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SPECTRA

IN

HIGH INTENSITY

INTERNATIONAL YEAR OF LIGHT 2015

APS physics

BY REBECCA THOMPSON, PH.D. & DAVID ELLIS

Welcome to PhysicsQuest: Spectra's High Intensity!

Your Mission

You are about to go on an adventure learning about light and optics as Spectra and her gang go on an adventure to stop the evil Miss Alignment from destroying their town. And they need your help! Miss Alignment has to strike at a very specific time of day for her plan to work and it is your job to find out what time of day that is so the kids know when to stop her.
After each activity you will see a section titled "Using your results to help Spectra find the time of Miss Alignment's attack." You have to pick the right answer that corresponds to a number, 1-4. After you've done all the activities you will add up the numbers to find the time of her evil attack. Good luck, a whole town is counting on you!

History of the PhysicsQuest Program

As part of the World Year of Physics 2005 celebration, the American Physical Society produced *PhysicsQuest: The Search for Albert Einstein's Hidden Treasure*. Designed as a resource for middle school science classrooms and clubs, the quest was received enthusiastically by nearly 10,000 classes during the course of 2005. Feedback indicated that this activity met a need within the middle school science community for fun and accessible physics material, so the American Physical Society (APS) has decided to continue this program. APS is pleased to present this tenth kit, *PhysicsQuest: Spectra's High Intensity*.

In the past each PhysicsQuest kit has followed a mystery-based storyline and requires students to correctly complete four activities in order to solve the mystery and be eligible for a prize drawing. For the sixth year in a row students will be following laser superhero Spectra. Past years have seen the downfall of the evil Miss Alignment, the unfortunate demise of General Relativity, the evil antics of Maxwell's Demon, the descent into competitive madness of Henri Toueaux and the unfortunate adventures of the Quantum Mechanic. In this edition of PhysicsQuest, Miss Alignment breaks out of jail with the help of her cousin Reigh Alignment. In a quest for revenge she uses the power of sunlight to try and take over the town. Students will learn about lenses, refraction, the connection

Spectra needs help from your students to defeat the evil Miss Alignment.

between heat and light, and the energy of the colors of the rainbow. This year's kit is part of APS's celebration of the International Year of Light. To find out more about IYL, please visit http://www.aps.org/programs/outreach/iyl/

About the International Year of Light

From the International Year of Light Website (www.light2015.org):

In proclaiming an International Year focusing on the topic of light science and its applications, the UN has recognized the importance of raising global awareness about how light-based technologies promote sustainable development and provide solutions to global challenges in energy, education, agriculture and health. Light plays a vital role in our daily lives and is an imperative cross-cutting discipline of science in the 21st century. It has revolutionized medicine, opened up international communication via the Internet, and continues to be central to linking cultural, economic and political aspects of the global society.

INTERNATIONAL YEAR OF LIGHT 2015

About the American Physical Society (APS)

APS is the professional society for physicists in the United States. APS works to advance and disseminate the knowledge of physics through its journals, meetings, public affairs efforts, and educational programs. Information about APS and its services can be found at www.aps.org.

APS also runs PhysicsCentral, a website aimed at communicating the excitement and importance of physics to the general public. At this site, www.physicscentral.com, you can find out about APS educational programs, current physics research, people in physics, and more.

About PhysicsQuest

PhysicsQuest is a set of four activities designed to engage students in scientific inquiry. This year's activities are linked together via a storyline and comic book that follows Spectra, a laser super hero. Spectra's super power is her ability to turn into a laser beam. Her powers are all real things that a laser beam does so in addition to learning via the 4 activities students will also learn through the comic book.
PhysicsQuest is designed with flexibility in mind – it can be done in one continuous session or split up over a number of weeks. The activities can be conducted in the classroom or as an extra credit or science club activity. The challenges can be completed in any order, but to get the correct final result all of the challenges must be completed correctly.

If you would like to join in with other teachers and classes, there is now a facebook group, PhysicsQuest. Talk with other PhysicsQuest groups or learn helpful tips and tricks.

About the PhysicsQuest Competition

APS sponsors an optional PhysicsQuest competition designed to encourage students to invest in the project. If you chose to participate in the competition, your class must complete AT LEAST ONE OF the four activities. You can then submit your answers online at www.physicscentral.com/physicsquest by May 25th. If you are unable to complete all 4 activities, you are encouraged to submit answers anyway. All classes that submit answers online will be entered into a prize drawing. Details on the prizes will be posted on the PhysicsQuest website as they become available. The online results submission form does not require the answers to all of the questions on the Final Report. If your class only has time to complete some of the activities, they can still submit their answers and are eligible for prizes. Each class can only submit one entry form, so class discussions of results are encouraged.

The PhysicsQuest Materials

The PhysicsQuest kit includes this manual and most of the hardware your students need to complete the activities. There is also a corresponding website, www.physicscentral.com/physicsquest, and PhysicsQuest Facebook group. Information regarding the PhysicsQuest will be posted in both of these locations.

Comic Book

Each activity will be preceded by several pages of a comic book that will follow the adventures of Spectra. The comic is also available online. Students will complete the activity and in the end they will need their answers to all four activities to help Spectra again defeat Miss Alignment. Many of the PhysicsQuest experiments are part of the comic book plot and you are encouraged to discuss these with your class.

Materials List

For more information on these items and where they can be purchased, please visit the PhysicsQuest website. If your kit is missing any of these materials, please contact Educational Innovations, www.teachersource.com (203) 229-0730.

Included in this kit

PhysicsQuest manual/comic book
Laser pointer
LED flashlight
Phosphorescent vinyl
Binder clips
20 packets of sugar
20 packets of sucralose
4 colored transparency material
Water gel cubes
3 sizes of water gel spheres
2 transparencies
1 small Hershey's bar
1 steel wire
1 copper wire
1 aluminum wire
1 Fresnel lens

Not included in this kit

Rock or cement surface
Paper
Scissors
Water
Plastic cups
Lots of Tape
Permanent Marker

The Teacher Guide The Teacher Guide for each activity includes:

Key Question
This question highlights the goal of the activity.

Key Terms
This section lists terms related to the activity that the students will encounter in the Student Guide.

Before the Activity…
Students should be familiar with these concepts and skills before tackling the activity.

After the Activity…
By participating in the activity, students are practicing the skills and studying the concepts listed in this section.

The Science Behind…
This section includes the science behind the activity. The Student Guide does not include most of this information; it is left to you to decide what to discuss with your students.

Safety
This section highlights potential hazards and safety precautions.

Materials
This section lists the materials needed for the activity. Materials not provided in the kit will be marked with a *.

Suggested Resources
This section lists the books and other resources used to create this activity and recommended resources for more information on the topics covered.

The Student Guide Each activity has a Student Guide that you will need to copy and hand out to all of the students. The Student Guide includes:

Key Question
This question highlights the goal of the activity.

Materials
This section lists the materials students will need for the activity.

Getting Started
This section includes discussion questions designed to get students thinking about the key question, why it's important, and how they might find an answer.

The Experiment
This section leads students step-by-step through the set-up and data collection process.

Analyzing your Results
This section leads students through data analysis and has questions for them to answer based on their results.

PhysicsQuest Website and Facebook Group

The PhysicsQuest website, www.physicscentral.com/physicsquest, has periodic updates on the program. Join the PhysicsQuest facebook group to connect with other groups doing the PhysicsQuest program.

PhysicsQuest Logistics Materials

The PhysicsQuest kit comes with only one set of materials. This means that if your students are working in four small groups (recommended), all groups should work simultaneously on different activities and then rotate activities, unless you provide additional materials. The Materials List on the PhysicsQuest website includes specific descriptions of the materials and where they can be purchased. All materials can be reused.

Time Required

The time required to complete the PhysicsQuest activities will depend on your students and their lab experience. Most groups will be able to complete one activity in about 45-minutes.

Small Groups

Working effectively in a group is one of the most important parts of scientific inquiry. If working in small groups is challenging for your students, you might consider adopting a group work model such as the one presented here.

Safety

While following the precautions in this guide can help teachers foster inquiry in a safe way, no manual could ever predict all of the problems that might occur. Good supervision and common sense are always needed. Activity-specific safety notices are included in the Teacher Guide when appropriate.

Group Work Model

Give each student one of the following roles. You may want to have them rotate roles for each activity so they can try many different jobs.

Lab Director
Coordinates the group and keeps students on task.

Chief Experimenter
Sets up the equipment and makes sure the procedures are carried out correctly.

Measurement Officer
Monitors data collection and determines the values for each measurement.

Report Writer
Records the results and makes sure all of the questions in the Student Guide are answered.

Equipment Manager
Collects all equipment needed for the experiment. Makes sure equipment is returned at the end of the class period and that the lab space is clean before group members leave.

Every super hero's buddy needs safety gear.

Using PhysicsQuest in the Classroom

This section suggests ways to use PhysicsQuest in the classroom. Since logistics and goals vary across schools, please read through the suggestions and then decide how best to use PhysicsQuest. Feel free to be creative!

PhysicsQuest as a stand-alone activity

PhysicsQuest is designed to be self-contained – it can be easily done as a special project during the day(s) following a test, immediately preceding/following a break, or other such times. PhysicsQuest also works well as a science club activity and extra credit opportunity.

PhysicsQuest as a fully integrated part of regular curriculum

The topics covered in PhysicsQuest are covered in many physical science classes, so you might have students do the PhysicsQuest activities during the corresponding units.

PhysicsQuest as an all-school activity

Some schools set up PhysicsQuest activity stations around the school gym for one afternoon. Then small groups of students work through the stations at assigned times.

PhysicsQuest as a mentoring activity

Some teachers have used PhysicsQuest as an opportunity for older students to mentor younger students. In this case, 8th or 9th grade classes first complete the activities themselves, and then go into 6th or 7th grade classrooms and help students with the activities.

Miss Alignment will not like you back on Facebook.

APS PhysicsQuest Pubication Staff
Coordinated, Researched, and Written by Rebecca Thompson, Ph.D.
Teacher Manual figures by Nancy Bennett-Karasic and David Ellis
Comic Art by David Ellis

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Educational Innovations

MEMBER:

MSDS
MATERIAL SAFETY DATA SHEET

PRODUCT IDENTIFICATION	TRADEMARK	SOIL MOIST™	Water retention aid
	CAS#	71042-87-0	
	SYNONYMS	None	
	CHEMICAL FAMILY	Crosslinked modified acrylic polymer	
	MOLECULAR FORMULA	Polymer	
	MOLECULAR WGT.	Polymer	
WARNING	SPILLS ARE SLIPPERY WHEN WET		
INGREDIENTS	SOIL MOIST contains polymer. No permissible exposure limits have been established.		
HEALTH INFORMATION	SOIL MOIST is a chemically neutral material. Prevent dust excape in the air, DO NOT breathe dust. A NIOSH, approved respirator for nuisance dust should be worn. After use, in horticulture work, normal hygenic practice should be followed.		
FIRE AND EXPLOSION	FLASH POINT	Not Applicable	
HAZARD INFORMATION	FLAMMABLE LIMITS	Not Applicable	
	FIRE FIGHTING	Use water, carbon dioxide or dry chemicals to extinguish fires. Wear self-contained, positive pressure breathing apparatus and full fire fighting protective clothing. Dust may be explosive if mixed with air in critical proportions and in the presence of a source of ignition.	
REACTIVITY DATA	STABILITY CONDITIONS TO AVOID	Stable None Known	
	POLYMERIZATION CONDITIONS TO AVOID	Will Not Occur None Known	
	INCOMPATIBLE MATERIALS	Strong oxidizing agents	
	HAZARDOUS DECOMPOSITION PRODUCTS	Thermal decomposition or combustion may produce carbon monoxide and/or oxides of nitrogen	
PHYSICAL PROPERTIES	APPEARANCE AND ODOR	Granular free flowing white material with typical odor	
	BOILING POINT	Not Applicable	
	MELTING POINT	Not Applicable	
	VAPOR PRESSURE	Not Applicable	
	SPECIFIC GRAVITY	Not Applicable	
	VAPOR DENSITY	Not Applicable	
	% VOLATILES	Approx. 4-10 % (H^2O)	
	pH	Not Applicable	
	SOLUBILITY IN WATER	Swells (does not dissolve). pH of aqueous system approx. 6.4 - 7.0	
SPILL PROCEDURES	Spilled material is slippery when wet. Remove sources of ignition. Sweep up spills and place in a waste disposal container. Disposal must be made in accordance with applicable governmental regulations.		
SPECIAL PRECAUTIONS	Maintain good housekeeping to control dust accumulations. DO NOT ALLOW MATERIAL TO ENTER DRAINS.		

NOTE: This information is given without any warranty or representation. We do not assume any legal responsibility for same. It is offered solely for your consideration, investigation and verification. Before using any product read its label.

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Educational Innovations

Todd S. Simmons, Ph.D.

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Lucinda Hene a.k.a. Spectra

Our heroine. She mysteriously developed laser superpowers around the time she entered Tesla Junior high and has been saving the town, and the world, ever since. Regular student and star swimmer most of the time, when it counts she can turn into a laser and save the day.

Kas

Lead guitarist of garage band “The Ultraviolet Catastrophe” and Spectra’s biggest fan. His greatest ambition is to go on tour with One Republic and rock out all over the world.

Ruby

Lucy’s best friend since 2nd grade, Ruby has an eye for fashion. When she’s not redecorating her room she can be found behind the lens of her camera. She has always loved science, particularly astronomy.

Gordy

He’s a star on and off the field. The starting quarterback for the Tesla Junior High Chargers and straight A student, Gordy can always keep his head and come up with a plan.

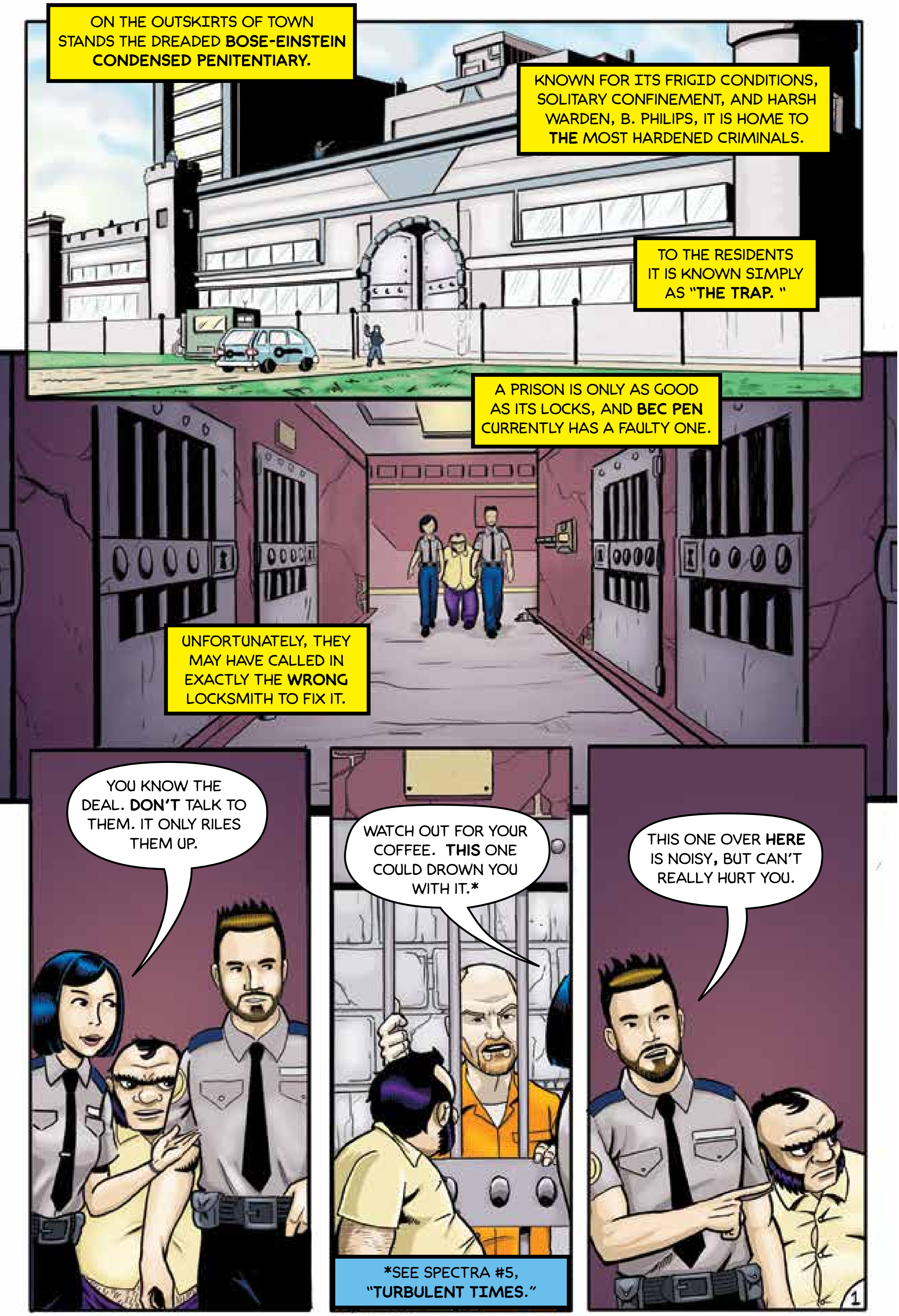
Ms. Pauli Black

Owner and proprietor of Black Body Repair auto body shop, she is also known as the “Quantum Mechanic.” She is fantastic at fixing a car and is also learning to control her quantum mechanical powers. Read Spectra’s Quantum Leap to find out more about what she can do.

