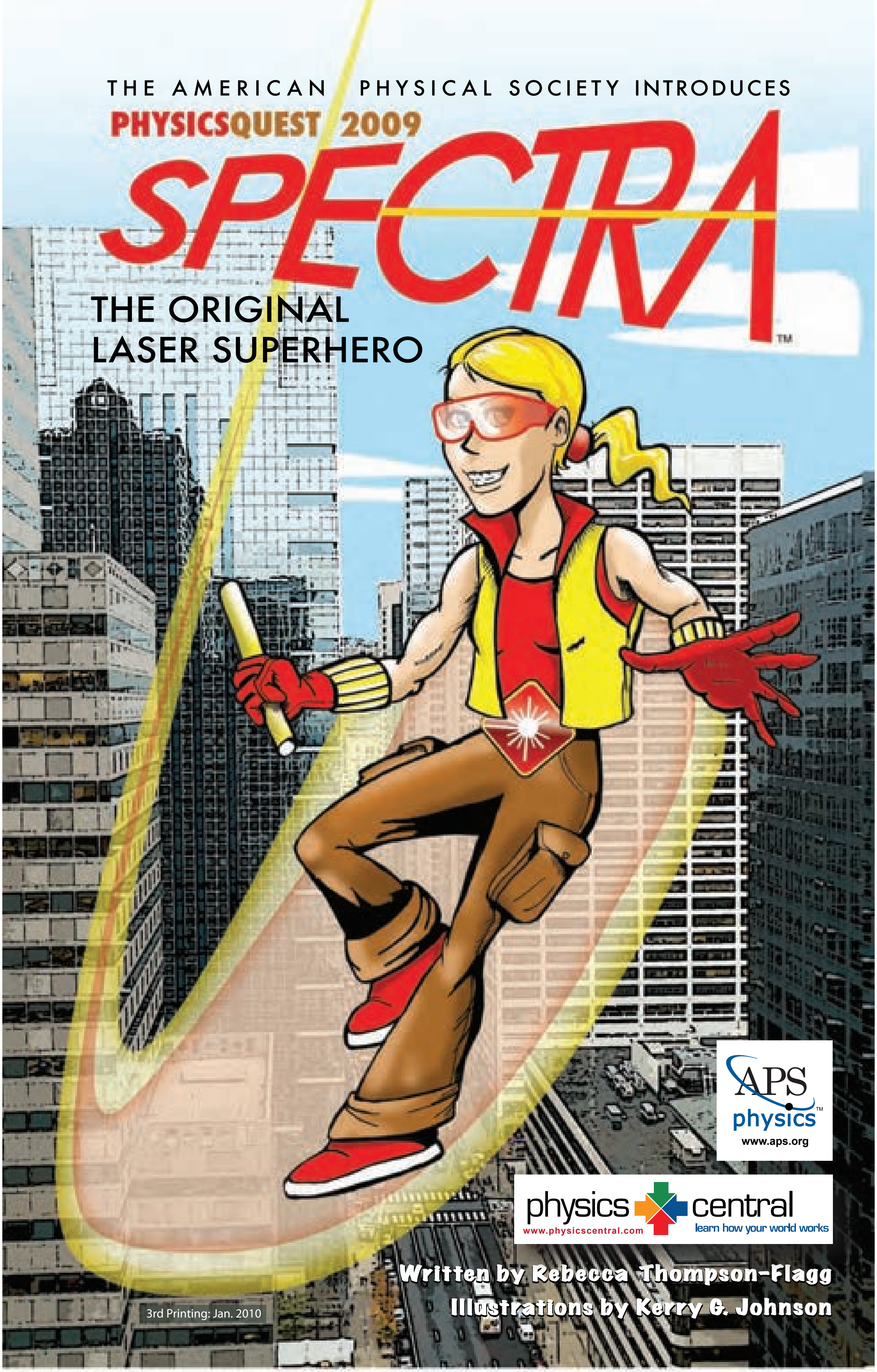
THE AMERICAN PHYSICAL SOCIETY INTRODUCES

PHYSICSQUEST 2009

SPECTRA™

THE ORIGINAL LASER SUPERHERO



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Written by Rebecca Thompson-Flagg
Illustrations by Kerry G. Johnson

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THE AMERICAN PHYSICAL SOCIETY PRESENTS

PHYSICSQUEST: SPECTRA

WELCOME TO PHYSICSQUEST 2010!

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 fifth kit, PhysicsQuest 2009: Spectra's Power.

In the past each PhysicsQuest kit follows a mystery-based storyline and required students to correctly complete four activities in order to solve the mystery and be eligible for a prize drawing. This year students will follow the APS created superhero SPECTRA and her showdown with the villain MISS ALIGNMENT. We hope that the comic book format will encourage students to learn more about physics and complete the four activities.

APS physics www.aps.org

The American Physical Society (APS) is the professional society for professional physicists and physics students 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 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 the four activities and you must submit their answers online by May 16, 2010. This date was chosen because on May 16, 1960, Theodore Maiman demonstrated the first working laser. All classes that submit answers online will receive a certificate of completion and 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 requires the answers to all of the questions on the Final Report. Each class can only submit one entry form, so class discussions of results are encouraged. Answers can be submitted online through the PhysicsQuest website beginning February 16, 2010. 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.

