water.

Mixing Cold Light Data Table

Color #1	Color #2	Color #3 (optional)	Resulting Color

Exercises Answer the questions below:

1. What color do you get when you mix blue and green liquid lights?
2. What happens when you start to add the red light?
3. What is your final color result when mixing red, blue, and green lights?
4. How would your result differ if you instead mixed red, blue and green *paints*?

Lesson #16: Refractive Index

Teacher Section

Overview: We're going to bend light to show the magic behind a popular optical illusion by using a cup of liquid as a lens.

Suggested Time: 30-45 minutes

Objectives: When a beam of light hits a different substance, it bends as it travels through the new substance. The speed that the light travels at and the wavelength (color) also changes. The amount of change depends on the index of refraction of the material.

Materials (per lab group)

- paper
- index card
- pencil
- scissors
- ruler
- disposable cups (4)
- flashlight
- rubbing alcohol
- water
- baby oil

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. You are going to do the *Disappearing Beaker* as a demonstration before the lab. You'll need two glass containers (one that fits inside the other), and the smaller one MUST be Pyrex. It's okay if your Pyrex glass has markings on the side. Use cooking oil such as canola oil, olive oil, or others to see which makes yours truly disappear. You can also try mineral oil or Karo syrup, although these tend to be more sensitive to temperature and aren't as evenly matched with the Pyrex as the first choices mentioned above.
5. If the kids are young, or you want to keep a set of these for the future, place the different liquids in clear, plastic jars and snap the lids on tightly. You'll need a fourth container of plain air.
6. To save time, prepare the index cards in advance by cutting two parallel slits in the center about an inch apart no thicker than a dime.

Background Lesson Reading

When a beam of light hits a different substance (like glass), the light bends and the speed of light changes, which means it slows down or speeds up as it travels through the new substance. The color of the light (called the wavelength) can also change, which is what prisms do to white light: Prisms bend the white light by different amounts to get a rainbow.

How much the light bends depends on the optical density of the substance. More dense materials bend the light more. Glass is optically denser than water, which is denser than air.

Optical Densities for Select Materials:

Vacuum (Space)	1.0000
Air	1.0003
Ice	1.3100
Water	1.3333
Pyrex	1.4740
Cooking oil	1.4740
Diamond	2.4170

Did you notice how Pyrex and cooking oil have the same optical density? This means if you place a Pyrex container inside a beaker of vegetable oil, it will disappear because the light will not bend, so you will not be able to detect one from the other. This trick also works for some mineral oils and Karo syrup.

(Note however that the optical densities of liquids vary with temperature and concentration, and manufacturers are not perfectly consistent when they whip up a batch of this stuff, so some adjustments are needed.)

Magnifying lenses, telescopes, and microscopes use this idea of bending light to distort images to make objects appear different sizes.

The light doesn't always appear to bend. For example, when light enters a new substance (like going from air to water) perpendicular to the surface (looking straight on), refraction does not occur. Where you are observing from will affect how the light appears to bend.

Lesson

1. Today you will do a super-cool magic trick to start off with to get the kids excited about refraction. Here's what you need:
 - a. two glass containers (one that fits inside the other), and the smaller one **MUST** be Pyrex (It's okay if your Pyrex glass has markings on the side.)
 - b. cooking oil such as canola oil or olive oil, or mineral oil or Karo syrup, although these tend to be more sensitive to temperature and aren't as evenly matched with the Pyrex as cooking oil
2. Fill both containers with oil while the students are watching.
3. When you're ready, place the smaller Pyrex container inside the larger container.
4. You should notice that the bottom part of the beaker disappears. Whoa.
5. Ask for ideas about what happened. What's really going on?
6. Explanation: The oil and the Pyrex bend light the same. They have the same index of refraction, which makes the beaker appear invisible.
7. Today they are going to bend light and find out which materials bend it the most!