Miss Alignment

Perennial villain Miss Alignment sees herself as the mastermind of evil. The world sees her slightly differently, but she is still determined to rule the town. Thwarted by Spectra and her gang in “Spectra’s Power” she is intent on coming out on top in...

Spectra’s High Intensity


ON THE OUTSKIRTS OF TOWN STANDS THE DREADED BOSE-EINSTEIN CONDENSED PENITENTIARY.
KNOWN FOR ITS FRIGID CONDITIONS, SOLITARY CONFINEMENT, AND HARSH WARDEN, B. PHILIPS, IT IS HOME TO THE MOST HARDENED CRIMINALS.
TO THE RESIDENTS IT IS KNOWN SIMPLY AS "THE TRAP."
A PRISON IS ONLY AS GOOD AS ITS LOCKS, AND BEC PEN CURRENTLY HAS A FAULTY ONE.
UNFORTUNATELY, THEY MAY HAVE CALLED IN EXACTLY THE WRONG LOCKSMITH TO FIX IT.
YOU KNOW THE DEAL. DON'T TALK TO THEM. IT ONLY RILES THEM UP.
WATCH OUT FOR YOUR COFFEE. THIS ONE COULD DROWN YOU WITH IT.*
*SEE SPECTRA #5, "TURBULENT TIMES."
THIS ONE OVER HERE IS NOISY, BUT CAN'T REALLY HURT YOU.
1


FOOLS! CAN'T HURT YOU?!? IF YOU ONLY KNEW! I AM THE NEFARIOUS MISS ALIGNMENT! I'LL RUN THIS TOWN ONE DAY!
SURE YOU WILL. AND I'M MR. UNIVERSE.
YOU NAIL 'EM WE JAIL 'EM
MY MISALIGNER 59 WOULD HAVE SHUT DOWN THE ENTIRE WORLD! IF ONLY THAT LASER GIRL AND HER FRIENDS HADN'T STOPPED ME! NEXT TIME WILL BE DIFFERENT! I'LL...
YEAH, YEAH. JUST STOP. WE'VE HEARD IT ALL BEFORE.
SHE SOUNDS HIGH MAINTENANCE.
PRISON LOCK PICK SET
OKAY, THE BROKEN LOCK IS THIS WAY. WE NEED IT OPERATIONAL ASAP. WE'RE GETTING A NEW BATCH OF INMATES TOMORROW.
I HOPE THIS DOESN'T TAKE LONG. "DAYS OF OUR LIVES" IS ON IN AN HOUR.
DON'T WORRY...
IT WON'T TAKE LONG. IN FACT...
"WE'LL BE OUTTA HERE --
PRISON LOCK PICK SET
-- BEFORE YOU KNOW IT."


REIGH, WHY ISN'T EVERYTHING READY!?
WHAT, NO "THANK YOU FOR BREAKING ME OUT OF JAIL, COUSIN?"
I DON'T HAVE TIME TO BE POLITE, YOU'VE PUT US TOO FAR BEHIND SCHEDULE!
MISS ALIGNMENT'S CON CAVE
"I HAVE TO GO FIND OUT WHAT THOSE KIDS ARE UP TO. IS THE LISTENING DEVICE READY?"
"YES, WITH NEW HEADPHONES."
"HOW'S MY LENS CLAMP COMING? IS THE LENS IN WORKING ORDER?"
"STILL NEEDS SOME MODIFICATIONS. I'VE BEEN PRACTICING ON TOY TRUCKS LIKE YOU SUGGESTED."
"ARE THE VISUAL AND AUDIO PROJECTORS READY? I NEED TO LET THIS TOWN KNOW I'M IN CHARGE!"
"STILL TRYING TO GET THE MAGNIFIER THE RIGHT SIZE AND STILL WORKING ON THE AUDIO."
I WILL RULE THIS PLACE AND MAKE SURE THE TOWN KNOWS THE POWER OF MISS ALIGNMENT!
THOSE KIDS WILL PAY AND THE TOWN WILL BE MINE!
YES, YOU WILL RULE THIS TOWN. BUT IT'S STILL GOING TO TAKE A WEEK OR SO FOR THIS TO BE FINISHED.
YOU'LL HAVE TO BE OKAY WITH RULING THIS CAVE 'TIL THEN.

TEACHER'S GUIDE
Activity 1: Bendy Light

Intro

In this activity students will learn about how light changes direction as it goes from one material to another. In this case they are going to look at the index of refraction of water and how that changes as two types of sweeteners are added. This is a really fun experiment using water and tiny little gel cubes and works better than fancier versions. The way the activity is written in the "For the Students" section is qualitative, but its easy to add a quantitative component by having the participants measure and compare angles. If you are interested in doing that, there is a link in the "other resources" section describing a way you might be able to do that.

Key Question
How does adding sucralose or sugar to water change its index of refraction?

Key Terms
Refraction: When light travels from one material to another it changes direction, or refracts.

Index of refraction: A number that describes how the speed of light in a material compares to the speed of light in vacuum. It also tells how much light changes direction when it moves from one material to another.

Transparent: Most light is transmitted, a little bit is reflected

Translucent: Some light is transmitted, some will be reflected

Opaque: All light it reflected or absorbed, none is transmitted.

Note to Teachers: This activity must be set up beforehand. It takes *several hours* to grow the water gel crystals.

Materials

Water Gel cubes
Sucralose Packets
Sugar Packets
Laser
Binder Clip
Transparencies
*White Paper
*Permanent Marker
*3 Cups
*Water
*Paper Towels
*Ruler

**Not included in the PhysicsQuest kit*

Setup (to be done the day before the activity is performed in class):

1. Fill 3 cups with water.

2. Label cup 1 "sugar" and dissolve the sugar into the water until no more sugar will fully dissolve.

3. Label cup 2 "sucralose" and dissolve the sucralose into the water until no more will fully dissolve.

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4. Label cup 3 "water."

5. Drop several gel cubes into each cup.

6. Allow the cubes to "grow" overnight in the cups. They grow in an interesting way so its fun to pull them out every now and then while they are growing.

Before the Activity Students should know...

- Light travels in a straight line.

- When light goes from one material to another it changes its path

After the Activity Students should be able to...

- Explain why we can see materials that are transparent even though light passes through them.

- Explain "index of refraction" and understand that larger indices of refraction make light change direction more.

The Science behind Refraction

Light travels in a straight line. If it weren't for this property of light there wouldn't be shadows or laser pointers. This rule however isn't completely true. When light moves from one material to another it changes its path. Some of the light changes it direction by reflecting and some changes direction by refracting. When a light ray goes from one transparent or translucent material to another it continues to move through the material but not in the same direction. This change in direction is called refraction.

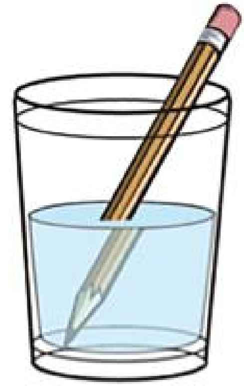

Fig. 1

In the year 984 Ibn Sahl noticed that light did this when it moved through a lens and he wondered if there was a rule that said how much light changed direction. He found that as light moved from air to the glass of the lens that the amount it refracted depended on the angle at which the light hit as well as the type of glass he used. He realized that the light was also changing speed. In 1621 both Willebrord Snellius and Renee Decartes both found an equation that tells how much of a light ray will reflect and how much will refract when the light hits a surface. Both of these depend on a number called the index of refraction, or "n". The larger the index of refraction of a material the more light it will reflect and the more it will bend the light that is transmitted. The index of refraction also tells how fast light travels in the new material.

Light is fastest when it is moving in a vacuum. No, not a Hoover, in this case "moving in a vacuum" means that light is moving through nothing, no matter at all, not even air. Outer space is an example of a vacuum. In a vacuum light travels at 300,000,000 meters per second but that's as fast as it can go. If it travels in any type of matter, even air it slows down a little bit. As it slows down it changes directions. Because the index of refraction tells how fast light goes in a particular material it can also say how much light changes direction as it moves from one material to another. It can also tell us how much light will be reflected. The speed of light in a material is related to the index of refraction by the formula: $n=c/v$ where c is the speed of light in a vacuum and v is the speed of light in a material.

The index of refraction depends on many things. Mostly it depends on the type of material. Water has an index of refraction of 1.3 while diamond has an index of refraction of 2.4. This means that diamond reflects more light than water and that light goes 2.4 times slower in diamond than it does in a vacuum. Index of refraction can also depend on temperature. The index of refraction of cooler air is 1.0003 but when the air is heated by 100 degrees C it changes to 1.0002. This may not seem like much but it bends light enough to cause the wavy appearance seen on top of roads and the hood of your car on hot days.

When we look at an object through a transparent material, such as water, we can see that the light is bending because it looks like the object has shifted a bit. Try this with a glass of water and a pencil. (Fig. 1) When you put the pencil in the water it looks like the part that is in the water is disjointed from the part that is still in air. This is because of refraction. But what happens when two different materials have the same index of refraction? Could we see them?

We can see transparent materials because of the reflections and in some cases because objects seen through these materials seem distorted by refraction. The index of refraction is different from that of air. But what would happen if two objects had the same index of refraction? Would we be able to distinguish between the two? Would one seem to disappear? That is what the students will be investigating with this experiment. The gel cubes are grown in water and because the final cube is 99% water it has the same index of refraction as water. While in water, it seems to disappear but in air it is clearly visible. Water with sucralose in it has a different index of refraction than plain water and water with sugar has yet another index of refraction. When the gel cubes are grown in sugar water or sucralose water the end up with the same index of refraction as sugar water or sucralose water.

By shining a laser, which travels in a straight line unlike light from a flashlight, through the gel cubes and tracing the laser beam, the students are able to see exactly how much the light is bent by the cube. (Fig. 2). When they do this for the three different cubes and then compare the results, they can see that the light changes direction more through some materials than others. If you would like to take this one step further, you could use a protractor to measure the angles involved to see exactly how much the light is bent for each case.

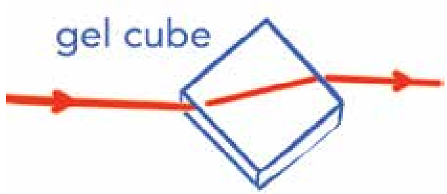

Fig. 2

Suggested Resources

https://www.youtube.com/watch?v=FAivtXJOsiI

http://phet.colorado.edu/en/simulation/bending-light

http://dev.physicslab.org/Document.aspx?doctype=2&filename=GeometricOptics_IndexRefractionGlass.xml

Safety

Warn students very strongly about the dangers of looking directly into the laser beam. Shining the beam into their eyes of the eyes of their classmates and cause serious injury and damage.

Consequences for student recklessly playing with the lasers should be outlined before giving out the supplies for the activity. If you are concerned, you may prefer to complete the portions of the procedure with the laser for your students and have them do the analysis.

For water gel cube safety see the MSDS sheet on page 8.

Intro

Water is clear and ice is clear, but you can usually see ice in your glass. Why is that? If you've ever tried to pick something up out of a pool of water you know the object isn't where your eyes tell you it should be. Why do diamonds sparkle more than glass and why does a prism give a rainbow? In this activity you'll get to explore these questions and play with lasers at the same time!

Key Question

How does adding sucralose or sugar to water change its index of refraction?

Getting Started

1. Why can we see clear objects such as glass or clear plastic? ____

____

____

2. What happens to light when it moves from air to water? ____

____

____

3. Can you see ice in water even when they are both clear? Why or why not? __

____

____

4. Does light always travel in straight lines? How do you know? ________________

____

____

____

5. Look in each of the three cups. What do you see?________________________

____

____

Materials

Water Gel cubes
Sucralose Packets
Sugar Packets
Laser
Binder Clip
Transparencies
*White Paper
*Permanent Marker
*3 Cups
*Water
*Paper Towels
*Ruler

**Not included in the PhysicsQuest kit*

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6. Stick your fingers in the cups. What do you feel? ______________________
____
____

7. Take a cube out of the cup labeled “water” and put it in the cup labeled “sucralose water.” What do you see now? __________________________________
____
____

Setting up the Experiment

1. Unscrew the cap on the laser, shake out the batteries, and make sure to remove the tiny piece of paper between the batteries. Replace the batteries and push the button to make sure the laser turns on.

DO NOT LOOK DIRECTLY AT THE LASER. NEVER SHINE A LASER INTO ANYONE’S EYES.

2. Put the laser in the binder clip so that the binder clip is pushing down the “on” button and keeping the laser turned on.

3. Take a cube out of cup marked “water” and put it on a piece of paper towel and dry it off a bit.

4. After its a bit drier, put it in the middle of the white piece of paper and trace around the base with the permanent marker. Label the paper “water.”

5. Aim the laser so that the laser beam hits the cube at a bit of an angle. Its easiest if the laser is far away from the cube. (Fig. 1)

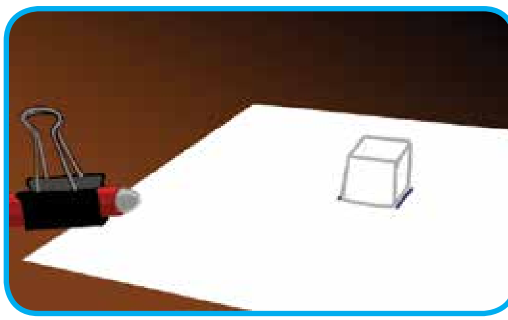

Fig. 1

Collecting Data

1. Turn off the room’s lights. Look at the gel cube. What do you see?

2. You want to trace the beam of the laser both before and after it passes through the gel cube. The easiest way to do this is to put the permanent marker in the way of the beam and make a dot on the paper. Do this in three or four spots on each side of the gel cube. The laser beam is going to be kind of

fuzzy after it passes through the cube so make sure you are putting the marker right in the middle of the beam when you are making marks.

3. Turn the lights on.

4. Use a ruler to connect the points and draw the laser beam both before and after it passed through the cube.

5. When the lights were off, you could see the laser beam traveling through the cube, but there was no way to trace it out while it was actually going on. But because light travels in straight lines unless it hits something, you can figure out the path the light traveled when it was in the block. Connect the point where the beam entered the block to the point where the beam left the block. There ya go! (Fig. 2)

6. Repeat all of these steps for the sugar water cubes and the sucralose water cubes, but instead of putting them on paper, put them each on a transparency.