Continued on inside back cover >>>

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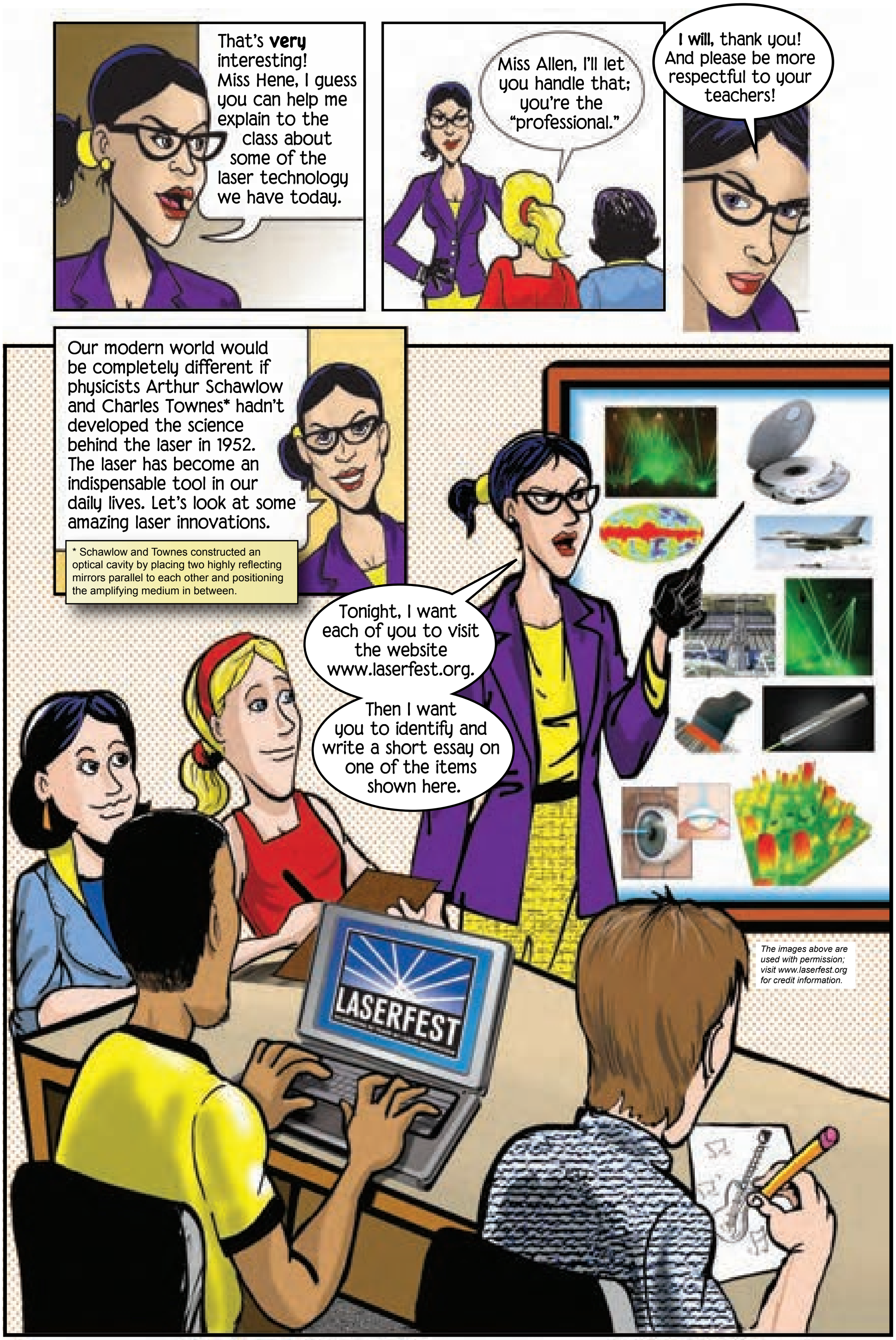
2010 LASERFEST
CELEBRATING 50 YEARS OF LASER INNOVATION
www.laserfest.org

APS PhysicsQuest Publication Staff

Coordinated, Researched and Written by: Rebecca Thompson-Flagg • Art Direction and Illustrations by Kerry G. Johnson


IT'S 7:50 A.M. TEN MINUTES BEFORE THE BELL RINGS FOR HER FIRST CLASS. **LUCINDA HENE** OVERSLEPT, SHE'S ABOUT TO BE LATE FOR SCHOOL.
NIKOLA TESLA MIDDLE SCHOOL
SCHOOL BUS
7:50
SHE MADE IT! SHE EVEN HAS A FEW MINUTES TO HANG WITH HER PEEPS AT THE USUAL SPOT.
THE FRONT HALLWAY LOCKERS
IF YOU WANT TO BE IN THE MIX AND GET THE LATEST SCHOOL GOSSIP, YOU'VE GOT TO BE IN "THE FRONT." LUCINDA'S SPOTS HER CREW.
GORDY HE'S A SUPERSTAR ON THE FIELD AND IN THE CLASSROOM.
KAS HE'S A CHARMER; MR. POPULARITY. BUT IT DOESN'T GO TO HIS HEAD. LOVES TO PLAY HIS GUITAR WITH HIS GARAGE BAND.
RUBY LUCINDA'S BFF. SHE WANTS TO BE AN ARTIST.
Physics Quest
Look who decided to show up to school.
Whazzup, Lucinda?
Okay, I get it! I overslept, but I'm here now. What did I miss?
The word is Mr. Johnson is sick. We've got a sub today in physics class.
That's hot! I didn't do my homework!
Hey! I like physics class.


PHYSICS LAB
Welcome students! My name is Miss Allen. I'll be taking over your physics class until Mr. Johnson returns.
G-MAN, we're all aware of your "fondness" for physics and sports.
But do you want to know what I like?
I like our sub! Wow!
After reading over your teacher's notes, it looks like you guys are studying about the importance of lasers.
That's an interesting and exciting topic. What do any of you know about lasers?
Hey Miss Allen, ask Lucinda, both her parents are famous laser scientists.
RUBY!?!


That's **very** interesting! Miss Hene, I guess you can help me explain to the class about some of the laser technology we have today.
Miss Allen, I'll let you handle that; you're the "professional."
I will, thank you! And please be more respectful to your teachers!
Our modern world would be completely different if physicists Arthur Schawlow and Charles Townes* hadn't developed the science behind the laser in 1952. The laser has become an indispensable tool in our daily lives. Let's look at some amazing laser innovations.
* Schawlow and Townes constructed an optical cavity by placing two highly reflecting mirrors parallel to each other and positioning the amplifying medium in between.
Tonight, I want each of you to visit the website www.laserfest.org.
Then I want you to identify and write a short essay on one of the items shown here.
LASERFEST
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EXPERIMENT 1

Spots, Lines and Lasers

TEACHER'S GUIDE

INTRODUCTION: You may often hear it said that light is both a particle and a wave. It is a little better to say that light has both wave properties an particle properties. In other words, sometimes it acts like a wave and sometimes it acts like a particle. For the next two experiments we will explore how light acts like a wave. In this experiment we will shine light through sheets of fabric that all have a different number of threads per inch and look at the patterns. We can use the pattern to find the wavelength of the laser. Wouldn't Martha Stewart be proud!?