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Turn off the lights and make the room very dark. If you don't have a dark enough room, you can do this experiment inside a shoebox.
4. Cut two small parallel slits in the index card about an inch apart, no thicker than a dime.
5. Place your sheet of paper on the table.
6. Place an empty cup on top of the paper and trace around the cup so you have a small circle on the paper.
7. Hold the index card up about 4-6 inches from the cup.
8. Shine your flashlight through the index card, about 4 more inches away. You should see two beams of light hitting the cup.
9. Using your ruler, trace the beams of light from the flashlight along the paper before and after the cup and label the lines "air."
10. Repeat steps 7-9 by filling the cup with a different liquid each time and trace each line.

Exercises

1. Which substance bent the light the most? (oil)
2. What other kinds of materials do you think might work in the cup? (answers vary)
3. Can we see light waves? (yes)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #16: Refractive Index

Student Worksheet

Name _____

Overview: We're going to bend light to show the magic behind a popular optical illusion by using a cup of liquid as a lens.

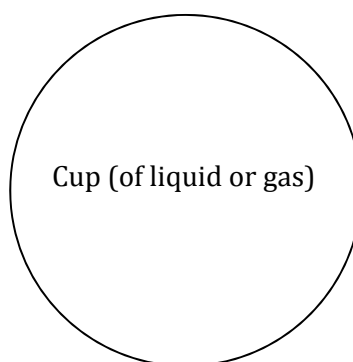
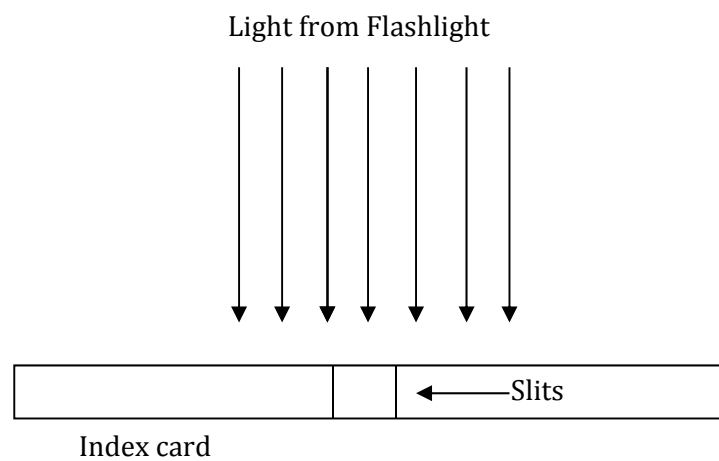
What to Learn: When a beam of light hits a different substance, it bends as it travels through the new substance. The speed at which the light travels and the wavelength (color) also changes. The amount of change depends on the index of refraction of the material.

Materials

- paper
- index card
- pencil
- scissors
- ruler
- disposable cups (4)
- flashlight
- rubbing alcohol
- water
- baby oil

Lab Time

1. Turn off the lights and make the room very dark. If you don't have a dark enough room, you can do this experiment inside a shoebox.
2. Cut two small parallel slits in the index card about an inch apart, no thicker than a dime.
3. Place your sheet of paper on the table (see sample on next page).
4. Place an empty cup on top of the paper and trace around the cup so you have a small circle on the paper.
5. Hold the index card up about 4-6 inches from the cup.
6. Shine your flashlight through the index card, about 4 more inches away. You should see two beams of light hitting the cup.
7. Using your ruler, trace the beams of light from the flashlight along the paper before and after the cup and label the lines "air."
8. Repeat steps 7-9 by filling the cup with a different liquid each time and trace each line.



Exercises Answer the questions below:

1. Which substance bent the light the most?
2. What other kinds of materials do you think might work in the cup?
3. Can we see light waves?

Lesson #17: Fire and Optics

Teacher Section

Overview: You're going to demonstrate what happens if you concentrate the energy from the sun through optical lenses. Since magnifying lenses, telescopes, and microscopes all use lenses to magnify images, students often wonder why they should never look at the sun. This demonstration will cure their curiosity for good.