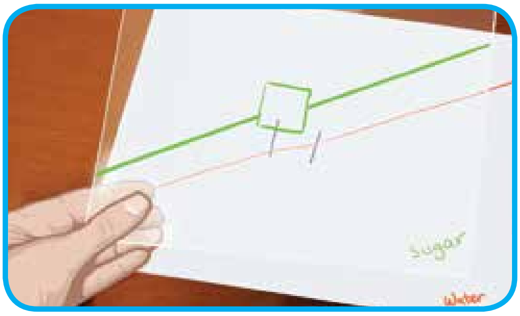

Fig. 2

Analyzing Your Results

1. What can you say happens to light when it goes from the air to the cube?

____

____

2. What happens when it goes from the cube back to the air?

____

____

3. When you looked at the cubes in the water, you couldn't see them when they were in the water they were grown in, but you could see them when you moved them from one cup to another. Why do you think that is?

____

____

4. Put the transparency labeled "sugar water" on top of transparency labeled "sucralose water" and then put those two on top of the paper labeled "water."

5. Line of the stack of transparencies and paper so that all "cubes" are on top of each other. The lines representing the incoming laser beams should also be lined up on top of each other. Draw what it looks like:

6. What do you notice about the lines coming out of the blocks? Are they lined up as well? If not, how are they different?

____

____

____

7. What path would the laser beam follow if there was no cube at all? Draw that on the white piece of paper in a different color.

8. Which cube caused the light to bend the most? ____________________________

____

____

9. "Index of Refraction" is a property of transparent materials that tells how much light bends when it passes through that material. The more light bends, the higher the index of refraction. Rank *water*, *sugar water*, and *sucralose water* from highest index of refraction to lowest index of refraction.

Highest ______________________________

____

Lowest ______________________________

Using your results to help Spectra find the time of Miss Alignment's attack.

What has the highest index of refraction?

1. Water
2. Sugar water
3. Sucralose water
4. Sucralose water and sugar water have the same index of refraction.

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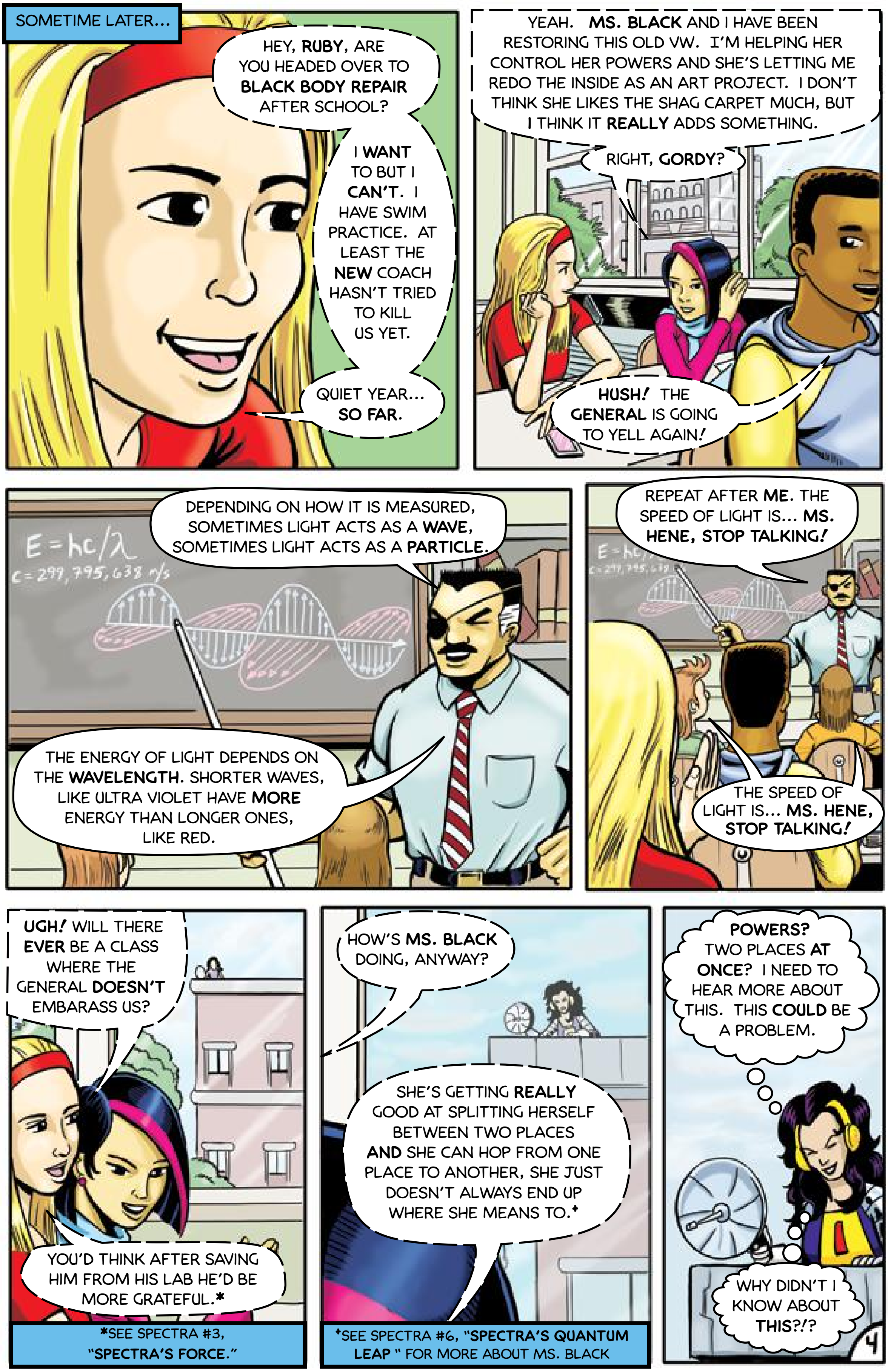

SOMETIME LATER...
HEY, RUBY, ARE YOU HEADED OVER TO BLACK BODY REPAIR AFTER SCHOOL?
I WANT TO BUT I CAN'T. I HAVE SWIM PRACTICE. AT LEAST THE NEW COACH HASN'T TRIED TO KILL US YET.
QUIET YEAR... SO FAR.
YEAH. MS. BLACK AND I HAVE BEEN RESTORING THIS OLD VW. I'M HELPING HER CONTROL HER POWERS AND SHE'S LETTING ME REDO THE INSIDE AS AN ART PROJECT. I DON'T THINK SHE LIKES THE SHAG CARPET MUCH, BUT I THINK IT REALLY ADDS SOMETHING.
RIGHT, GORDY?
HUSH! THE GENERAL IS GOING TO YELL AGAIN!
E=hc/λ
c=299,795,638 m/s
DEPENDING ON HOW IT IS MEASURED, SOMETIMES LIGHT ACTS AS A WAVE, SOMETIMES LIGHT ACTS AS A PARTICLE.
THE ENERGY OF LIGHT DEPENDS ON THE WAVELENGTH. SHORTER WAVES, LIKE ULTRA VIOLET HAVE MORE ENERGY THAN LONGER ONES, LIKE RED.
REPEAT AFTER ME. THE SPEED OF LIGHT IS... MS. HENE, STOP TALKING!
THE SPEED OF LIGHT IS... MS. HENE, STOP TALKING!
UGH! WILL THERE EVER BE A CLASS WHERE THE GENERAL DOESN'T EMBARASS US?
YOU'D THINK AFTER SAVING HIM FROM HIS LAB HE'D BE MORE GRATEFUL.*
*SEE SPECTRA #3, "SPECTRA'S FORCE."
HOW'S MS. BLACK DOING, ANYWAY?
SHE'S GETTING REALLY GOOD AT SPLITTING HERSELF BETWEEN TWO PLACES AND SHE CAN HOP FROM ONE PLACE TO ANOTHER, SHE JUST DOESN'T ALWAYS END UP WHERE SHE MEANS TO.+
+SEE SPECTRA #6, "SPECTRA'S QUANTUM LEAP" FOR MORE ABOUT MS. BLACK
POWERS? TWO PLACES AT ONCE? I NEED TO HEAR MORE ABOUT THIS. THIS COULD BE A PROBLEM.
WHY DIDN'T I KNOW ABOUT THIS?!?
4


REIGH DIDN'T TELL ME ANYTHING!
I ONLY PUT UP WITH HIM BECAUSE HE'S FAMILY. THAT NO GOOD, LAZY...
RIIIIIIIIIIING!!
AARGHH!
WHERE ARE YOU GUYS HEADED? I HAVE PRACTICE LATER. I'M HOPING TO MAKE STARTING QUARTERBACK THIS SEASON.
I'M OFF TO PRACTICE, TOO, AND RUBY'S HEADED TO THE GARAGE. MEET FOR PIZZA LATER?
SOUNDS GOOD!
NICE SHIRT, KAS! RUBY'S HEADED OVER TO THE GARAGE, WANNA GO WITH? I'M HEADED TO SWIM PRACTICE.
CAN'T. BAND PRACTICE. WE HAVE A GIG THIS WEEKEND. YOU'RE COMING, RIGHT LUCY?
MEET FOR PIZZA LATER?
YEP!
HEY, LUCY! I REALLY LIKE YOUR HAIR LIKE THAT!
DARN REIGH AND HIS FAULTY EQUIPMENT! NOW I'LL NEED ANOTHER WAY TO LISTEN TO THEM AT THE GARAGE.
I HAD NO IDEA THIS TOWN HAD SO MANY PEOPLE WITH SCIENCE POWERS. I HAVE TO FIND OUT MORE. I CAN'T LOSE AGAIN!
KRAK!

TEACHER'S GUIDE
Activity 2: Magnifying Marbles

Intro

When learning about lenses students usually get a standard magnifying glass or concave, diverging lens. They may hear these referred to as "spherical lenses" even though they look anything but spherical. The mostly look like bulging pancakes. This experiment will use 3 different sizes of clear spheres to show kids where the term "spherical lens" comes from and to show them the relationship between the radius of the sphere and the magnification.

Key Question

How does the radius of a sphere affect how much it will magnify an image?

Key Terms

Optical Axis: An imaginary line that goes through the center of the lens and the center of the face of the lens. In Figure 1, the optical axis is the horizontal line.

Focal Point: If light rays hit a lens going parallel to the optical axis, they are bent through the focal point.

Focal Length: Distance from the center of the lens to the focal point.

Converging Lens: A lens that causes light rays to come together is a converging lens.

Diverging Lens: A lens that causes light rays to spread out is a diverging lens.

Convex: Something that curves outward is said to be convex.

Concave: If something curves inward it is concave.

Note to Teachers: *This activity needs to be set up beforehand. It can take up to 24 hours for the gel spheres to grow. Be sure to check on them as they are growing. They aren't going to grow like you think they might.*

Materials

3 sizes of water gel spheres
Binder clips
Transparency
Flashlight
*Water
*Stiff paper
*White piece of paper
*Dark room

**Not included in the PhysicsQuest kit*

Setup (to be done the day before the activity is performed in class):

1. Fill a large cup with water.

2. Put several spheres of each size in the water and let them grow overnight.

Before the Activity Students should know...

- Convex lenses magnify images.
- How much a lens magnifies an image depends on the shape of the lens.

After the Activity Students should be able to...

- Define magnification.
- Discuss how radius of a spherical lens, focal length, and magnification are related.

The Science behind Magnification

Usually when we teach or learn about lenses, there isn't much talk about the shape of the lens. If you've done a lot of lens experiments you notice that the ones that bulge out more usually magnify images more than flatter lenses. There are almost no experiments that deal with this or even talk at all about how shape, magnification, and focal length are related.

Almost all lenses you deal with are **spherical lenses**. Sometimes people will talk about the **radius of curvature** of the lens. It may seem strange to call them spherical when they look closer to flat. A **converging** spherical lens, which is **convex**, can be thought of as a being made by taking a sphere and cutting off the ends and then sandwiching them together (Fig.1). The radius of curvature is the radius of the sphere from which the ends used for the lens were cut. For a **diverging**, **concave**, lens, the radius of curvature is the radius of the sphere that would fit in the "cave."

Every spherical lens has a **focal point**. This is the point where rays are focused if they hit the lens parallel to the **optical axis**. If you are trying to find the focal point of a lens you can hold it over a desk or piece of paper and try and focus the sun's rays or the overhead lights to a point. Because those light rays are hitting the lens roughly parallel, the focused spot is the focal point. In the final experiment of PhysicsQuest you will focus the sun's light to a point. You are focusing it at the focal point of the Fresnel lens. If you would like, have your students find the focal point of the gel spheres using this method. The distance from the center of the lens to the focal point is called the **focal length**.

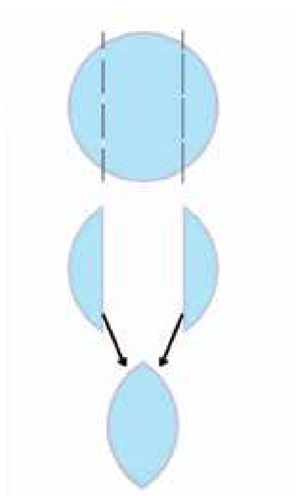


Fig. 1

The focal length of a lens is determined by two different things. First, the index of refraction of the lens material affects

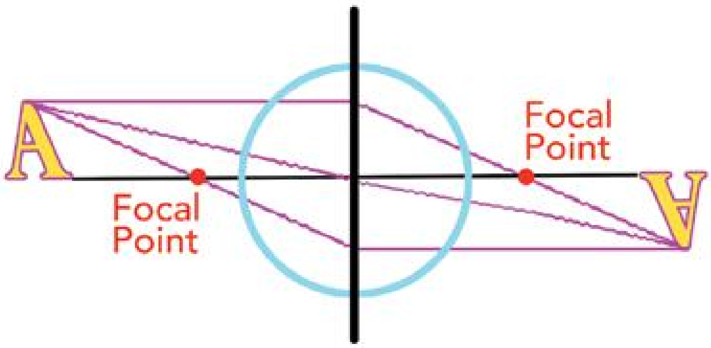


Fig. 2

the focal length. If you've had a chance to do the "Bendy Light" experiment you have an idea why. Though that aspect is not dealt with in this activity, you can have your students discuss how index of refraction affects focal length as an extension of this activity. If you have extra gel spheres you could grow them in sugar water or sucralose water and see how that affects the focal length. The second thing that affects the focal length is the radius of curvature of the lens. The radius of curvature and the focal length of the lens are directly proportional, meaning that as the radius of curvature is increased the focal length also increases. Larger spheres focus farther distances and smaller spheres focus closer to the lens.

In this experiment your students are going to see how the radius of curvature can affect a different, but related, property of lenses, magnification. Magnification is a numerical way to describe how much bigger an image is than the object that it is magnifying. If a particular image is magnified 10 times, it means the image is 10 times bigger than object. If you measured the object height and multiplied times 10 you would get the image height. Or, if you measure the image height and divided by 10 you should get the object height. But most importantly, if you divide the image height by the object height you should get 10. You can find how much a lens is magnifying by dividing the image height by the object height. What's really cool about lenses is that object distance and image distance have the same ratio as object height and image height. We're going to find the magnification of the sphere in both of these ways.