KEY QUESTION: Using a laser pointer and 4 pieces of cloth, find the wavelength of your laser pointer.

MATERIALS:
- Laser pointer
- Masking Tape
- Four small strips of cloth, one white, one white with black, one yellow, one yellow with black
- Binder Clips (2)
- Large sheet of paper
- Diffraction Grating Cloth card
- Ruler

BEFORE THE ACTIVITY, STUDENTS SHOULD KNOW:
- Light can act like a wave.
- A laser pointer is a beam of light that is coherent and all the same color.

AFTER THE ACTIVITY, STUDENTS SHOULD BE ABLE TO:
- Describe how wave interact
- Explain the pattern formed on the wall when a laser is shined on a human hair
- Explain how to use this pattern to measure the width of a small obstacle such as a human hair.
- The science behind interference

THE SCIENCE BEHIND INTERFERENCE:

Light is both a particle and a wave, or better yet, light has both wave properties and particle properties. In this kit we will do experiments that will show both sides of light. This experiment is one that shows that light has wave properties.

Lets start by thinking about what happens when waves interact. We will assume that we are dealing with two waves that have the same wavelength. When two waves come together they add up to make a resultant wave. If the two waves have crests and troughs at the same points, they add up to make a wave that is twice as big as the two individual waves.This is called "constructive interference." When two waves have crests and troughs at the same points they are said to be "in phase." If two waves are completely "out of phase" which means one wave is up while the other is down, they cancel each other out. This is called "destructive interference."

You have always heard that light always goes in a straight line. Well it does. Except when it doesn't. When light encounters and obstacle that is really small, only slightly larger than the wavelength of light, it will spread out again as it passes the obstacle, just like water flowing through a small slit. This is called diffraction. When there are two slits close together the waves interact with each other when they spread out. Light does the same thing when it passes through two small slits. By looking at when the waves are in phase, how far apart the slits are and how far the waves have traveled since they passed through the slits we can figure out the wavelength. To do this we need a formula that explains how all of these variables interact. The wavelength= (the spacing of the slits)x(the distance between bright spots)/the distance from the cloth to the screen. This is a very powerful formula. It also means that if you know the wavelength you can figure out what kind of slit the light has gone through. This method is used to figure out the structure of crystals such as salt and even DNA! Instead of knowing what the material looks like and looking at the pattern, they know what the pattern looks like and can figure out with the material looks like. This is what the students will do in the next activity.

In addition to learning about waves, this experiment will give students a chance to learn about the need to preform multiple trials of an experiment and average the results. It will also give them experience in unit conversion.

KEY TERMS:

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

Diffraction: When light goes around an obstacle or through a single slit the light rays interact with each other. When they do, a patterns of dark and bright spots is created.

Interference: When light passes through two slits and the light rays from each of the slits interacts. It is like diffraction but involves more than one slit or obstacle.

Constructive Interference: When two waves come together and make a bigger wave

Destructive Interference: When two waves come together and cancel each other out

In Phase: When two waves are going up and down together

Out-of-Phase: When one wave is going up as the other is going down

EXPERIMENT 1

Spots, Lines and Lasers

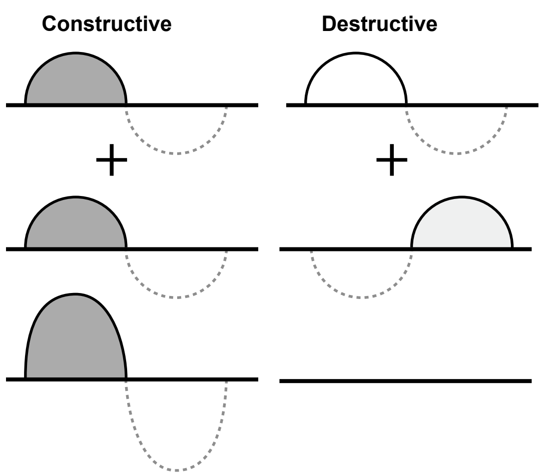
TEACHER'S GUIDE

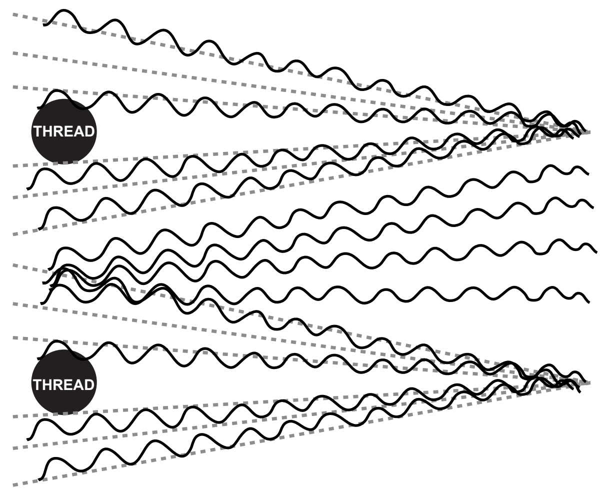
SAFETY:

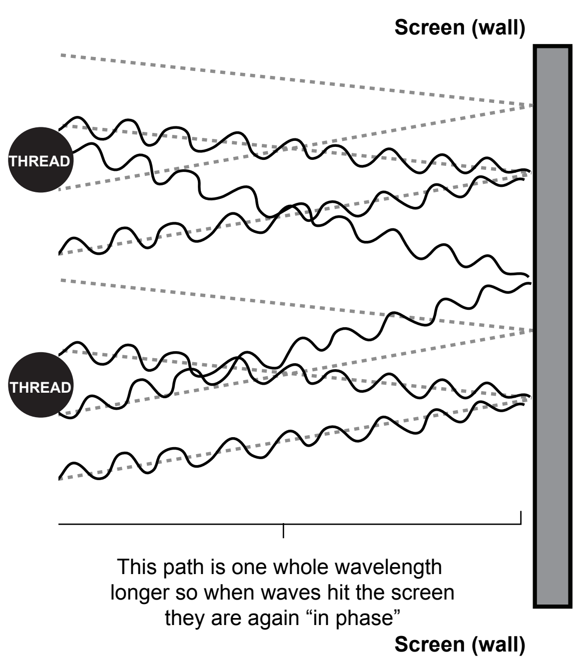
Please review these guidelines closely with students before the activity and outline consequences for failure to follow them! Warn students very strongly about the dangers of looking directly into the laser beam. Shining the beam into their eyes of the eyes of their classmates can cause serious injury 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.

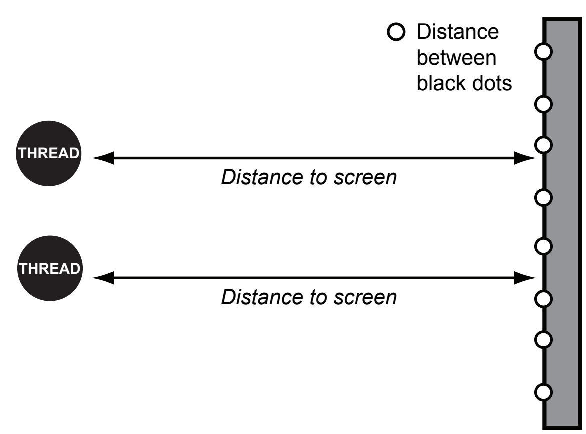
CORRESPONDING EXTENSION ACTIVITIES:

- Interference on paper.
- How big is the hole?
- Splash it!









EXPERIMENT 1

Spots, Lines and Lasers

STUDENT'S GUIDE

INTRODUCTION:

You may have heard it said that light is both a wave and a particle. It's probably better to say that sometimes when we do experiments with light it acts like a wave and sometimes it acts like a particle. In this experiment was are going to use a laser and cloth to look at light's wave properties and even find the wavelength of your laser. Wouldn't Martha Stewart be proud?

MATERIALS:

- Laser pointer
- Tape
- 4 small strips of cloth, one white, one white with black, one yellow, one yellow with black
- Binder clips (2)
- Large sheets of paper (4)
- Diffraction Grating Cloth card
- Ruler

KEY QUESTION:

Can you find the wavelength of your laser using the pattern formed when you shine the laser through cloth?

GETTING STARTED:

1. If you were to put a piece of cloth under a microscope, what would it look like? Draw it!

2. What type of pattern do you think you will see when you shine the laser through a piece of cloth?

3. When two waves come together, and they are both going up and down at the same time, what would happen? What if one was going up when the other was going down?

SETTING UP THE EXPERIMENT:

1. Assemble the Diffraction Grating Card as instructed on the card

2. Attach binder clips so that the card can stand unsupported.

3. Place the card several meters from the wall. Measure this distance.

4. Tape a piece of paper to the wall so that the pattern created by shining the laser through the cloth falls on the sheet of paper

COLLECTING DATA:

1. Shine the laser through the white cloth. You should see a pattern on the sheet of paper.

2. Use a pencil to record the pattern you see onto the screen. Make sure you label the paper so you know which cloth strip was used.

3. Repeat this for the 3 remaining pieces of cloth.

ANALYZING YOUR RESULTS:

1. How does the pattern you saw compare to the patter you predicted you would see?

____

____

____

2. What do you think is happening to form the pattern? Can you explain using the ideas of interference?

____

____

____

KEY TERMS:

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

Diffraction: When light goes around an obstacle or through a single slit the light rays interact with each other. When they do, a patterns of dark and bright spots is created.

Interference: When light passes through two slits and the light rays from each of the slits interacts. It is like diffraction but involves more than one slit or obstacle.

Constructive Interference: When two waves come together and make a bigger wave

Destructive Interference: When two waves come together and cancel each other out

In Phase: When two waves are going up and down together

Out of Phase: When one wave is going up as the other is going down

EXPERIMENT 1

Spots, Lines and Lasers

STUDENT'S GUIDE

ANALYZING YOUR RESULTS

3. As the number of threads per centimeter increased, what happened to the pattern?

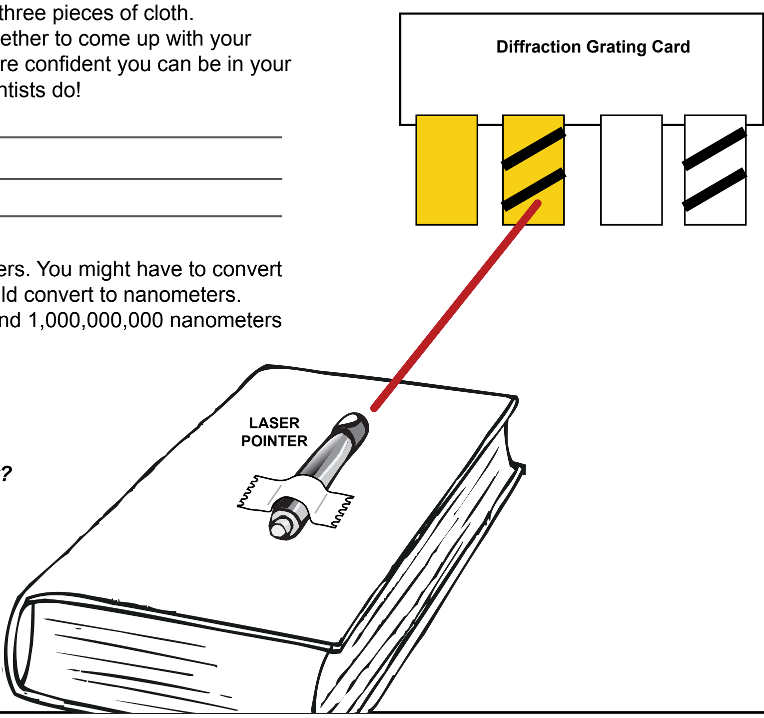
4. You can use the pattern you see to find the wavelength of your laser pointer. The bright spots correspond to the places where light waves are all going up and down together, where they are "in phase" and the dark spots are when the light waves are out of phase. By knowing when that happens, you can learn about the material that created the pattern. If you think about it, you have lots of data to work with here. The more data you have the more accurately you can find an answer. You are going to find the wavelength of your laser using all 4 pieces of cloth and then average them together to get the best answer.