Suggested Time: 30-45 minutes

Objectives: Students will learn the real reason why they are NEVER to look through anything that has lenses in it at the sun, including binoculars or telescopes.

Because this activity involves fire, make sure you do this on a flame-proof surface and not your dining room table! Good choices are your driveway, cement parking lot, the concrete sidewalk, or a large piece of ceramic tile. Don't do this experiment in your hand, or you're in for a hot, nasty surprise.

Materials (per lab group)

- sunlight
- glass jar
- nail that fits in the jar
- 12" thread
- hair from your head
- 12" string
- 12" fishing line
- 12" yarn
- paperclip
- magnifying glass
- fire extinguisher
- adult help

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. There are two videos for this lab. The burning leaf experiment is the one *you* get to do as a demonstration. The second video is the one the kids get to do, because there's less flammable material and less chance of them starting fires and getting into trouble. Watch the video for this experiment to prepare for teaching this class.
4. You'll need a magnifier and a dead leaf for your demonstration for the kids.
5. Ask the kids to bring in their jars ahead of time so you can prepare the lids before class. No water bottles – you want something that doesn't melt, like a glass jar from pickles or mayo.
6. When you have all the jars, remove the lids and pinch a hole in the center of each lid. Use a drill with a ¼" drill bit or smaller, or a hammer and nail.

Background Lesson Reading

Magnifying lenses, telescopes, and microscopes use this idea to make objects appear different sizes by bending light. When light passes through a different medium (from air to glass, water, a lens...) it changes speed and usually the angle at which it's traveling. A prism splits incoming light into a rainbow because the light bends as it moves through the prism. A pair of eyeglasses will bend the light to magnify the image.

Lesson

1. This lab is in two parts. The demonstration you do with the kids is not the one they do for their activity. You're going to concentrate the power of the sun on a flammable surface.
2. Please do this on a fireproof surface! This experiment will damage tables, counters, carpets, and floors. Do this experiment on surface like concrete or blacktop.
3. Hold the magnifier above the leaf and bring it down toward the leaf until you see a bright spot form on its surface. Adjust it until you see the light as bright and as concentrated as possible. First you'll notice smoke, then a tiny flame as the leaf burns.
4. You are concentrating the light, specifically the heat, from the sun into a very small area. Normally, the sunlight would have filled up the entire area of the lens, but you're shrinking this down to the size of the dot that's burning the leaf.
5. Thermoelectric power plants use this principle to power entire cities by using this principle of concentrating the heat from the sun.
6. Never look through anything that has lenses in it at the sun, including binoculars or telescopes, otherwise what's happening to the leaf right now is going to happen to your eyeball.

Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Screw the lid on the jar.
4. Tie one end of the thread to the paperclip.
5. Poke the other end of the thread inside the hole on the lid.
6. Unscrew the lid and tie a nail to the other end of the thread. You want the nail to be hanging above the bottom of the jar by an inch or two, so adjust the height as needed.
7. Bring your jar outside.
8. Question: *Without breaking the glass or removing the lid, how can you get the nail to drop to the bottom of the jar?*
9. Once you've successfully got the nail to drop, substitute a hair from your head for the thread and do the experiment again and time it. Complete the table below.

Exercises

1. What happened to the leaf? Why? (You are concentrating the light, specifically the heat, from the sun into a very small area. Normally, the sunlight would have filled up the entire area of the lens, but you're shrinking this down to the size of the dot that's burning the leaf.)
2. How did you get the nail to drop? (By concentrating the energy from the sun using the magnifier.)
3. Which material ignited the quickest? (Refer to data table.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Experiment 17: Fire and Optics

Student Worksheet

Name _____

Overview: Today you get to concentrate light, specifically the heat, from the sun into a very small area. Normally, the sunlight would have filled up the entire area of the lens, but you're shrinking this down to the size of the dot.

What to Learn: Magnifying lenses, telescopes, and microscopes use this idea to make objects appear different sizes by bending the light. When light passes through a different medium (from air to glass, water, a lens...) it changes speed and usually the angle at which it's traveling. A prism splits incoming light into a rainbow because the light bends as it moves through the prism. A pair of eyeglasses will bend the light to magnify the image.