Magnification is proportional to 1/(radius of curvature)and 1/(focal length). We call this "inversely proportional." When the radius of curvature gets smaller, the lens can magnify more. This activity is really, really cool because when the gel spheres are used, the students can actually measure the radius of curvature. This is something that's pretty impossible to do with a normal magnifying glass. Sure, its possible to talk about how much it magnifies and what the focal length is, but there is no easy way for students to relate this numerically to the shape of the lens. Because magnification is proportional to 1/(radius of curvature) the graph your students make will look a little strange. It's not going to be a straight line. What might be even more frustrating is that there will only be three points on the graph so its hard to see what type of shape it really is. The goal is to understand that as radius decreases, magnification increases and it doesn't do that in a straight line type of way. Hopefully that is clear from the graphs they make. There are many ways to extend this experiment. You could look at the focal length and how that compares to radius of curvature or you could look at how focal length compares to magnification or other ideas that your class may come up with.

Safety

For water gel crystal safety see attached MSDS sheet on page 8.

Suggested Resources

http://physics.info/lenses/

http://www.exploratorium.edu/snacks/giant_lens/

https://phet.colorado.edu/sims/geometric-optics/geometric-optics_en.html

Intro

You have probably played with magnifying glasses before. Did you know they were called "spherical" lenses? This is kind of an odd name since they usually look like bulging pancakes. In this experiment you will not only get to make a desktop version of Miss Alignment's evil projector, you will get to learn about spheres and how they magnify and image.

Key Question

How does the radius of a sphere affect how much it will magnify an image?

Getting Started

NOTE: *Your teacher should have set this activity up beforehand. He or she should provide you with a cup full of gel spheres.*

1. What happens when you look through a magnifying glass at a tiny bug or small writing?
2. What do you have to do to see the small writing or bug clearly?
3. Take one of the gel spheres and look at something in the room. How does it look? Is it right side up or up-side down?
4. Pick up a gel sphere of a different size and look around the room. What's the same? What's different?

Materials

3 sizes of water gel spheres
Binder clips
Transparency
Flashlight
*Water
*Stiff paper
*Permanent marker
*White piece of paper
*Dark room

**Not included in the PhysicsQuest kit*

Setting up the Experiment

You will be setting up a small version Miss Alignment's projection system from the comic book page 16.

1. Cut a small piece of transparency and use the permanent marker to draw an "A" on it. Make one leg of the "A" longer than the other.
2. Take a tiny piece of stiff paper and roll it into a small cylinder that has a radius a bit smaller than the radius of the biggest gel sphere.
3. Turn on the flashlight and put it in a binder clip.
4. Put the white piece of paper in a binder clip to use as a screen.
5. Place the rolled up paper cylinder

on the table and balance the largest gel sphere on top.

6. Place the flashlight so it shines on the sphere.
7. Put the transparency "A" in the small binder clip and place between the flashlight and the gel sphere.
8. Put the screen on the other side of the sphere. The "A" should now be projected on the screen. (Fig. 1)

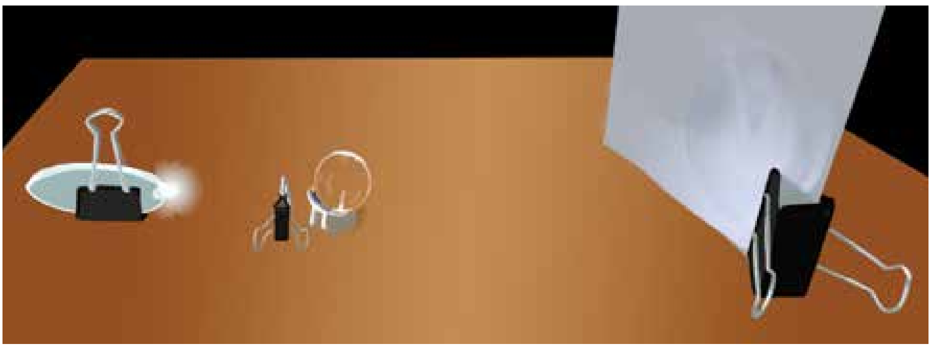


Fig. 1

Collecting Data

1. Turn off the room lights.

2. If you've set up the experiment correctly, you should see a giant "A" projected on your screen.

3. Move the screen back and forth until the "A" on the screen, which we're going to call the image, is in focus. What does the image look like? Is it right side up or upside down? Is it flipped left to right or not? Draw it here:

4. Move the transparency "A," which we're going to call the object. What happened to the image? Can you get it in focus again? What did you have to do?

5. Measure the height of the object.

6. Put the object close to the sphere and focus the image on the screen.

7. Measure the distance from the object to the center of the sphere

8. Measure the distance from screen with the focused image to the center of the sphere.

9. Change the distance between the object and the sphere and take the same measurements. Do this for one more object distance.

10. Record your answers in the chart below.

11. Leave the last two columns of the chart blank for now, you'll fill them in in the next section.

12. Repeat all of this for the other two marbles using the same distances from the center of the marble. You may have to make new paper stands for the different sized spheres.

Height of "A"___________________________ (This is your "object size")

Marble 1: Radius _______________________

Object Distance	Image Distance	Image Height	Image Height/Object Height	Image Distance/Object Distance

Marble 2: Radius _______________________

Object Distance	Image Distance	Image Height	Image Height/Object Height	Image Distance/Object Distance

Marble 3: Radius ______________________

Object Distance	Image Distance	Image Height	Image Height/Object Height	Image Distance/Object Distance

Analyzing Your Results

The image on the screen is much bigger than the object. Its magnified. But is there a way to use the numbers you have to see how much it is magnified?

If a particular image is magnified 10 times, it means the image is 10 times bigger than object. If you measured the object height and multiplied times 10 you would get the image height. Or, if you measure the image height and divided by 10 you should get the object height. But most importantly, if you divide the image height by the object height you should get 10.

You can find how much a lens is magnifying by dividing the image height by the object height. What's really cool about lenses is that object distance and image distance have the same ratio as object height and image height. We're going to find the magnification of the sphere in both of these ways.

1. In the charts you just filled in, there are two columns for your calculations of magnification, one using distances and one using heights.

Object Distance 1

Sphere Radius	Magnification

Object Distance 2

Sphere Radius	Magnification

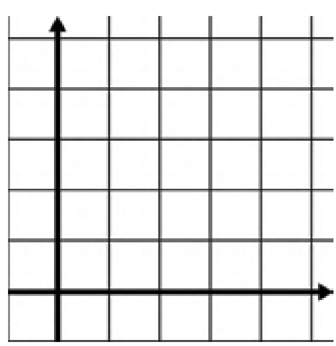
Object Distance 3

Sphere Radius	Magnification

2. What is the magnification for each object distance? Is the magnification the same for any object distance?

3. Does the radius of the sphere change how much it magnifies an object? How? Is it the same for any object distance?

4. To get a better idea of how magnification changes as the radius of the sphere changes, make a graph with radius on the x axis and magnification on the y axis. You will have to decide on your own what scale you should put on your x and y axes. Do this for all three object distances on the same graph.



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5. Do the graphs look similar for each object distance or do they look different?____

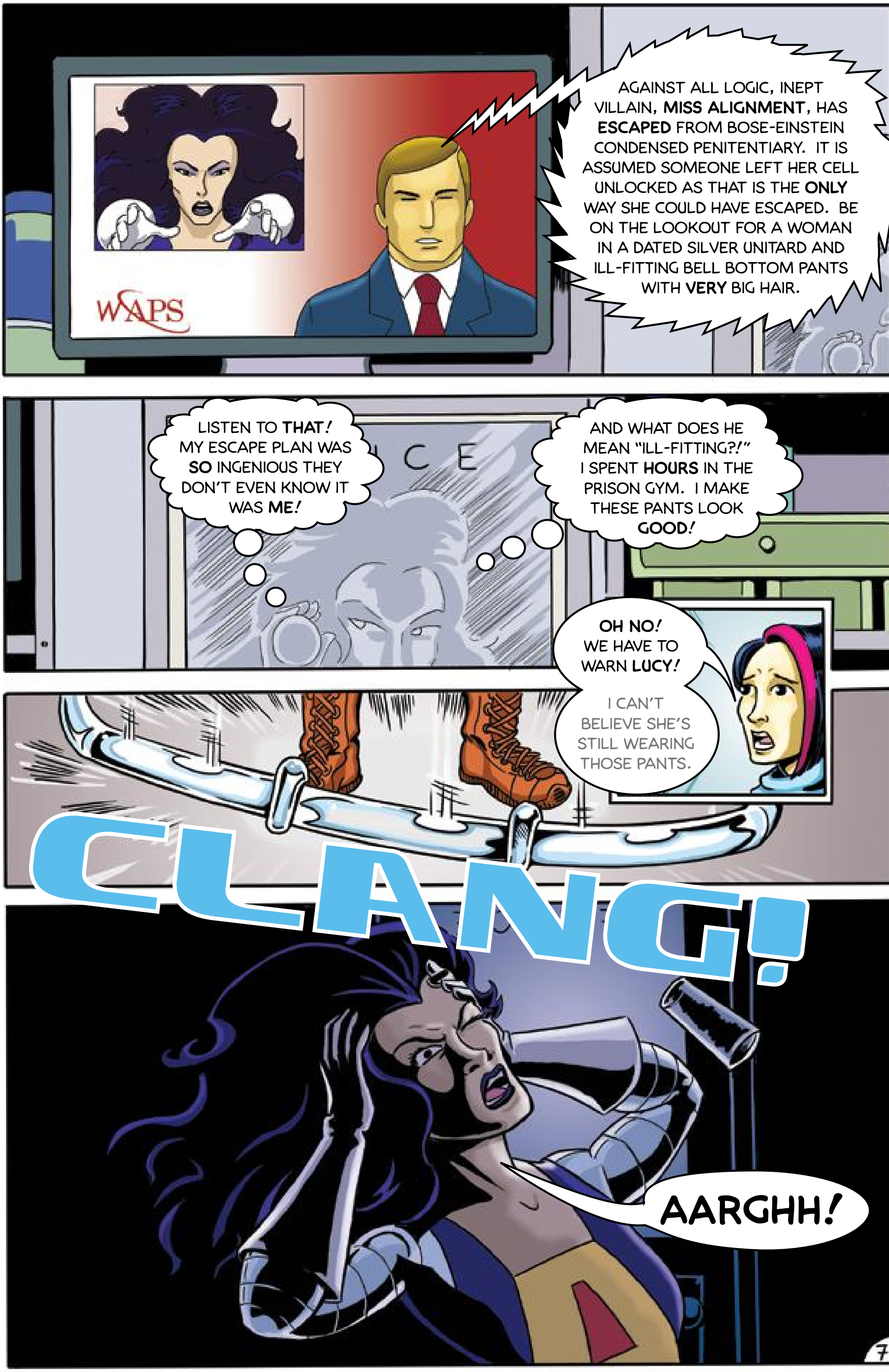
6. How do you think a marble the size of a pea would magnify an object? What about a bowling ball? ____

7. For Miss Alignment to project her giant "A" in the sky, would her marble lens have to be really big or really small? ____________________________________

Using your results to help Spectra find the time of Miss Alignment's attack.

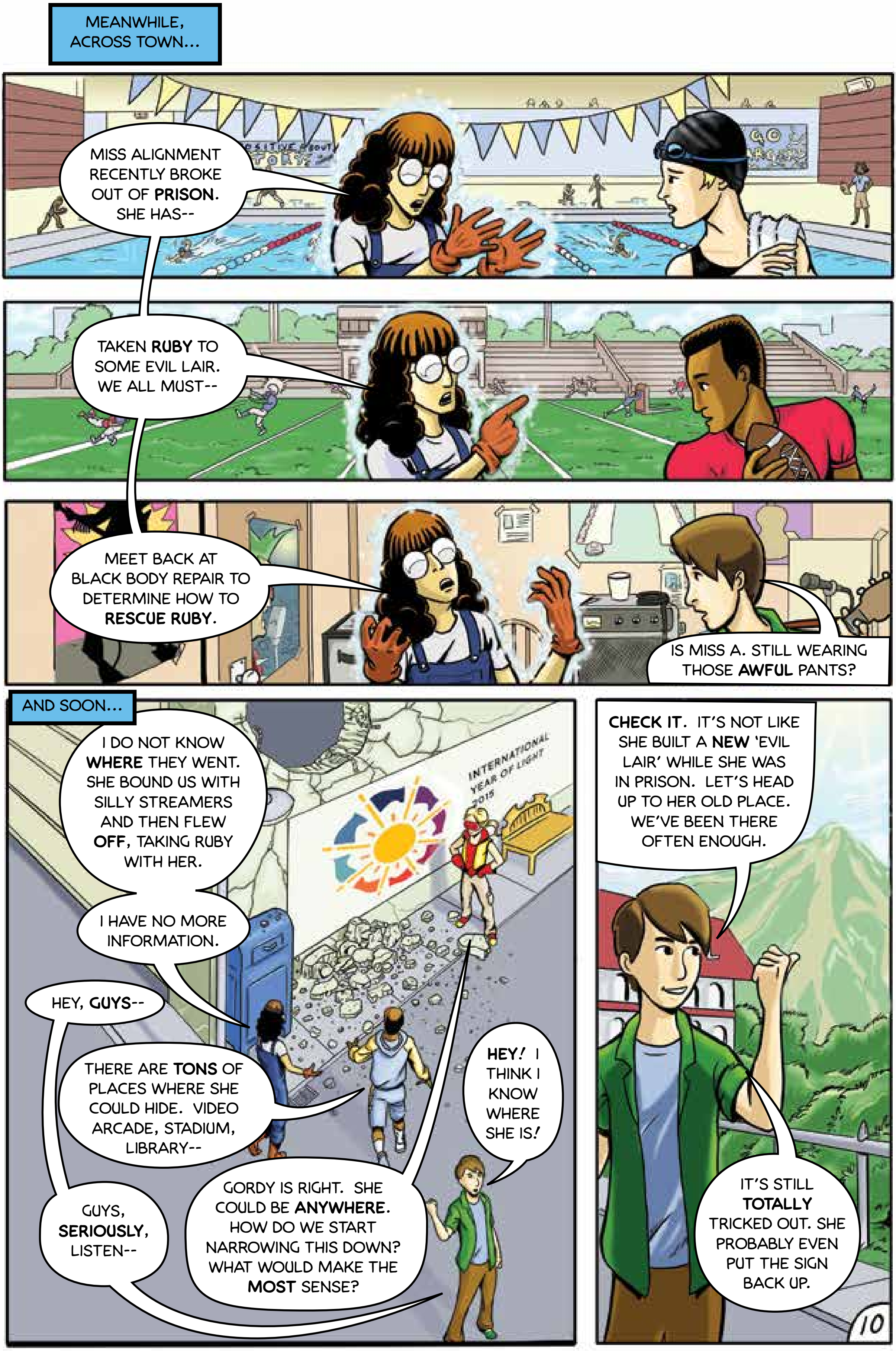
1. As the radius increases, the magnification increases
2. As the radius increases, the magnification doesn't change
3. As the radius decreases, the magnification decreases
4. As the radius increases, the magnification decreases


SHORTLY, AT BLACK BODY REPAIR...
I KNOW YOU AREN'T A HUGE FAN OF THE PURPLE CARPET WITH THE YELLOW CAR, BUT THIS COMBO WAS ALL OVER NEW YORK FASHION WEEK.
I AM HAPPY THAT YOU ARE HAPPY WITH IT.
WOW! YOU ARE GETTING REALLY GOOD AT BEING IN TWO PLACES AT ONCE.
WHY THANK YOU, RUBY. I HAVE BEEN PRACTICING A BIT. THOUGH I DO VERY MUCH WISH I COULD CONTROL IN WHICH PLACES I AM.
I AM STILL HAVING QUITE A BIT OF TROUBLE REMAINING IN THE LOCATIONS I DESIRE. I FEEL UNFOCUSED.
HOWEVER, I HAVE BEEN CONTROLLING MY MOMENTUM MUCH BETTER. I AM GOOD AT KNOWING HOW FAST I AM BUT NOT WHERE I AM.
I MUST NOW ENDEAVOR TO KNOW WHERE I AM BUT NOT HOW FAST I AM GOING. THERE SEEMS TO BE A DELICATE BALANCE BETWEEN THE TWO.
SOUNDS COMPLICATED. WHERE'S THE RED PAINT, SILVER GLITTER, AND SUPER GLUE?
WAPS
WE INTERRUPT THIS BROADCAST WITH A SPECIAL ALERT...
OFFICE
6