5. Look at the pattern you copied for the first piece of cloth. Measure the distance between the bright spots and come up with an average distance. Next you want to figure out how far apart the threads are in the cloth. The number of thread per centimeter is written on the card. From that, you need to find the distance, in centimeters between each thread. Now you need one more pice of data, the distance from the cloth to the wall. You should have measured that while doing the experiment. Now to put it all together.

6. The wavelength of your laser can be found like this: Wavelength=Wd/L. So what do all the letters mean. W=the distance between the bright spots.This should be the average distance that you found in step 4. L is the distance to the wall and d is the distance between the threads. Looking at this formula, can you see what the pattern changed the way it did as the number of threads per centimeter changed?

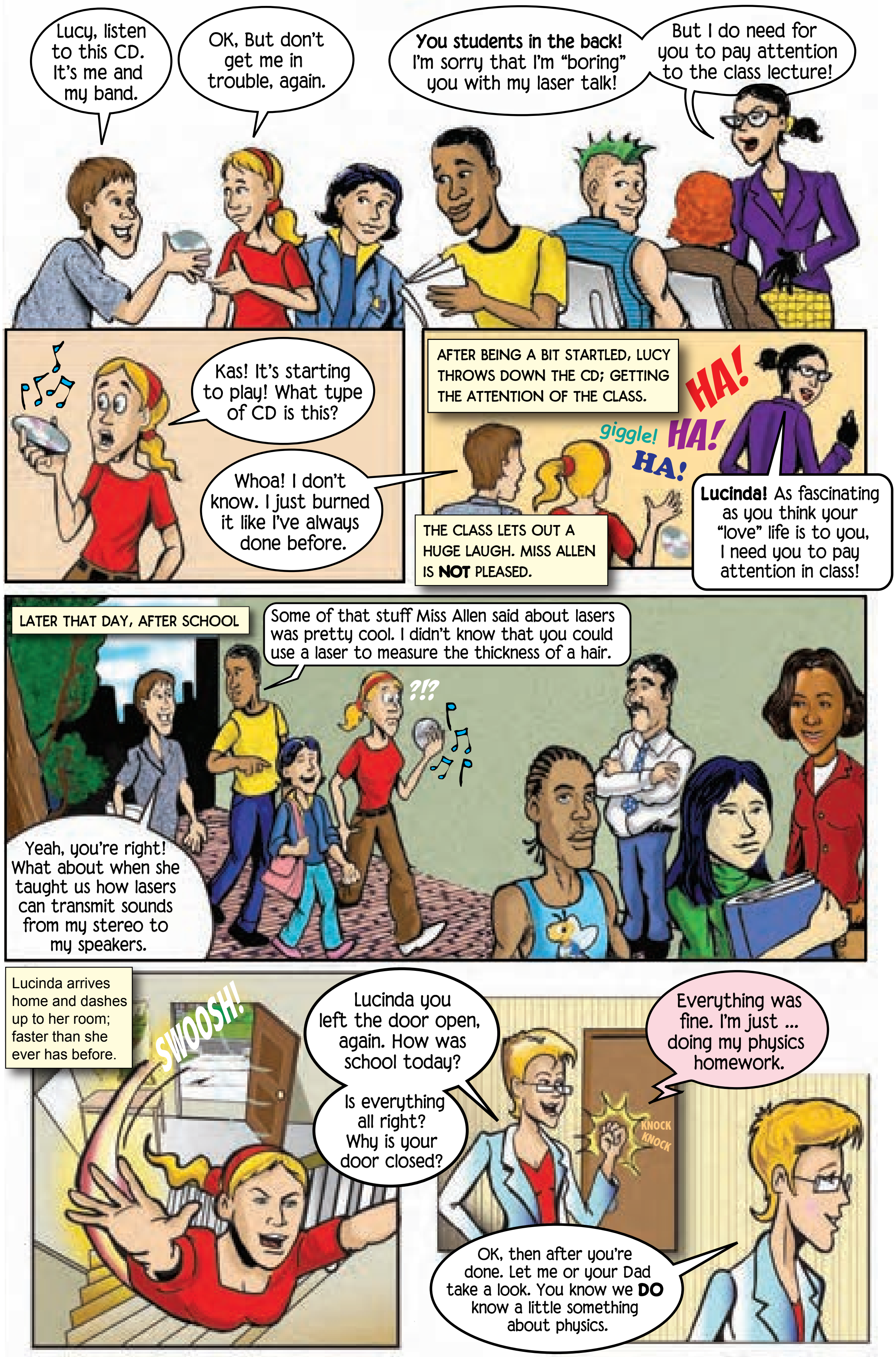
7. You should now do this for the other three pieces of cloth. Now average all those wavelengths together to come up with your answer. The more data you get, the more confident you can be in your final answer. This is what all good scientists do!

8. All of your answers should be in meters. You might have to convert your answers to do this. Now you should convert to nanometers. There are 100 centimeters in a meter and 1,000,000,000 nanometers (nm) in a meter. That's a lot!