Materials

- sunlight
- glass jar
- nail that fits in the jar
- 12" thread
- hair from your head
- 12" string
- 12" fishing line
- 12" yarn
- paperclip
- magnifying glass
- fire extinguisher
- adult help

Lab Time

1. Screw the lid on the jar.
2. Tie one end of the thread to the paperclip.
3. Poke the other end of the thread inside the hole on the lid.
4. Unscrew the lid and tie a nail to the other end of the thread. You want the nail to be hanging above the bottom of the jar by an inch or two, so adjust the height as needed.
5. Bring your jar outside.
6. Question: *Without breaking the glass or removing the lid, how can you get the nail to drop to the bottom of the jar?*

Fire & Optics & Eyes Data Table

Material for Suspending Nail	How Long Did It Take to Drop? <i>(measure in seconds)</i>

Exercises Answer the questions below:

1. What happened to the leaf? Why?
2. How did you get the nail to drop?
3. Which material ignited the quickest?

Lesson #18: Simple Microscopes & Telescopes

Teacher Section

Overview: Did you know you can create a compound microscope *and* a refractor telescope using the same materials? It's all in how you use them to bend the light. These two experiments cover the fundamental basics of how two double-convex lenses can be used to make objects appear larger when right up close or farther away.

Suggested Time: 20-25 minutes

Objectives: Things like lenses and mirrors can bend and bounce light to make interesting things, like compound microscopes and reflector telescopes. Telescopes magnify the appearance of some distant objects in the sky, including the moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.

Materials (per lab group)

- window
- dollar bill
- penny
- handheld magnifying lenses (2)
- ruler

Lab Preparation

1. Print out copies of the student worksheets.
2. Read over the Background Lesson Reading before teaching this class.
3. Watch the video for this experiment to prepare for teaching this class.
4. Get a pencil and a glass of water ready for your demonstration.

Background Lesson Reading

What I like best about this activity is how easily we can break down the basic ideas of something that seems much more complex and intimidating, like a telescope or microscope in a way that kids really understand.

Imagine tossing a rock into a still pond and watching the circles of ripples form and spread out into rings. Now look at the ripples in the water - notice how they spread out. What makes the ripples move outward is energy.

The ripples are like light. Notice the waves are not really moving the water from one side of the pond to the other, but rather moving energy across the surface of the water.

To put it another way, energy travels across the pond in a wave. Light works the same way – light travels as energy waves. Only light doesn't need water to travel through the way the water waves do - it can travel through a vacuum (like outer space).

Light can change speed the same way sound vibrations change speed. (Think of how your voice changes when you inhale helium and then try to talk.)

The fastest light can go is 186,000 miles per second – that's fast enough to circle the Earth seven times every second, but that's also inside a vacuum. You can get light going slower by aiming it through different gases. In our own atmosphere, light travels slower than it does in outer space.

Lesson

1. When a beam of light hits a different substance (like a window pane or a lens), the speed at which the light travels changes. (Sound waves do this, too!) In some cases, this change turns into a change in the direction of the beam.
2. For example, if you stick a pencil in a glass of water and look through the side of the glass, you'll notice that the pencil appears shifted. The speed of light is slower in the water (140,000 miles per second) than in the air (186,000 miles per second). This is called optical density, and the result is bent light beams and broken pencils.
3. You'll notice that the pencil doesn't always appear broken. Depending on where your eyeballs are, you can see an intact or broken pencil. When light enters a new substance (like going from air to water) perpendicular to the surface (looking straight on), refractions do not occur.
4. However, if you look at the glass at an angle, then depending on your sight angle, you'll see a different amount of shift in the pencil. Where do you need to look to see the greatest shift in the two halves of the pencil?
5. Why does the pencil appear bent? Is it always bent? Does the temperature of the water affect how bent the pencil looks? What if you put two pencils in there?
6. Depending on if the light is going from a lighter to an optically denser material (or vice versa), it will bend different amounts. Glass is optically denser than water, which is denser than air.
7. Not only can you change the shape of objects by bending light (broken pencil or whole?), but you can also change the size. Magnifying lenses, telescopes, and microscopes use this idea to make objects appear different sizes.