AGAINST ALL LOGIC, INEPT VILLAIN, MISS ALIGNMENT, HAS ESCAPED FROM BOSE-EINSTEIN CONDENSED PENITENTIARY. IT IS ASSUMED SOMEONE LEFT HER CELL UNLOCKED AS THAT IS THE ONLY WAY SHE COULD HAVE ESCAPED. BE ON THE LOOKOUT FOR A WOMAN IN A DATED SILVER UNITARD AND ILL-FITTING BELL BOTTOM PANTS WITH VERY BIG HAIR.
WAPS
LISTEN TO THAT! MY ESCAPE PLAN WAS SO INGENIOUS THEY DON'T EVEN KNOW IT WAS ME!
AND WHAT DOES HE MEAN "ILL-FITTING?!" I SPENT HOURS IN THE PRISON GYM. I MAKE THESE PANTS LOOK GOOD!
OH NO! WE HAVE TO WARN LUCY!
I CAN'T BELIEVE SHE'S STILL WEARING THOSE PANTS.
CLANG!
AARGHH!
7


I'LL TEXT THE GANG TO MEET US HERE AND FIGURE OUT WHAT TO DO.
I SHALL TRY TO PULL MYSELF TOGETHER AND BE READY FOR THEIR ARRIVAL.
SLAM!
STOP! PUT DOWN THAT PHONE!!!
THIS IS A NO TEXTING ZONE!
YOU AREN'T GOING ANYWHERE! I HAVE YOU TRAPPED!
FWIP
FWIP
FWIP
IT APPEARS THAT YOU HAVE TRIED TO INCAPACITATE US WITH SILLY STREAMERS.
I DO NOT BELIEVE THIS IS STRUCTURALLY SOUND ENOUGH TO HOLD US.
THEY ARE PRETTY COLORS, THOUGH.
8


IT DOESN'T MATTER HOW SILLY THE STREAMERS ARE, IT'S SLOWED YOU DOWN JUST ENOUGH.
YOU'RE COMING WITH ME.
ASSUMING REIGH INSTALLED MY BOOSTER ROCKETS CORRECTLY.
MISS BLACK, DO YOU THINK YOU CAN BE IN THREE PLACES AT ONCE? YOU NEED TO TELL LUCY, GORDY, AND KAS TO COME TO THE GARAGE.
LUCY'S AT THE POOL, GORDY IS ON THE FIELD, AND KAS IS WITH HIS BAND.
YES, RUBY, I THINK I HAVE THE ABILITY TO DO THAT IF I FOCUS VERY HARD. I SHALL TELL THEM NOW.
HURRY!!!
FZZZP
WHERE... WHERE DID SHE GO? IS THIS THE "SUPERPOWER" YOU WERE TALKING ABOUT? TELL ME!
LOOKS LIKE ONE OF US GOT AWAY.
NOW I KNOW WHY YOU WEAR THOSE BELL BOTTOMS --
TO HIDE YOUR BOOSTER ROCKETS.
GO AHEAD...
"MAKE FUN ALL YOU WANT. THESE BOOSTER ROCKETS ARE TAKING YOU WITH ME."
ZOOOM
KRBOOM
HOTEL
AHHH! WHAT WAS THAT?!
WOOF
WOOF
WOOF
"I'LL FIND SOME WAY TO GET INFORMATION OUT OF YOU!"
9



MEANWHILE, ACROSS TOWN...
MISS ALIGNMENT RECENTLY BROKE OUT OF **PRISON**. SHE HAS--
TAKEN **RUBY** TO SOME EVIL LAIR. WE ALL MUST--
MEET BACK AT BLACK BODY REPAIR TO DETERMINE HOW TO **RESCUE RUBY**.
IS MISS A. STILL WEARING THOSE **AWFUL** PANTS?
AND SOON...
INTERNATIONAL YEAR OF LIGHT 2015
I DO NOT KNOW **WHERE** THEY WENT. SHE BOUND US WITH SILLY STREAMERS AND THEN FLEW **OFF**, TAKING RUBY WITH HER.
I HAVE NO MORE INFORMATION.
HEY, **GUYS**--
THERE ARE **TONS** OF PLACES WHERE SHE COULD HIDE. VIDEO ARCADE, STADIUM, LIBRARY--
HEY! I THINK I KNOW WHERE SHE IS!
GUYS, **SERIOUSLY**, LISTEN--
GORDY IS RIGHT. SHE COULD BE **ANYWHERE**. HOW DO WE START NARROWING THIS DOWN? WHAT WOULD MAKE THE **MOST** SENSE?
CHECK IT. IT'S NOT LIKE SHE BUILT A **NEW** 'EVIL LAIR' WHILE SHE WAS IN PRISON. LET'S HEAD UP TO HER OLD PLACE. WE'VE BEEN THERE OFTEN ENOUGH.
IT'S STILL **TOTALLY** TRICKED OUT. SHE PROBABLY EVEN PUT THE SIGN BACK UP.

TEACHER'S GUIDE
Activity 3: Let it Glow! Let it Glow!

Intro

Energy comes in many forms; energy of motion, energy of position, thermal energy, sound energy and many more. Light is also a form of energy. Its easy to say that something that is hotter or is moving faster has more energy, but what does it mean for light to have more energy? Most people assume that brighter light has more energy than dimmer light. But that's only part of the story. In this experiment you and your students will learn how color affects light's energy.

Key Question
What colors of light cause a glow in the dark square to glow?

Key Terms
Wavelength: The distance from one wave peak to the next.

Intensity: The strength of something. Brighter light has a higher intensity.

Transparent: Most light is transmitted, a little bit is reflected

Energy: Energy is the ability to do work. Energy can come in different forms such as light energy, heat energy, energy of motion or chemical energy. Energy cannot be created or destroyed but it can change from one form to another.

Photon: A packet of light energy. Different colors of light have different amounts of energy in their "packets."

Before the Activity Students should know...

- A rainbow is made of Red, Orange, Yellow, Green, Blue, Indigo and Violet.
- Different colors of light have different wavelengths.
- Energy is never created or destroyed.

Materials

Phosphorescent vinyl
Red, blue, orange & purple gel filters
+ Laser pointer
* White light
* Dark room

** Not included in the PhysicsQuest kit*

+ Make sure you unscrew the cap of the laser and remove the piece of paper between the laser batteries. This may involved removing all the batteries. Take care to put them back in the laser in the correct direction.

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After the Activity Students should be able to...

- Describe why the glow in the dark square will only glow when it is hit with certain colors of light.
- Explain how color of light is related to its energy.
- Say why the rainbow is in the order it is.

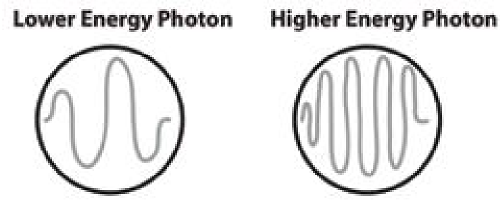
The Science behind Glowing in the Dark

This experiment is essentially a table top, easy to do version of one of the most famous physics experiments of all time, the photoelectric effect. Light is a very interesting entity. You may have heard it said that it is both a particle and a wave. It may be better to phrase this as "light has both wave and particle properties." It was the photoelectric effect that led scientists to develop the idea that light had particle properties. Probably the best way to think about this mind bending notion is to picture photons as little packets of waves. Different colors of photons have different wavelengths. Blue and purple photons have shorter wavelengths than red or yellow light. The shorter the wavelength, the more energy the wave has. This is why we get sunburned by ultraviolet rays and not infrared rays. Because the ultraviolet rays have high energy they can burn our skin.

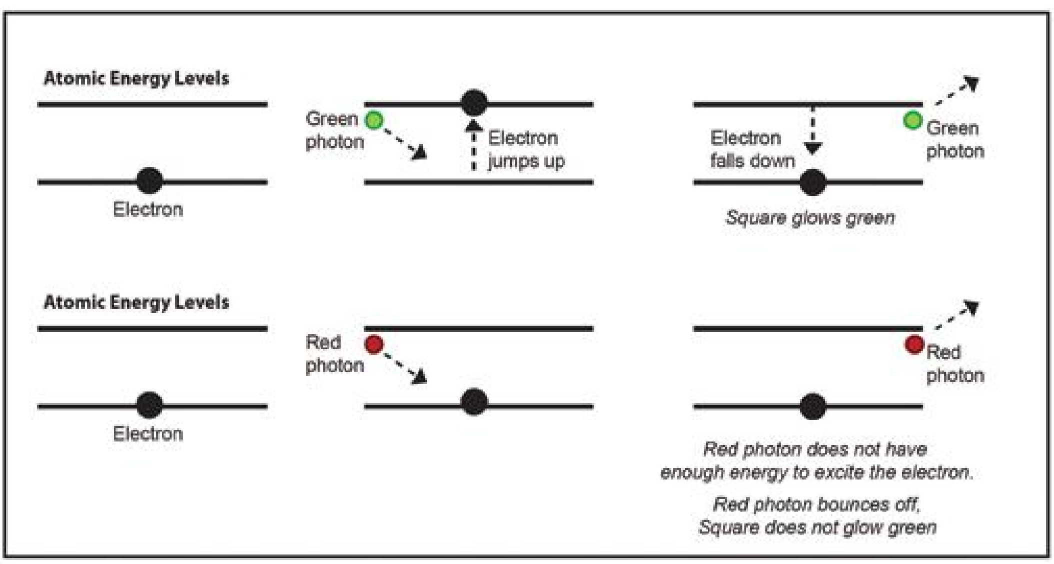
The glow in the dark material is made up of special molecules called phosphors. Electrons sit in different energy levels. To move to a higher energy level they need energy from photons. When photons from a light source hit the molecules they excite the electrons and make them jump up to a higher energy level. Once they are up there they don't stay there forever. When they fall back down to a lower energy level, something has to happen to the energy they are losing because we know that energy can't be created or destroyed. The energy the electrons lose pops out as photons. The energy of a photon is based on its wavelength. If you think of the colors of the rainbow, red has the least energy and violet has the most energy. Energy increases as you go from red to violet. This is why the rainbow is in the order it is in, it goes in order of energy. Electrons have specific energy levels at which they like to sit. They can't just have any old amount of energy, they must sit at specific energy levels. To get an electron to jump from one energy level to a higher level it must be hit by a photon with a high enough energy. So if the difference in energy from one level to the next is the energy a blue photon carries, if the electron is hit by a red photon, it won't jump up to a higher energy level. It will just sit right where it is and the red photon will simply continue on its way. But if that same electron is hit by a blue, or even violet photon it will jump up and then eventually fall down and emit a photon as it falls down. One really cool thing to realize is that this electron which needs a blue photon to jump up could be hit by hundreds, millions, or even quadrillions of red photons and it still won't budge. It must have the energy of a blue photon or higher.

In this experiment students will allow

only certain colors of light to be used to "charge up" their phosphorescent squares. Because the squares glow green you know that the difference in energy level for the electrons must be the energy in a green photon because as the electrons fall down, they are emitting green photons. The students will be using violet, blue, red and yellow light to charge up their squares. Blue and violet photons have enough energy to make the electrons jump up, red and yellow do not. When the students are asked to predict which colors will make the square glow they will almost inevitably say the yellow light will make the square glow the brightest and be shocked when the yellow doesn't glow at all. They predict this because the yellow gel filter is very light and lets the most amount of light through. But as we said before, it doesn't matter how many photons are hitting an electron if the photons themselves are not of a high enough energy.



In the last part students charge up the square with white light and then "write" on it with a red laser. This is an interesting phenomenon because red light, which is less energetic than green light, should be able to be transformed into green light. In this case, the square already has enough energy to glow green, the red laser is just making it glow brighter by adding a bit more energy. It doesn't need all of the energy of green light to glow, it just needs a little extra kick. So it may seem like red light



is being turned into green light, but it is not.

You (and your students) might be asking "is it possible to have a wave with more energy than a violet wave or less energy than a red one?" Visible light is just the tip of the iceberg. In fact, microwaves are just like light waves, only they have much much less energy than red light with a wavelength of a few centimeters and x-rays have much more energy than violet light.

SAFETY

Review these guidelines closely with students before the activity and outline consequences for failure to follow them! Warn students very strongly about the dangers of looking directly into the laser beam. Shining the beam into their eyes of the eyes of their classmates can cause serious injury and damage. Consequences for student recklessly playing with the lasers should be outlined before giving out the supplies for the activity. If you are concerned, you may prefer to complete the portions of the procedure with the laser for your students and have them do the analysis.

Bibliography / Suggested Resources

http://van.physics.illinois.edu/qa/listing.php?id=1864
http://eosweb.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html
http://www2.slac.stanford.edu/vvc/theory/photoelectric.html

Intro

Have you ever wondered why your favorite glow in the dark tshirt glows? Have you ever wondered why you have to “charge it up” before you can impress your friends with its stunning glow? Have you ever wondered what would happen to it if you stood in red light instead of white light? Well this experiment will answer all those questions and more.

Key Question

What colors of light will cause glow in the dark material to glow?

Getting Started

To get a glow in the dark material to glow, what do you have to do to it first?

Will just any material glow, or does it have to be special?

Why is a rainbow in the order it is?

Materials

Phosphorescent vinyl
Red, blue, orange and purple gel filters
Laser pointer
* White light
* Dark room

**Not included in the PhysicsQuest kit*

Setting up the Experiment

NOTE: *Make sure you unscrew the cap of the laser and remove the piece of paper between the laser batteries. This may involve removing all the batteries. Take care to put them back in the laser in the correct direction.*

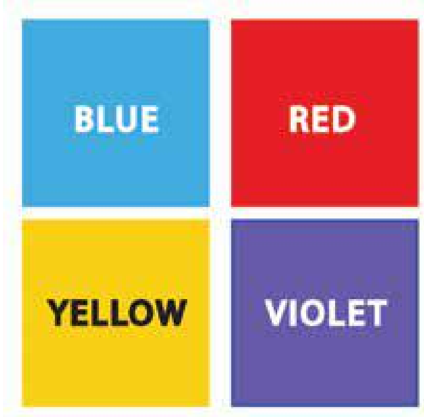
1. Hold the vinyl square up to a white light.

2. Turn off the lights and look at the square. What is happening? What color is it glowing?

3. Wait for the vinyl to stop glowing. Place one color of gel filter on each corner of the vinyl and again hold it up to the white light for several minutes.

While you are waiting, draw a picture in the box below indicating which color is on which part of the vinyl. Which color gel filter do you think will allow the square to glow? Why? Take the gel filters off and take it into a dark room. On your drawing indicate which sections of the square are glowing.

4. Again charge up the square in white light, this time, with no gel filters, and take the square and a laser pointer into a dark room. “Write” on the square with the laser pointer, what happens? Thinking back to the experiment with the gel filters, is red light more or less energetic than green light? How is it possible to make the square glow brighter green by applying red light?



Analyzing Your Results

1. When you charged up the square and then put it in a dark room, why is it glowing?

2. When you put the gel filters over the square you only allowed light of certain colors to get through and charge up the square.

Which colors charged up the square and made it glow?

Write down the colors of the rainbow in order. Circle the colors that allowed the square to glow and x out the colors that did not.