USING YOUR RESULTS TO HELP SPECTRA "MISALIGN" ALIGNMENT:

What is the wavelength of your laser?
(Circle one)
1. About 200 nm
2. About 3,000 nm
3. About 600 nm
4. About 2 nm.


Lucy, listen to this CD. It's me and my band.
OK, But don't get me in trouble, again.
You students in the back! I'm sorry that I'm "boring" you with my laser talk!
But I do need for you to pay attention to the class lecture!
Kas! It's starting to play! What type of CD is this?
Whoa! I don't know. I just burned it like I've always done before.
AFTER BEING A BIT STARTLED, LUCY THROWS DOWN THE CD; GETTING THE ATTENTION OF THE CLASS.
HA! HA! HA!
giggle!
THE CLASS LETS OUT A HUGE LAUGH. MISS ALLEN IS NOT PLEASED.
Lucinda! As fascinating as you think your "love" life is to you, I need you to pay attention in class!
LATER THAT DAY, AFTER SCHOOL
Some of that stuff Miss Allen said about lasers was pretty cool. I didn't know that you could use a laser to measure the thickness of a hair.
?!?
Yeah, you're right! What about when she taught us how lasers can transmit sounds from my stereo to my speakers.
Lucinda arrives home and dashes up to her room; faster than she ever has before.
SWOOSH!
Lucinda you left the door open, again. How was school today?
Is everything all right? Why is your door closed?
KNOCK KNOCK
Everything was fine. I'm just ... doing my physics homework.
OK, then after you're done. Let me or your Dad take a look. You know we DO know a little something about physics.


Lucinda pulls out one of her favorite CDs. As she touches the CD, it starts playing. She's puzzled and shocked. But she still thinks her new "power" is pretty cool.
How is this CD playing?
Now I don't need to buy any more batteries for my CD player. SWEET!
KNOCK! KNOCK!
Lucinda, your mother told me that you were home. How's the homework coming?
Are you listening to your CDs or working on your homework?
Actually, I'm doing a little bit of both.
Huh?!?
Okay, finish up, dinner's ready.
I'll be down in a minute.
What's this I hear that you're studying lasers in physics class?
Yeah, we had a substitute. She gave us a long lecture about lasers and stuff.
... and stuff? Please use your vocabulary.
Lucinda begins to tell her parents about Miss Allen and all the information that she learned from the class. She then asked them to explain how lasers work.
First, Ruby tried to embarrass me in front of Miss Allen when she told her about you guys being physicists.
We also learned that lasers can play CDs and DVDs.
And we also learned that different colored lasers have different energies,
And did you know that light can bend when it goes through objects such as glass.
Hhhhmm..... I know that I can play CDs. I wonder what other powers I may have?
I'm done. May I be excused? I have to finish my homework.
ZOOM!!!
She's up to Something.
Definitely!


Lucinda begins to explore her new powers. She quickly flies across her room....
... bounces off the wall, to her hanging lamp; then gets redirected towards the mirror.
She reflects off the mirror...
PLING!
... and right into her fish bowl.
oh, oh! This is going to hurt!
Yet, instead of getting wet, Lucinda goes completely through the bowl.
WOW! That wasn't so bad. I've gotta try that again.
This time with more control, she runs toward her window.
She goes through the window.
SWEET! No more doors for me!
This is amazing! My body now plays CDs. I can go through windows, reflect and move super fast!
It seems that that I have the powers of a laser!
She flies back into her room and looks at herself in the mirror.
I remember Miss Allen talking about the change of colors with lasers.
She told the class that red light has less energy.
Like a laser, I must now have "low energy" after all that flying.
Perhaps, my playing around has caused me to turn red.
I wonder if I looked blue before dinner?
But why am I reddish?
Lucinda realizes that she's really exhausted and falls asleep. She dreams of saving the world with her new laser powers.

EXPERIMENT 2

How Thick is Your Hair?

TEACHER'S GUIDE

INTRODUCTION: In the last experiment we saw what happened when laser light was passed through fabric to find its wavelength as long as we knew how far apart the threads were. Now we can use wavelength to find the width of a hair.

KEY QUESTION: How can a laser be used to measure the width of a human hair?

MATERIALS:
- Laser pointer
- Tape
- Large sheet of paper
- Human hair
  (Ask nicely before plucking this from your friend's head)
- Binder Clips (2)
- Scissors
- Pencil
- Index card
- Ruler

BEFORE THE ACTIVITY, STUDENTS KNOW:
- Light can act like a wave.
- A laser pointer is a beam of light that is coherent and all the same color.

AFTER THE ACTIVITY, STUDENTS SHOULD BE ABLE TO:
- Describe how wave interact
- Explain the pattern formed on the wall when a laser is shined on a human hair
- Explain how to use this pattern to measure the width of a small obstacle such as a human hair.

KEY TERMS:

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

Diffraction: When light goes around an obstacle or through a single slit the light rays interact with each other. When they do, a patterns of dark and bright spots is created.

Interference: When light passes through two slits and the light rays from each of the slits interacts. It is like diffraction but involves more than one slit or obstacle.

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Destructive Interference: When two waves come together and cancel each other out

In Phase: When two waves are going up and down together

Out of Phase: When one wave is going up as the other is going down

THE SCIENCE BEHIND DIFFRACTION

Light is both a particle and a wave, or better yet, light has both wave properties and particle properties. In this kit we will do experiments that will show both sides of light. This experiment is one that shows that light has wave This is tricky thing to comprehend.

Lets start by thinking about what happens when waves interact. We will assume that we are dealing with two waves that have the same wavelength. When two waves come together they add up to make a resultant wave. If the two waves have crests and troughs at the same points, they add up to make a wave that is twice as big as the two individual waves. This is called "constructive interference." When two waves have crests and troughs at the same points they are said to be "in phase." If two waves are completely "out of phase" which means one wave is up while the other is down, they cancel each other out. This is called "destructive interference."

When water waves flow around a pylon because they spread out on the other side of the pylon they will come back together and interact with each other. Sometimes they constructively interfere and sometime they destructively interfere. If we were to measure the height of the waves on the other side of the pylon we would sometimes see big waves and sometimes see no waves at all.