Lab Time

1. Review the instructions on their worksheets and then break the students into their lab groups.
2. Hand each group their materials and give them time to perform their experiment and write down their observations.
3. Place a penny on the table.
4. Hold one magnifier above the penny and look through it.
5. Bring the second magnifying lens above the first so now you're looking through both. Move the second lens closer and/or further from the penny until the penny comes into sharp focus. You've just made a compound microscope.
6. Who's inside the building on an older penny?
7. Try finding the spider/owl on the dollar bill. (Hint: it's in a corner next to the "1".)
8. Keeping the distance between the magnifiers about the same, slowly lift up the magnifiers until you're now looking through both to a window.
9. Adjust the distance until your image comes into sharp (and upside-down) focus. You've just made a refractor telescope, just like Galileo used 400 years ago.
10. Find eight different items to look at through your magnifiers. Make four of them up-close so you use the magnifiers as a microscope, and four of them far-away objects so you use the magnifiers like a telescope. Complete the table below.

Exercises

1. Can light change speeds? (Yes, when it travels through different mediums.)
2. Can you see ALL light with your eyes? (No, only visible light, like a rainbow.)
3. Give three examples of a light source. (Answer will vary, but here are mine: sun, a candle, and a glow stick.)
4. What's the difference between a microscope and a telescope? (A microscope magnifies an image before the focal point; a telescope magnifies an image after the focal point. Both are used to make images appear closer and larger. A microscope is used when objects are near; a telescope is used for far away objects.)
5. Why is the telescope image upside-down? (Because you've focused the image beyond the focal point.)

Closure: Before moving on, ask your students if they have any recommendations or unanswered questions that they can work out on their own. Brainstorming extension ideas is a great way to add more science studies to your class time.

Lesson #18: Simple Microscope & Telescope

Student Worksheet

Name _____

Overview: Did you know you can create a compound microscope *and* a refractor telescope using the same materials? It's all in how you use them to bend the light. These two experiments cover the fundamental basics of how two double-convex lenses can be used to make objects appear larger when right up close or farther away.

What to Learn: Things like lenses and mirrors can bend and bounce light to make interesting things, like compound microscopes and reflector telescopes. Telescopes magnify the appearance of some distant objects in the sky, including the moon and the planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.

Materials

- window
- dollar bill
- penny
- handheld magnifying lenses (2)
- ruler

Lab Time

1. Place a penny on the table.
2. Hold one magnifier above the penny and look through it.
3. Bring the second magnifying lens above the first so now you're looking through both. Move the second lens closer and/or further from the penny until the penny comes into sharp focus. You've just made a compound microscope.
4. Who's inside the building on an older penny?
5. Try finding the spider/owl on the dollar bill. (Hint: it's in a corner next to the "1".)
6. Keeping the distance between the magnifiers about the same, slowly lift up the magnifiers until you're now looking through both to a window.
7. Adjust the distance until your image comes into sharp (and upside-down) focus. You've just made a refractor telescope, just like Galileo used 400 years ago.
8. Find eight different items to look at through your magnifiers. Make four of them up-close so you use the magnifiers as a microscope, and four of them far-away objects so you use the magnifiers like a telescope. Complete the table below.

Simple Microscope & Telescope Data Table

For the last two columns, measure with your ruler carefully. Don't forget to label your units!

Magnification Used: _____ (multiply the magnification of both lenses together)

Object Looked At	Did you use the Magnifiers as a Microscope or Telescope?	How Far Apart are the Lenses?	How Far is your Eye from the Eyepiece?

Exercises Answer the questions below:

1. Can light change speeds?
2. Can you see ALL light with your eyes?

3. Give three examples of a light source.
4. What's the difference between a microscope and a telescope?
5. Why is the telescope image upside-down?