Do you see a pattern? ____

On which side of green are the non-glowing colors? ___________________

On which side are the glowing colors? ____________________________

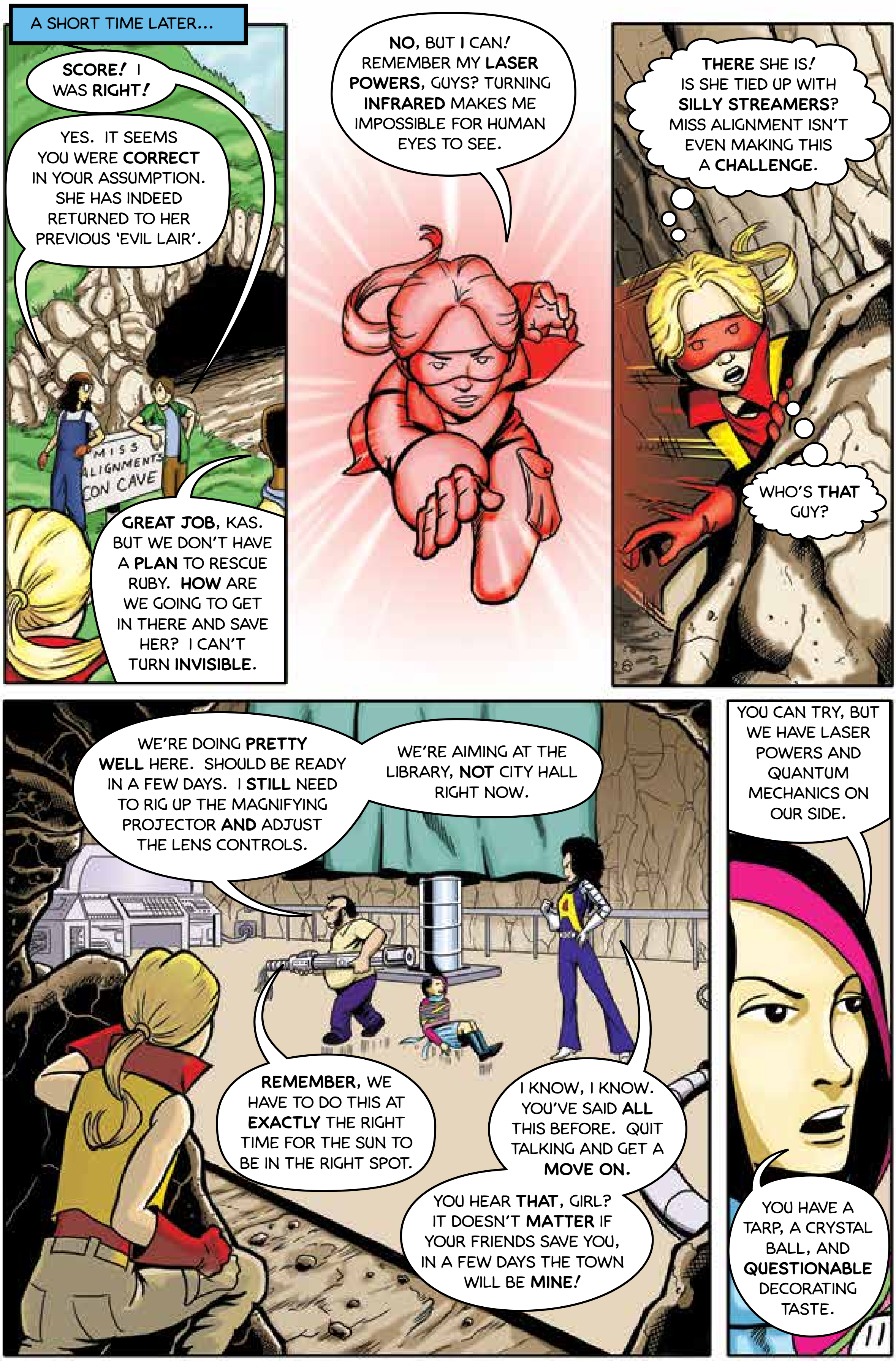
In a rainbow, violet light has the most energy and red light has the least. What can you say about the energy of light that is needed to charge up the square? Does it have to be more or less than green? _______________________
____
____
____

3. Thinking back to the experiment with the gel filters, is red light more or less energetic than green light? How is it possible to make the square glow green by applying red light? ____
____
____

Using your results to help Spectra find the time of Miss Alignment's attack.

Which color gel filters allowed the vinyl to glow?

1. Blue and Purple
2. Red and Yellow
3. Red and Blue
4. Purple and Yellow



A SHORT TIME LATER...
SCORE! I WAS RIGHT!
YES. IT SEEMS YOU WERE CORRECT IN YOUR ASSUMPTION. SHE HAS INDEED RETURNED TO HER PREVIOUS 'EVIL LAIR'.
MISS ALIGNMENT'S CON CAVE
GREAT JOB, KAS. BUT WE DON'T HAVE A PLAN TO RESCUE RUBY. HOW ARE WE GOING TO GET IN THERE AND SAVE HER? I CAN'T TURN INVISIBLE.
NO, BUT I CAN! REMEMBER MY LASER POWERS, GUYS? TURNING INFRARED MAKES ME IMPOSSIBLE FOR HUMAN EYES TO SEE.
THERE SHE IS! IS SHE TIED UP WITH SILLY STREAMERS? MISS ALIGNMENT ISN'T EVEN MAKING THIS A CHALLENGE.
WHO'S THAT GUY?
WE'RE DOING PRETTY WELL HERE. SHOULD BE READY IN A FEW DAYS. I STILL NEED TO RIG UP THE MAGNIFYING PROJECTOR AND ADJUST THE LENS CONTROLS.
WE'RE AIMING AT THE LIBRARY, NOT CITY HALL RIGHT NOW.
REMEMBER, WE HAVE TO DO THIS AT EXACTLY THE RIGHT TIME FOR THE SUN TO BE IN THE RIGHT SPOT.
I KNOW, I KNOW. YOU'VE SAID ALL THIS BEFORE. QUIT TALKING AND GET A MOVE ON.
YOU HEAR THAT, GIRL? IT DOESN'T MATTER IF YOUR FRIENDS SAVE YOU, IN A FEW DAYS THE TOWN WILL BE MINE!
YOU CAN TRY, BUT WE HAVE LASER POWERS AND QUANTUM MECHANICS ON OUR SIDE.
YOU HAVE A TARP, A CRYSTAL BALL, AND QUESTIONABLE DECORATING TASTE.


WHY IS IT TAKING SO LONG?! I THOUGHT YOU HAD IT ALMOST ALL DONE. IT CAN'T BE THAT COMPLICATED. LIGHTHOUSES HAVE BEEN DOING THIS SINCE 1823. I WANT TO DO IT NOW!
LOOK, DO YOU WANT IT DONE NOW OR DO YOU WANT IT DONE RIGHT? IT HAS TO BE AT EXACTLY THE RIGHT ANGLE IN EXACTLY THE RIGHT SPOT. A FEW DEGREES OFF AND WE JUST LOOK LIKE FOOLS WITH A STRANGE ROOF ORNAMENT. CHILL!
WE MUST HURRY! THOSE KIDS HAVE A TENDENCY TO RUIN MY PLANS. BUT NOT THIS TIME!
WHAT'S THAT SMELL?
I'M GUESSING THAT'S YOU, LUCY, AND NOT COMBUSTABLE SILLY STREAMERS?
YEP! I'M BUSTING YOU OUTTA HERE.
beeepbeeepbeeep
AARGHH!
WE'RE OUTTA HERE. GRAB ON.
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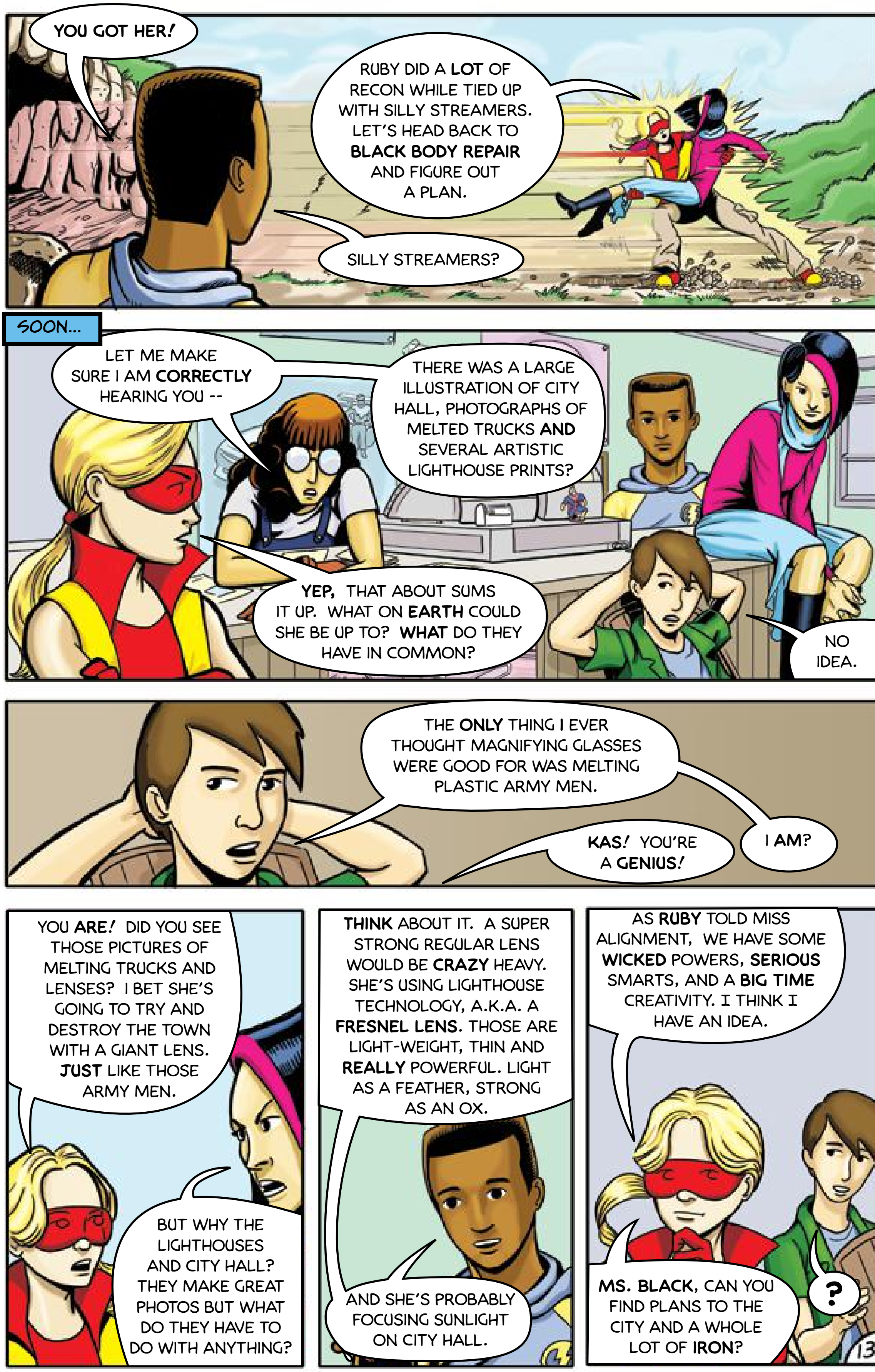
YOU GOT HER!
RUBY DID A LOT OF RECON WHILE TIED UP WITH SILLY STREAMERS. LET'S HEAD BACK TO BLACK BODY REPAIR AND FIGURE OUT A PLAN.
SILLY STREAMERS?
SOON...
LET ME MAKE SURE I AM CORRECTLY HEARING YOU --
THERE WAS A LARGE ILLUSTRATION OF CITY HALL, PHOTOGRAPHS OF MELTED TRUCKS AND SEVERAL ARTISTIC LIGHTHOUSE PRINTS?
YEP, THAT ABOUT SUMS IT UP. WHAT ON EARTH COULD SHE BE UP TO? WHAT DO THEY HAVE IN COMMON?
NO IDEA.
THE ONLY THING I EVER THOUGHT MAGNIFYING GLASSES WERE GOOD FOR WAS MELTING PLASTIC ARMY MEN.
KAS! YOU'RE A GENIUS!
I AM?
YOU ARE! DID YOU SEE THOSE PICTURES OF MELTING TRUCKS AND LENSES? I BET SHE'S GOING TO TRY AND DESTROY THE TOWN WITH A GIANT LENS. JUST LIKE THOSE ARMY MEN.
BUT WHY THE LIGHTHOUSES AND CITY HALL? THEY MAKE GREAT PHOTOS BUT WHAT DO THEY HAVE TO DO WITH ANYTHING?
THINK ABOUT IT. A SUPER STRONG REGULAR LENS WOULD BE CRAZY HEAVY. SHE'S USING LIGHTHOUSE TECHNOLOGY, A.K.A. A FRESNEL LENS. THOSE ARE LIGHT-WEIGHT, THIN AND REALLY POWERFUL. LIGHT AS A FEATHER, STRONG AS AN OX.
AND SHE'S PROBABLY FOCUSING SUNLIGHT ON CITY HALL.
AS RUBY TOLD MISS ALIGNMENT, WE HAVE SOME WICKED POWERS, SERIOUS SMARTS, AND A BIG TIME CREATIVITY. I THINK I HAVE AN IDEA.
MS. BLACK, CAN YOU FIND PLANS TO THE CITY AND A WHOLE LOT OF IRON?
?
13

TEACHER'S GUIDE
Activity 4: Melts in the Sun, Not in Your Hand

Intro

Outside on a hot, sunny day, when faced with a choice between a metal chair and a beach towel, most people would pick the beach towel. We intuitively understand that metal sitting in the sun is going to be really, really hot. But why? Do different metals heat up differently in the sun? What happens to the sun's heat when you focus the sun's light with a lens, does the heat focus, too? This experiment uses a Fresnel lens, different types of metal, the sun's rays and tasty, tasty chocolate to explore these questions.

Key Questions

What types of energy does the sun produce?

How do different metals conduct heat?

Key Terms

Conduction: Energy in the form of heat moving from one thing to another.

Kinetic Energy: Energy of motion. When things are moving, they have kinetic energy.

Lens: A transparent, curved, object for focusing or dispersing light. Converging lenses focus light, diverging lenses disperse light.

Focal Point: If light from a far away source hits a converging lens, the focal point is the point at which the light is focused. The distance to the focal point is called the focal length. Differently shaped lenses have different focal points.

Materials

1 Small Hershey's bar
1 Steel wire
1 Copper wire
1 Aluminum wire
1 Fresnel lens
PhysicsQuest Box
* Rock
* Tape
* Scissors
* Sun

* *Not included in the PhysicsQuest kit*

Before the Activity Students should know...

- When solids such as chocolate get hot they melt.
- Metals conduct heat.
- Converging lenses focus light

After the Activity Students should be able to...

- Discuss how light energy can be transformed into heat energy.
- Discuss how different types of metal conduct heat at different rates.

The Science Behind Conduction

Metals are generally good at transferring, or conducting, heat. We know not to touch a cookie sheet without a pot holder and that putting an gloved hand on your metal car in the winter won't exactly feel nice. But do all metals conduct the same?

There are two things going on in this experiment; metals conducting heat and melting of chocolate. Most of us can explain melting without too much difficulty. Melting is when something changes from a solid to a liquid. This happens when there is enough energy, usually in the form of heat, to raise the temperature to the melting point and make the ordered atoms or molecules in the solid become less ordered and move around. At that point it becomes a liquid. (Fig. 1)

Conduction in metal moves energy in the form of heat from the focused sunlight to the chocolate and causes it to melt. Temperature is a measure of the average kinetic energy in some space, in this case the metal rod. When the focused sunlight hits the ends of the wires, the energy from the sunlight makes the molecules in the end of the wire start moving faster, and the metal heat up. The infrared, or IR, wavelengths of light are about the same size as the molecules in the metal. Because they are close to the same size they are really good at making them jiggle back and forth and increasing their kinetic energy. Then the faster moving metal molecules in the end of the wire start jiggling the ones next to them and so on right up to the end of the wire and the chocolate. Which gets hot, melts, and allows the wire to sink into the chocolate.