You have always heard that light always goes in a straight line. Well it does. Except when it doesn't. When light encounters and obstacle that is really small, only slightly larger than the wavelength of light, it will spread out again as it passes the obstacle, just like water flowing around a pylon. This is called diffraction. So light behaves just like the example of water flowing around the pylon that we talked about before. But what does this have to do with finding the thickness of a hair? Well, as the light goes around the hair it is going to come back together at different points based on the thickness of the hair and the wavelength of light. (Figure 2) Sometimes the light waves will cross when they are both up, sometimes they will cross when one is up and one is down. It will depend on the wavelength of light and how far it has traveled. (Fig. 3) If the wavelength of light is smaller, say, blue or green light, then the pattern you would see would have the bright spots closer together. What do you think you would see if you could do this with white light?

So far we know the pattern on the wall depends on at least two different things, the thickness of the hair and the wavelength of the laser Does it depend on anything else? Imagine what would happen if you moved the hair closer to the wall. The pattern would change. In fact, the spots would get closer together. The mathematical way of saying all this is: thickness of hair=((wavelength of laser) * (Distance from hair to wall))/(average spacing between bright spots).

So to find the thickness of the hair, we need to know the wavelength of the laser. If you have done activity one you can use the value of wavelength you found there. If not, or if you are not sure of your answer to activity one, the wavelength of your laser is 670nm. In doing this experiment it is going to be necessary to pay close attention to units of distance. I would recommend changing everything to meters and then changing micrometers to determine your final answer. This will allow students to get practice in unit conversion.

EXPERIMENT 2

How Thick is Your Hair?

TEACHER'S GUIDE

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 an 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.

CORRESPONDING EXTENSION ACTIVITIES

- Spiraling CDs and DVDs
- Prisms
- Colors of Compact Florescent Bulbs

BIBLIOGRAPHY/SUGGESTED RESOURCES

http://www.exploratorium.edu/snacks/diffraction/index.html

Figure 1

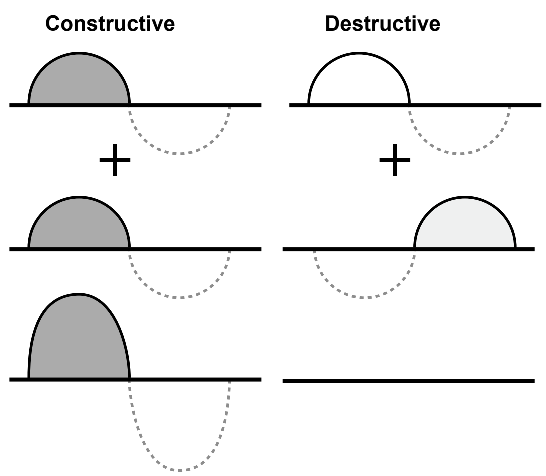


Figure 2

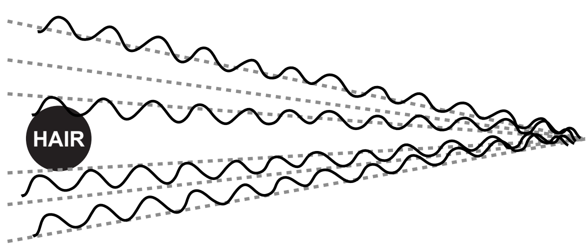


Figure 3

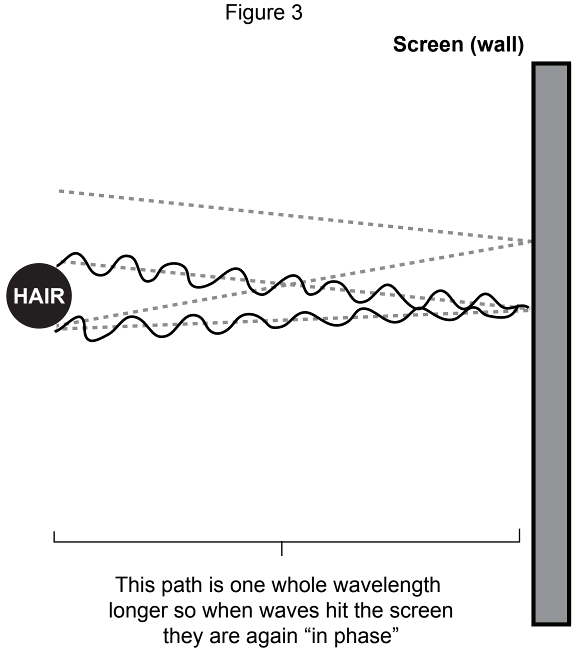
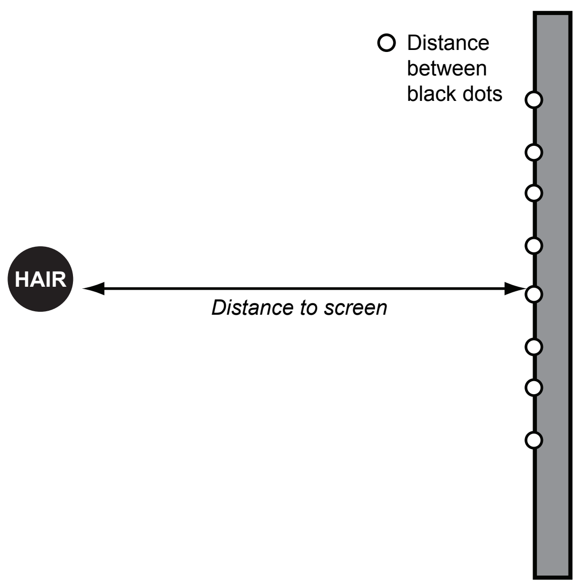


Figure 3



EXPERIMENT 2

How Thick is Your Hair?

STUDENT'S GUIDE

INTRODUCTION:

Ever wondered how thick your hair is? How do you think you might measure? Well it turns out that you can do it with a laser!