Light 1 Evaluation

Teacher Section

Overview: Kids will demonstrate how well they understand important key concepts from this section.

Suggested Time: 45-60 minutes

Objectives: Students will be tested on the key concepts of visible light.

1. Light has a source and travels in a direction.
2. Sunlight can be blocked to create shadows.
3. Light is reflected from mirrors and other surfaces.
4. The color of light striking an object affects how our eyes see it.
5. We see objects when light traveling from an object enters our eye.
6. Light can travel through a vacuum, like space.
7. Light can change speeds, but the maximum speed is through a vacuum (186,000 miles per second).
8. The three primary colors of light are red, blue, and green. Red and green light mixed together make yellow light.
9. Prisms un-mix light into its colors or wavelengths.

Students will also demonstrate these principles:

1. Light changes speeds when it passes through a different material.
2. Lenses work to bend light in a certain direction, called refraction.
3. Concave lenses work to make objects smaller and convex lenses make them larger.

Materials (one set for entire class)

- Two magnifying lenses
- Glass of water
- Pencil

Lab Preparation

1. Print out copies of the student worksheets, lab practical, and quiz.
2. Have a tub of the materials in front of you at your desk. Kids will come up when called and demonstrate their knowledge using these materials.

Lesson

The students are taking two tests today: the quiz and the lab practical. The quiz takes about 20 minutes, and you'll find the answer key to make it easy to grade.

Lab Practical

Students will demonstrate individually that they know how to bend light to distort images. While other kids are waiting for their turn, they will get started on their homework assignment. You get to decide whether they do their assignment individually or as a group.

Light 1 Evaluation

Student Worksheet

Overview: Today you're going to take two different tests: the quiz and the lab practical. You're going to take the written quiz first, and the lab practical at the end of this lab. The lab practical isn't a paper test – it's where you get to show your teacher that you know how to do something.

Lab Test & Homework

1. Your teacher will call you up so you can share how much you understand about the basics of light and how it works. Since science is so much more than just reading a book or circling the right answer, this is an important part of the test to find out what you really understand.
2. While you are waiting for your turn to show your teacher how much of this stuff you already know, you get to choose which homework assignment you want to complete. The assignment is due tomorrow, and half the credit is for creativity and the other half is for content, so really let your imagination fly as you work through it. Choose one:
 - a. Write a short story or skit about light from the perspective of the photon or the wave. You'll read this aloud to your class.
 - b. Make a poster that teaches the main concepts about light waves. When you're finished, you'll use it to teach to a class in the younger grades and demonstrate each of the principles that you've learned.
 - c. Write and perform a poem or song about light. This will be performed to your class.

Light 1 Quiz

Teacher's Answer Key

1. What are the three primary colors of light? (red, blue, and green)
2. What color do you get when mixing the primary colors of light? (white)
3. What is a light source? Please give an example. (a source of light waves – the sun, light bulbs, fire, etc. are all examples)
4. What property can help make something a good prism material? (transparency: a material that allows light to pass through it)
5. What is a light reflector? Please give an example. (A reflector does not emit light. Instead it bounces light off of it and reflects the light back to our eyes. Water, mirrors, the moon are all examples)
6. Does the sun always light up half the Moon? (Yes. We don't always get to see it, which is because the Moon has phases.)
7. How many phases does the Moon have? (Eight)
8. How does your eye work like a camera? (both have lenses, both produce images with lots of components working together)
9. What is the difference between convex and concave? (A concave surface curves inward, while a convex surface bulges out.)
10. Can you see ALL light with your eyes? (No, only visible light, like a rainbow.)
11. Give three examples of a light source. (Answer will vary, but here are mine: sun, a candle, and a glow stick.)
12. What's the difference between a microscope and a telescope? (A microscope magnifies an image before the focal point; a telescope magnifies an image after the focal point. Both are used to make images appear closer and larger. A microscope is used when objects are near; a telescope is used for far away objects.)