The reason metals conduct heat well is that it is easy for them to get their molecules moving and transfer the energy to other molecules in the metal. This process is easier for some metals than others. Even though metals as a group are good conductors, some are better conductors than others. One of the places this is easy to see is in cookware. Before the new fancy-dancy pots and pans we have now, most good cookware had copper bottoms. This is because cop-

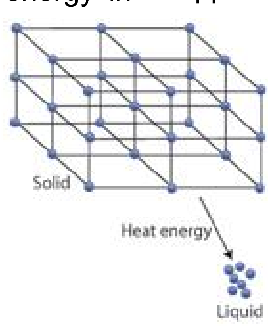

Fig. 1

per is extremely good at conducting heat. Now think of an iron skillet. Unlike other pots, the handle of the skillet is also iron, but we don't have a problem grabbing it without a pot holder. This is because iron is not a good conductor at all. Important thing to note is that steel is mostly iron. For this experiment it is ok to assume the steel wire is really an iron wire. This experiment is a really tasty and fun way to show that not all metals conduct equally. (Fig 2)

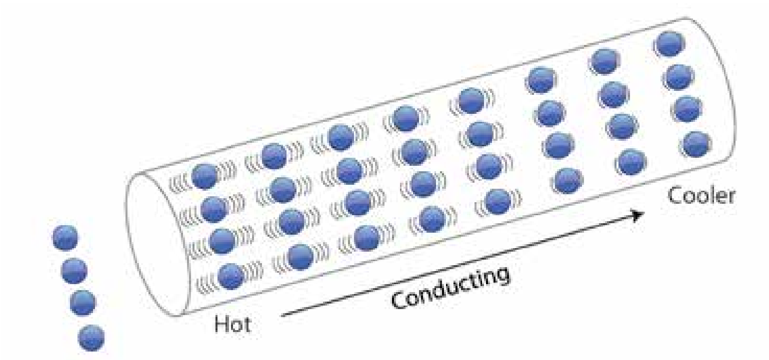

Fig. 2

SAFETY

Always make sure the Fresnel lens is focused on a non-flammable surface such as a rock or pavement. The focused rays of the sun can be extremely hot and cause a fire if focused on a surface such as paper or leaves.

Bibliography / Suggested Resources

http://van.physics.illinois.edu/qa/listing.php?id=1864
http://eosweb.larc.nasa.gov/EDDOCS/Wavelengths_for_Colors.html
http://www2.slac.stanford.edu/vvc/theory/photoelectric.html

Intro

Outside on a hot, sunny day, when faced with a choice between a metal chair and a beach towel, most people would pick the beach towel. We intuitively understand that metal sitting in the sun is going to be really, really hot. But why? Do different metals heat up differently in the sun? What happens to the sun's heat when you focus the sun's light with a lens, does the heat focus, too? This experiment uses a Fresnel lens, different types of metal, the sun's rays, and tasty, tasty chocolate to explore these questions.

Key Questions

What types of energy does the sun produce?

How do different metals conduct heat?

Getting Started

How many different types of metal can you think of? What are some of the differences between all of these metals?

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What does it mean for something to be 'hot' and 'heat up'?

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____
____

How can you tell if chocolate has melted?

____
____

Materials

1 Small Hershey's bar
1 Steel wire
1 Copper wire
1 Aluminum wire
1 Fresnel lens
PhysicsQuest Box
* Rock
* Tape
* Scissors
* Sun

**Not included in the PhysicsQuest kit*

Predict which metal you think would conduct heat best, steel (mostly iron), copper, or aluminum. Think about where you have seen these metals before and what they are often used for when making your predictions.

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What happens when light passes through a lens?

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Setting up the Experiment

NOTE: ***This experiment is done using sunlight. It must be done outside on a sunny day.***

1. Poke a small hole in the side of the PhysicsQuest box just large enough for the three wires to fit through.

2. Unwrap Hershey's bar and put it inside the PhysicsQuest box, close to the edge with the hole.

3. Stick the 3 wires half way through the hole in the box and lay them on top of the Hershey's bar. Using a pin or other small object, scratch and "A" in the chocolate next to the aluminum wire, an "S" next to the steel wire and an "C" next to the copper wire. (Fig. 1)

4. Take your entire contraption outside and place the ends of the wires that are not inside the box on a hard surface such as a cement sidewalk or rock. This experiment can get very hot and you don't want to hurt anything!

5. Carefully close the top of the PhysicsQuest box. Make sure the wires are still on the chocolate bar.

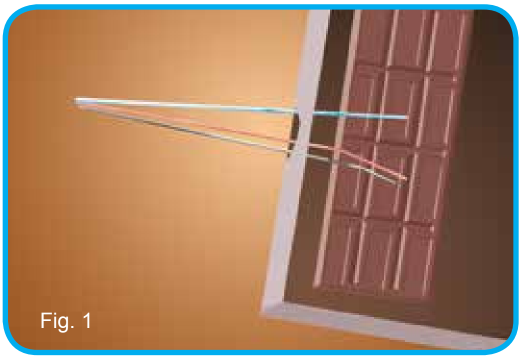

Fig. 1

Collecting Data

1. Use the Fresnel lens to focus sunlight on the exposed ends of the wire. Just like Miss Alignment's lens, you have to keep yours at just the right angle to focus the sunlight. It might take a few tries to get it right. You want the spot of light you are shining on the wires to be as bright as possible. (fig.2)

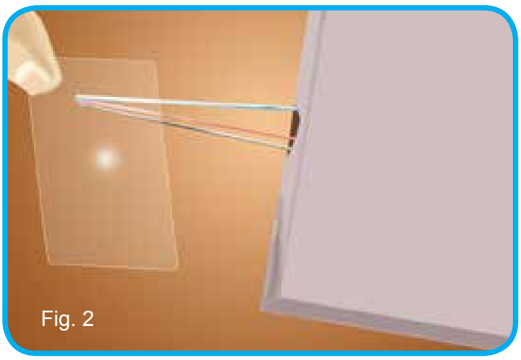

Fig. 2

2. Keep sunlight focused on the wires for 5 minutes. You might want to take turns holding the lens, it can get tiring!

3. Open the box and carefully remove the chocolate bar. You can go inside now if you want, but if its a nice day, maybe your teacher will let you stay outside for the next part.

Analyzing Your Results

What can you say about how light and heat are related? What happens to the metal wires when light is focused on them?

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____

What type of energy was transferred down the wires to the chocolate, light or heat or both?

____
____
____
____

What metal caused the chocolate to melt the most? Which one caused it to melt the least?

____
____
____

Rank the metals from most to least conductive.

_______ Steel
_______ Copper
_______ Aluminum

Using your results to help Spectra find the time of Miss Alignment's attack.

Which metal is the most conductive?

1. Steel
2. Copper
3. Aluminum
4. Both steel and aluminum conduct the same

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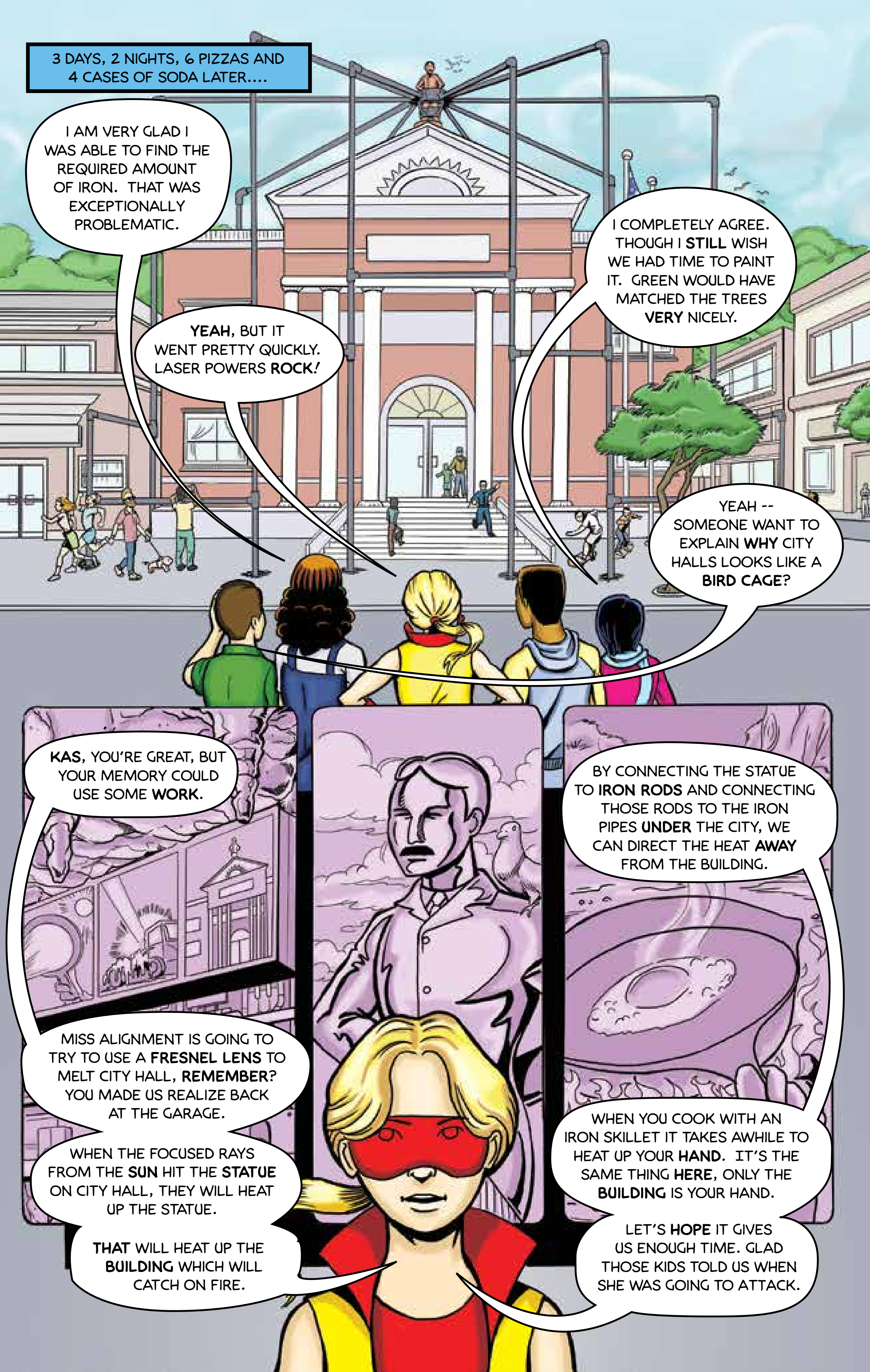
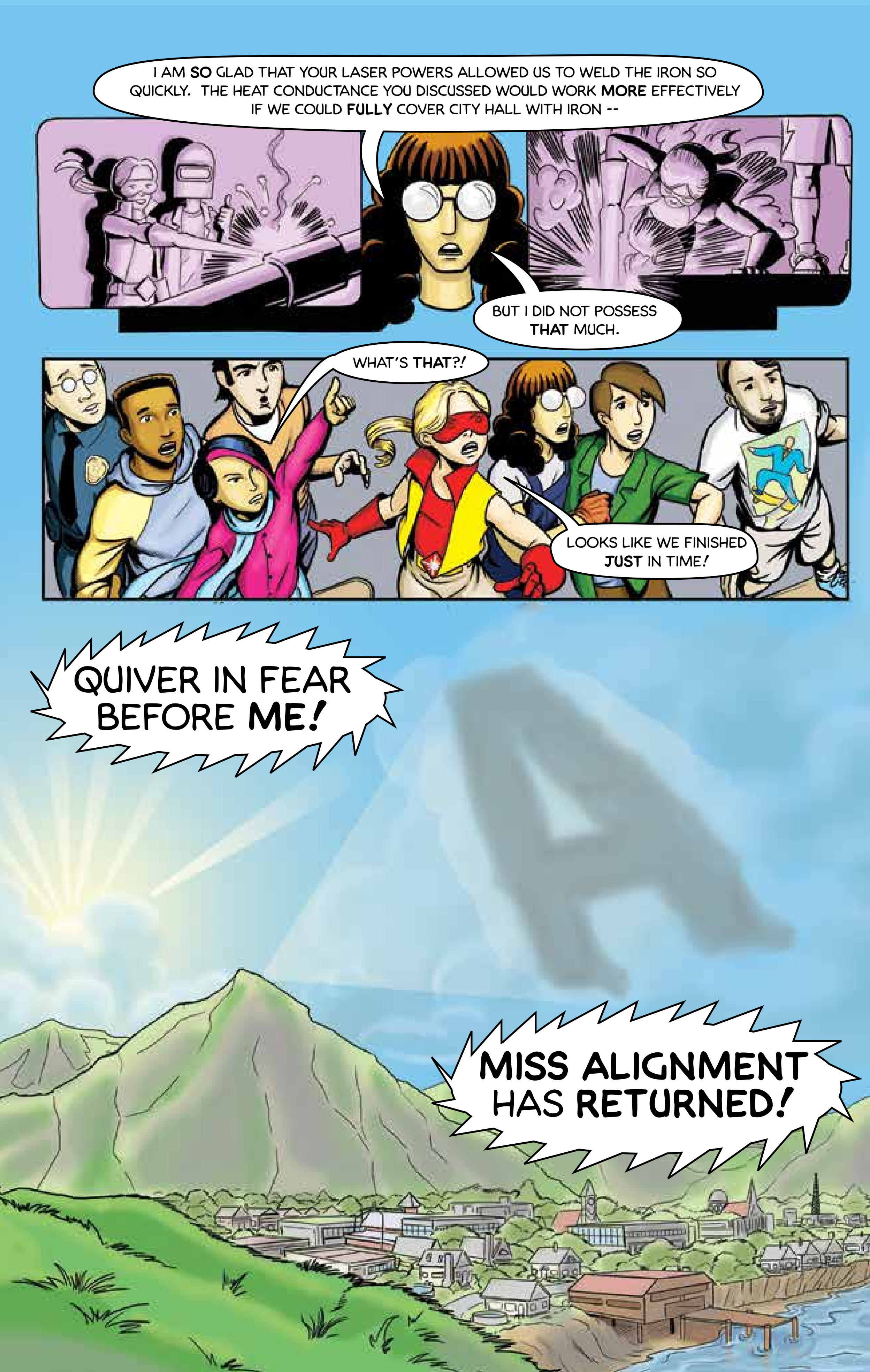
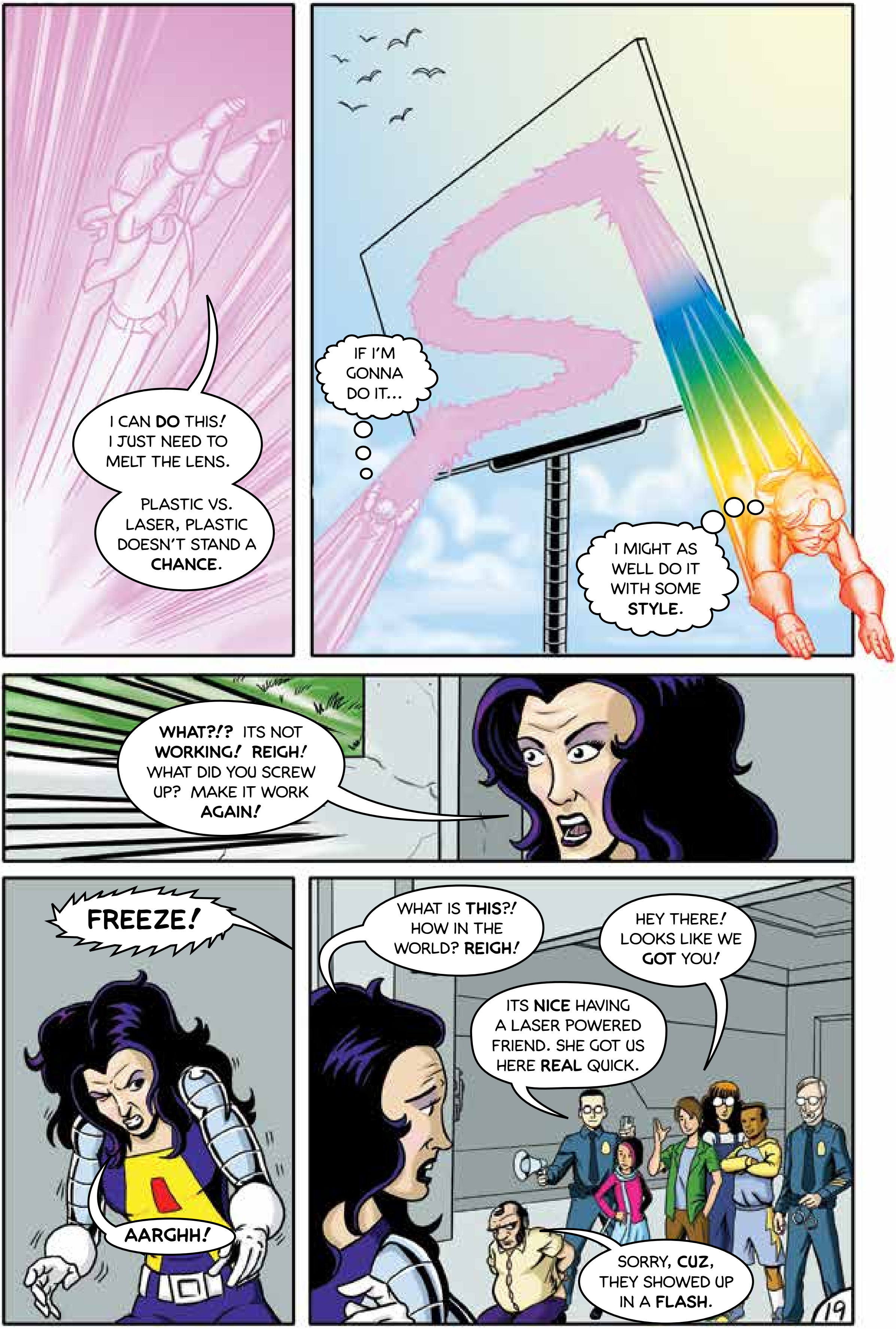

3 DAYS, 2 NIGHTS, 6 PIZZAS AND 4 CASES OF SODA LATER....
I AM VERY GLAD I WAS ABLE TO FIND THE REQUIRED AMOUNT OF IRON. THAT WAS EXCEPTIONALLY PROBLEMATIC.
YEAH, BUT IT WENT PRETTY QUICKLY. LASER POWERS ROCK!
I COMPLETELY AGREE. THOUGH I STILL WISH WE HAD TIME TO PAINT IT. GREEN WOULD HAVE MATCHED THE TREES VERY NICELY.
YEAH -- SOMEONE WANT TO EXPLAIN WHY CITY HALLS LOOKS LIKE A BIRD CAGE?
KAS, YOU'RE GREAT, BUT YOUR MEMORY COULD USE SOME WORK.
MISS ALIGNMENT IS GOING TO TRY TO USE A FRESNEL LENS TO MELT CITY HALL, REMEMBER? YOU MADE US REALIZE BACK AT THE GARAGE.
WHEN THE FOCUSED RAYS FROM THE SUN HIT THE STATUE ON CITY HALL, THEY WILL HEAT UP THE STATUE.
THAT WILL HEAT UP THE BUILDING WHICH WILL CATCH ON FIRE.
BY CONNECTING THE STATUE TO IRON RODS AND CONNECTING THOSE RODS TO THE IRON PIPES UNDER THE CITY, WE CAN DIRECT THE HEAT AWAY FROM THE BUILDING.
WHEN YOU COOK WITH AN IRON SKILLET IT TAKES AWHILE TO HEAT UP YOUR HAND. IT'S THE SAME THING HERE, ONLY THE BUILDING IS YOUR HAND.
LET'S HOPE IT GIVES US ENOUGH TIME. GLAD THOSE KIDS TOLD US WHEN SHE WAS GOING TO ATTACK.


I AM SO GLAD THAT YOUR LASER POWERS ALLOWED US TO WELD THE IRON SO QUICKLY. THE HEAT CONDUCTANCE YOU DISCUSSED WOULD WORK MORE EFFECTIVELY IF WE COULD FULLY COVER CITY HALL WITH IRON --
BUT I DID NOT POSSESS THAT MUCH.
WHAT'S THAT?!
LOOKS LIKE WE FINISHED JUST IN TIME!
QUIVER IN FEAR BEFORE ME!
MISS ALIGNMENT HAS RETURNED!

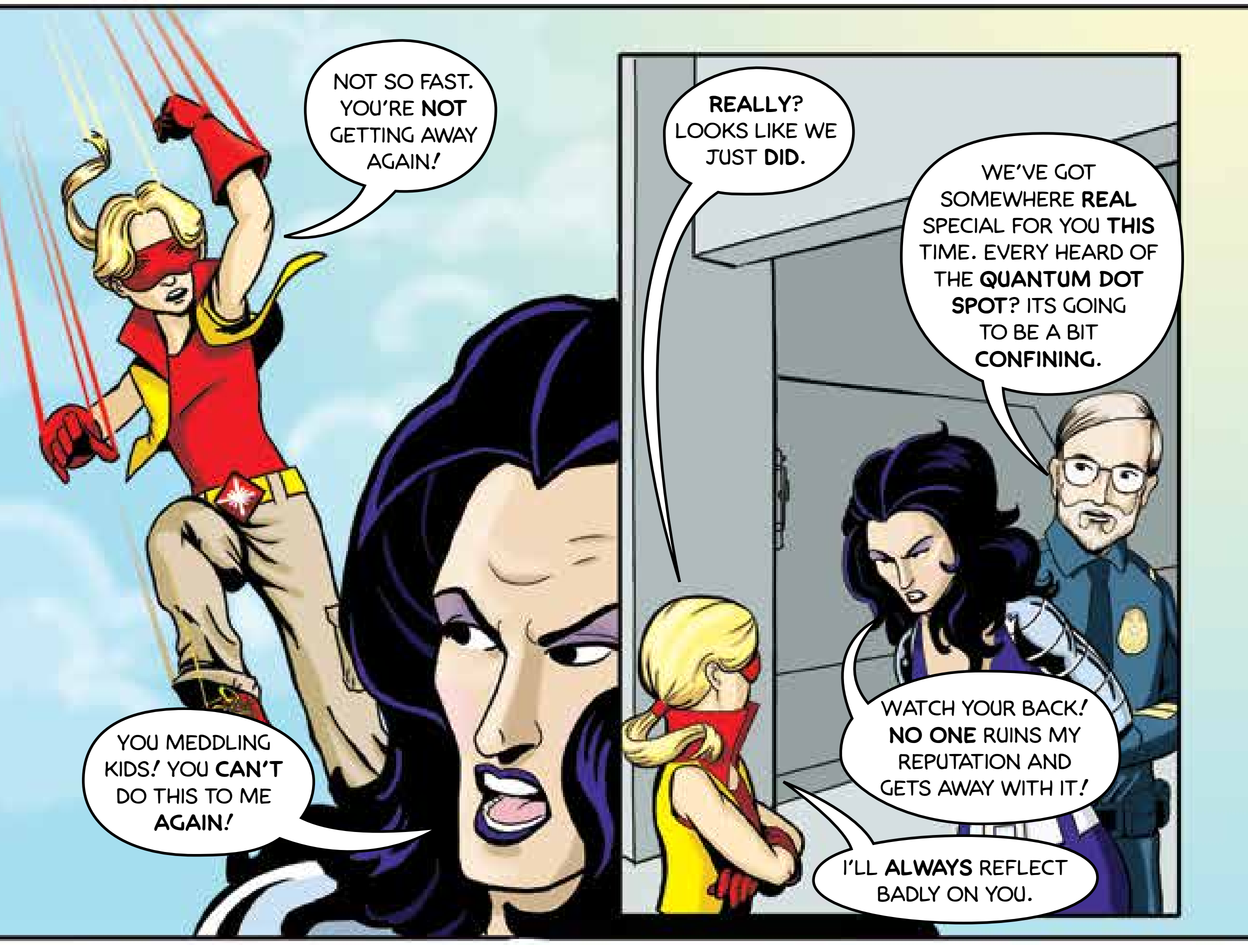

YOU STOPPED ME ONCE, BUT YOU CANNOT STOP ME AGAIN!
YOU SURE THIS IS LOUD ENOUGH?
YEAH, I'M SURE EVEN PERTH IS QUIVERING IN FEAR.
IN JUST A FEW MINUTES THE SUN WILL BE PERFECTLY ALIGNED TO BURN YOUR TOWN TO THE GROUND!
SPECTRA! SURRENDER AND I WILL BE MERCIFUL!
BUT IF YOU DO NOT, YOU WILL LIVE WITH THE GUILT OF CAUSING YOUR TOWN'S DESTRUCTION!

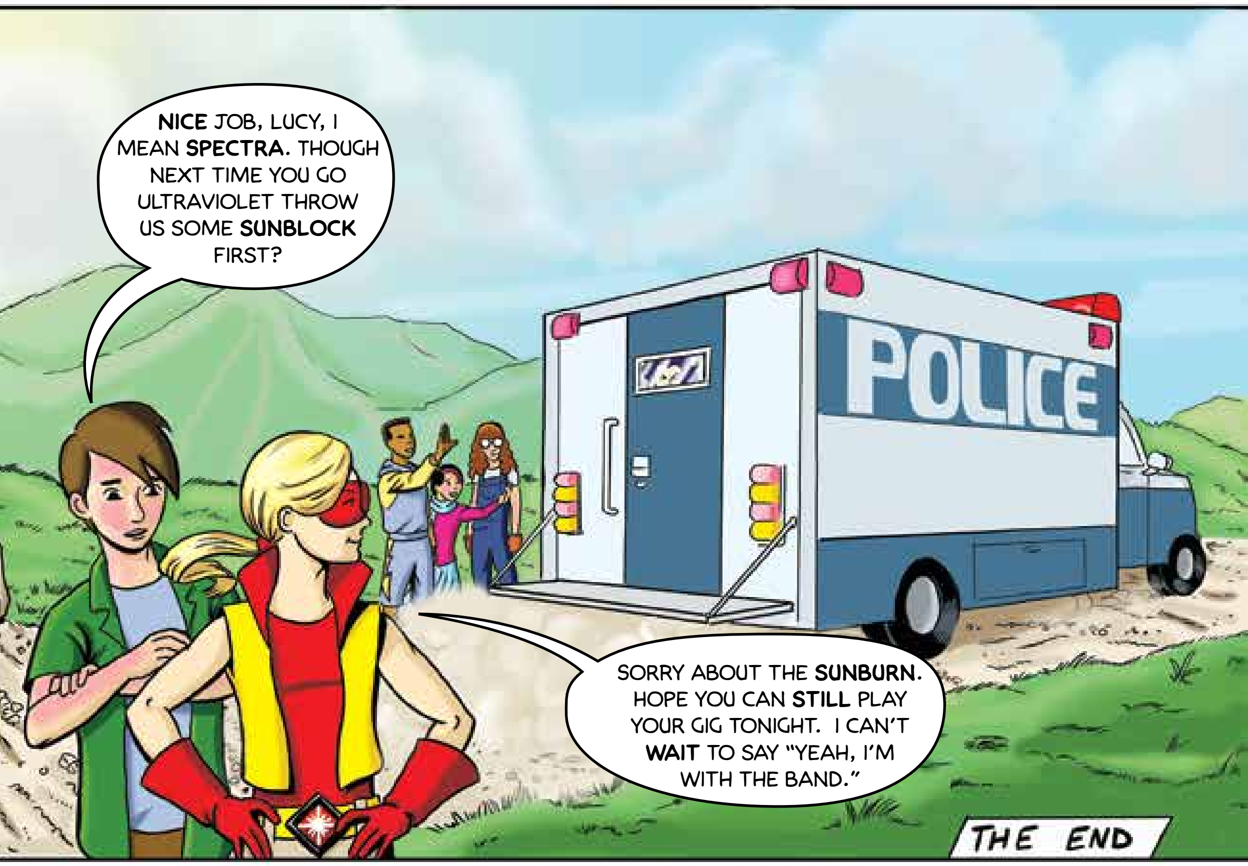

"IT'S WORKING! REIGH YOU ARE NOT COMPLETELY INCOMPETENT! THE LENS ANGLE IS PERFECT!"
"LOOK AT THE STATUE MELT! CITY HALL WILL BURN!"
"MUAHAHAHAHA"
OUR SYSTEM IS WORKING! IT'S ABSORBING THE HEAT FROM THE FOCUSED SUNLIGHT AND THE STATUE. BUT IT CAN'T LAST FOREVER.
I HAVE TO DESTROY THAT LENS! I NEED SOME SERIOUS ENERGY!
UV, HERE I COME!

OKAY, WHO'S GOT SOME **FOOD**?
UH... NOT SURE HOW I FEEL ABOUT THOSE **ENERGY BARS**, GORDY.
TRUST ME. THE BERRY FLAVOR IS **DELISH!**
UM...
NOM. YOU WERE **RIGHT!** NOM! NOM!
I **GOT** THIS!
ALMOST THERE...
HIGH ENERGY LASER POWERS **ACHIEVED!**
MISS ALIGNMENT, YOU ARE GOING **DOWN!**



I CAN **DO** THIS! I JUST NEED TO MELT THE LENS.
PLASTIC VS. LASER, PLASTIC DOESN'T STAND A **CHANCE**.
IF I'M GONNA DO IT...
I MIGHT AS WELL DO IT WITH SOME **STYLE**.
WHAT?!? ITS NOT **WORKING! REIGH!** WHAT DID YOU SCREW UP? MAKE IT WORK **AGAIN!**
FREEZE!
AARGHH!
WHAT IS **THIS?!** HOW IN THE WORLD? **REIGH!**
HEY THERE! LOOKS LIKE WE **GOT** YOU!
ITS **NICE** HAVING A LASER POWERED FRIEND. SHE GOT US HERE **REAL** QUICK.
SORRY, **CUZ**, THEY SHOWED UP IN A **FLASH**.


NOT SO FAST. YOU'RE **NOT** GETTING AWAY AGAIN!
YOU MEDDLING KIDS! YOU **CAN'T** DO THIS TO ME **AGAIN**!
REALLY? LOOKS LIKE WE JUST **DID**.
WE'VE GOT SOMEWHERE **REAL** SPECIAL FOR YOU **THIS** TIME. EVERY HEARD OF THE **QUANTUM DOT SPOT**? ITS GOING TO BE A BIT **CONFINING**.
WATCH YOUR BACK! **NO ONE** RUINS MY REPUTATION AND GETS AWAY WITH IT!
I'LL **ALWAYS** REFLECT BADLY ON YOU.


NICE JOB, LUCY, I MEAN **SPECTRA**. THOUGH NEXT TIME YOU GO ULTRAVIOLET THROW US SOME **SUNBLOCK** FIRST?
POLICE
SORRY ABOUT THE **SUNBURN**. HOPE YOU CAN **STILL** PLAY YOUR GIG TONIGHT. I CAN'T **WAIT** TO SAY "YEAH, I'M WITH THE BAND."
THE END

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Chad Orzel, Physics Professor at Union College and author of *Eureka! Discovering your Inner Scientist*

"I liked Spectra's superpowers. They were amazing and she's really cool!."

Nina Parker, 9, daughter of plasma physicist Dr. Carolyn Kuranz

"Reading SPECTRA comics will teach you everything you need to be a scientific researcher! First, she displays a mastery of the laws of Nature. Second, she demonstrates her creative problem solving skills, and third, she knows how to rock a pair of sunglasses!"

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