Light 1 Quiz

Name _____

1. What are the three primary colors of light?
2. What color do you get when mixing the primary colors of light?
3. What is a light source? Please give an example.
4. What property can help make something a good prism material?
5. What is a light reflector? Please give an example.
6. Does the sun always light up half the Moon?
7. How many phases does the Moon have?
8. How does your eye work like a camera?
9. What is the difference between convex and concave?

10. Can you see ALL light with your eyes?

11. Give three examples of a light source.

12. What's the difference between a microscope and a telescope?

Light 1 Lab Practical

Teacher's Answer Key

This is your chance to see how well your students have picked up on important key concepts, and if there are any holes. Your students also will be working on their homework assignment as you do this test individually with the students.

Materials:

- Two magnifying lenses
- Glass of water
- Pencil

Lab Practical: Ask the student *Note: Answers given in italics!*

- Design and build an experiment that shows how to change the speed of light. *Put a pencil in a glass of water and discuss how when light moves from one medium to another, it changes speeds, as shown by the pencil appearing to be broken.*
- Design a simple microscope to look at one of your hairs from your head. *Student holds one magnifying lens above the hair first (after ripping one out) and brings it into focus. Then they bring the second lens in above the first, parallel to each other but spaced apart until the hair appears in focus again. Ask them if the image is upside down or right side up and why. The image is right side up because they are focusing the image before the focal point of the lens.*

The Scientific Method

One of the problems kids have is how to experiment with their great ideas without getting lost in the jumble of result data. So often students will not have any clear ideas about what change caused which effect in their results! Students often have trouble communicating their ideas in ways that not only make sense but are also acceptable by science fairs or other technical competitions designed to get kids thinking like a real scientist. Another problem they face is struggling to apply the scientific method to their science project in school, for scout badges, or any other type of report where it's important that other folks know and understand their work.

The scientific method is widely used by formal science academia as well as scientific researchers. For most people, it's a real jump to figure out not only how to do a decent project, but also how to go about formulating a scientific question and investigate answers methodically like a real scientist. Presenting the results in a meaningful way via "exhibit board" ... well, that's just more of a stretch that most kids just aren't ready for. There isn't a whole lot of useful information available on how to do it by the people who really know how. That's why I'm going to show you how useful and easy it is.

The scientific method is a series of 5 steps that scientists use to do their work. But, honestly, you use it every day, too! The five steps are Observation, Hypothesis, Test, Collect Data, and Report Results. That sounds pretty complicated, but don't worry, they are just big words. Let me tell you what these words mean and how to play with them.

Step 1: Observation means what do you see, or hear, or smell, or feel? What is it that you're looking at? Is that what it usually does? Is that what it did last time? What would happen if you tried something different with it? Observation is the beginning of scientific research. You have to see or touch or hear something before you can start to do stuff with it, right?

Step 2: Once you observe something, you can then form a hypothesis. All hypothesis really means is "guess." A hypothesis is an educated guess. Tonight at dinner, when someone asks you, "Do you want peas or carrots?" Say, "I hypothesize that I would like the carrots." Everyone will think you're a genius! Basically you're saying "I guess that I would like the carrots." Hypotheses aren't right or wrong, they are just your best guess.

Step 3: To see if your guess is correct, you need to do the next step in the scientific method: test. The test is just what it sounds like: running experiments to see whether or not your hypothesis is correct.

Step 4: As you do your tests, you need to collect data. That means collecting the numbers, the measurements, the times, the data of the experiment. Once you collect your data, you can take a look at it, or in other words, analyze it.

Step 5: Once you analyze your data you can report your results. That basically means tell someone about it. You can put your data in a chart or a graph or just shout it from the rooftops!

Here's a great way to remember the 5 steps. Remember the sentence "Orange Hippos Take Classes Regularly." The first letter in each word of that goofy sentence is the same as the first letter in each step of the scientific method. That's called a mnemonic device. Make up your own mnemonic devices to remember all sorts of stuff.

"OK, so that's what the words mean. How do I use that every day?"

Well, I'm glad you asked that question. If you had cereal for breakfast this morning, you did the scientific method. On the table you had a bowl of cereal with no milk in it. As you looked at your dry cereal, you made an observation, "I need milk!" At that point, you made a hypothesis, "There's milk in the fridge." You can't be sure there's milk in the fridge. Someone might have used it up. It might have gone bad. Aliens may have used it to gas up their milk-powered spaceship. You just don't know! So you have to do a test.

What would be a good test to see if there is milk in the fridge? Open the fridge! Now once you move the week-old spaghetti and the green Jell-O (at least you hope it's Jell-O) out of the way, you can see if there is milk or not. So you collect your data. There is milk or there isn't milk. Now you can finally report your results. If there is milk, you can happily pour it on your cereal. If there isn't any milk, you report your results by shouting, "Hey, Mom...We need milk!" Scientific method, not so hard is it?

You'll get familiar with the scientific method by doing the activities and experiments in your lessons. Most scientists don't use the *full* version of the scientific method, which actually includes several additional steps to the ones I've outlined above. You'll find the full-blown version of the scientific method in the back of this book. I've included a copy of a special project which won first prize at a science fair. You'll find this complete project explains every detail and how it uses the full version of the scientific method so you can see how to do it for yourself on any project you choose.

Vocabulary for the Unit

The three primary **colors of light** are red, blue, and green. Red and green light mixed together make yellow light. Prisms unmix light into its colors (wavelengths).

Concave lenses work to make objects smaller (door peep hole), and are curved inward like a cave.

Convex lenses make them larger (magnifying lenses), and have a "bump" in the middle you can feel with your fingers.

The amount of **energy** a photon has determines whether it's a particle or a wave. Photons with the lowest amounts of energy and longest wavelengths (some are the size of football fields) are **radio waves**. The next step up are **microwaves**, which have more energy than radio waves. **IR** has slightly more energy, and **visible light** (the rainbow you can see with your eyes) has more energy and shorter wavelengths. Ultraviolet (UV) light has more energy than visible, and X-rays have even more energy than **UV**, and finally the deadly **gamma rays** have the most amount of energy.

Filters can be used to block certain wavelengths.

Intensity, or brightness, is the amount of photons (packets of light) you have in a certain amount of space. A flashlight has less intensity than a car headlight.

LASER stands for Light Amplification by Stimulated Emission of Radiation. Most lasers are monochromatic (one color). Lasers are concentrated beams of light, and are illuminated by small particles (like smoke and dust).

Lenses work to bend light in a certain direction (refraction). A lens is a curved piece of glass or plastic that changes the speed of the light. Lenses have the same effect on lasers as on light beams.

Light can be defined by four things: intensity (how bright), frequency (or wavelength), polarization (the direction of the electric field), and phase (time shift).

Objects can either be a **light source** (like the sun) or **reflect light** (like the moon).

Light can change speeds, but the maximum **light speed** is through a vacuum (186,000 miles per second). Light changes speeds when it passes through a different material (like water, glass, or fog).

Depending on the **optical density** of the material, light will bend by different amounts. Glass is optically denser than water. Water is more optically dense than air.

When two beams of light are out of phase with each other, it's like playing a *G* and *A* on the piano. This is called **phase shift**.

Blue and UV light eject electrons from metal plates, but red light does not (**photoelectric** effect).

Polarization has to do with the direction of the electric field. Your sunglasses are polarizing filters, meaning that they only let light of a certain direction in.

When a beam of light hits a window, it bends and changes speed (**refraction**). Technically, the wavelength (color) changes but the frequency stays the same. In order for this to happen, the speed of light must also change.

Razor-edge **slits** create interference patterns. Slits are skinny holes that allow light to pass through. Scientists use slits to filter out all other light sources except the one they want to use in their experiment.

When you change the **wavelength**, you change the color of the light. The wavelength (λ) equals the speed of light (c) divided by the frequency (ν), or $\lambda = c / \nu$.