MATERIALS:

- Laser pointer
- Masking Tape
- Large sheet of paper
- Human hair
  (Ask nicely before plucking this from your friend's head)
- Binder Clips (2)
- Scissors
- Pencil
- Index card
- Ruler

KEY QUESTION:

How can a laser be used to measure the width of a human hair?

GETTING STARTED:

1. How thick do you think your hair is?

2. Do you think everyone in the class has hair of the same thickness?

3. When you shine a laser on a human hair, what do you think the resulting light pattern will look like? Draw it here.

SETTING UP THE EXPERIMENT:

1. Cut out the center of a 3 in. x 5 in. index card.

2. Have everyone in the group donate a hair. Ask nicely as this may hurt a bit!

3. Tape the hair in the middle of the index card. (Fig. 1)

4. Attach binder clips to sides of card so that it will stand up. (Fig. 2)

5. Place the laser pointer on top of a book so that the laser beam will shine directly on the hair and tape it down securely. (Fig. 3)

6. Put this set-up 4 meters from a wall and tape the large piece of paper to the wall so that the laser beam will shine on it.

KEY TERMS:

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

Diffraction: When light

goes around an obstacle or through a single slit the light rays interact with each other. When they do, a patterns of dark and bright spots is created.

Interference: When light passes through two slits and the light rays from each of the slits interacts. It is like diffraction but involves more than one slit or obstacle.

Constructive Interference: When two waves come together and make a bigger wave

Destructive Interference: When two waves come together and cancel each other out

In Phase: When two waves are going up and down together

Out of Phase: When one wave is going up as the other is going down

COLLECTING DATA

1. Turn off the lights in the room and turn on the laser pointer.

2. Make sure the laser is shining directly on the hair.

3. You should see a pattern of bright spots and dark spots on the wall.

4. Draw this pattern on the paper and then turn off the laser.

5. Repeat this for the hairs of all members in the group. You can mount them all on the same card and just move the laser.

EXPERIMENT 2

How Thick is Your Hair?

STUDENT'S GUIDE

ANALYZING YOUR DATA

How does the pattern compare to what you predicted?

Would you have gotten the same pattern if you shined a light bulb on the hair? Why not?

To use the pattern to find the width of the hair we are going to have to do some tricky, fun math.

For this experiment you can think of light as a wave. When it goes around the hair it does the same thing as wavy water going around a pylon. The waves spread out and then come back together. When waves come together if they are going up and down at the same time, they add up. If one is going up when the other is going down, they cancel each other out. With light, the bright spots are where the light is all going up and down together and the dark spots are formed when the waves are out of sync.

Or you can use the fancy terms "in phase" and "out of phase." The spacing of the bright and dark spots depends on the thickness of the obstacle the light has to go around, in this case the hair. The mathematical way of saying this is: thickness=((wavelength of laser) (Distance from hair to wall))/ (average spacing between bright spots). So now you need to find all those values. You also need to make sure all your measurements are in meters. The distance from the hair to the wall is 4 meters.

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You found the wavelength of your laser in activity one, but in case you skipped activity one, the wavelength is 650 nanometers (you need to convert to meters). To measure the average distance between bright spots see Fig. 2 (in the Teacher's Guide) Now put it all together and find the width of your hair!

How does the thickness you found compare to your prediction? ______________________________

____

Is the thickness different for different people's hair? Does hair color matter?

____

____

Figure 1

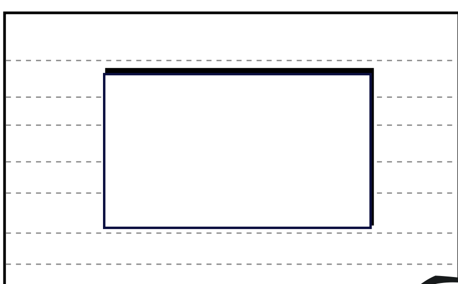


Figure 2

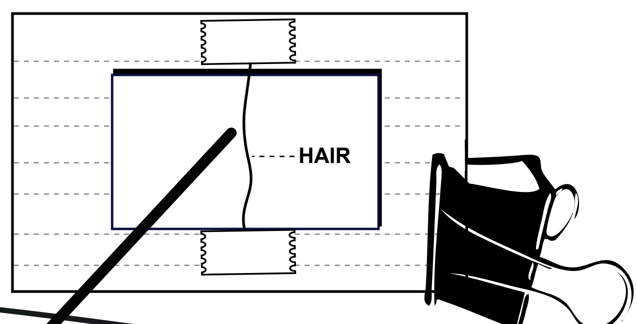
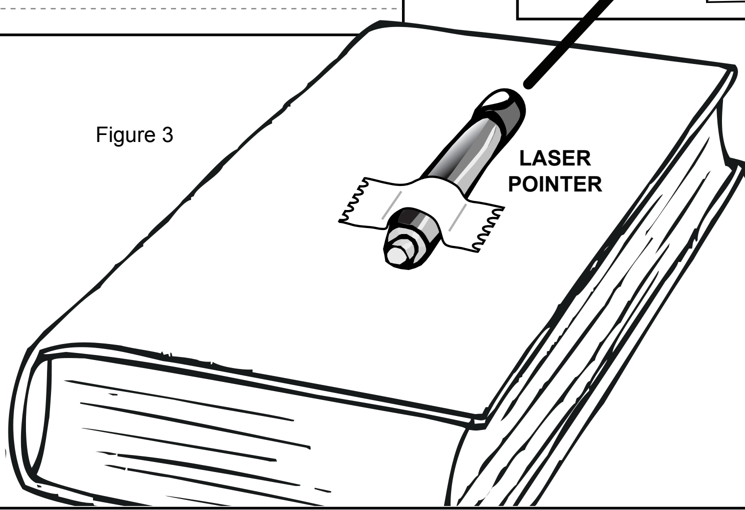


Figure 3



USING YOUR DATA TO HELP SPECTRA "MISALIGN" MISS ALIGNMENT

How thick is your hair?

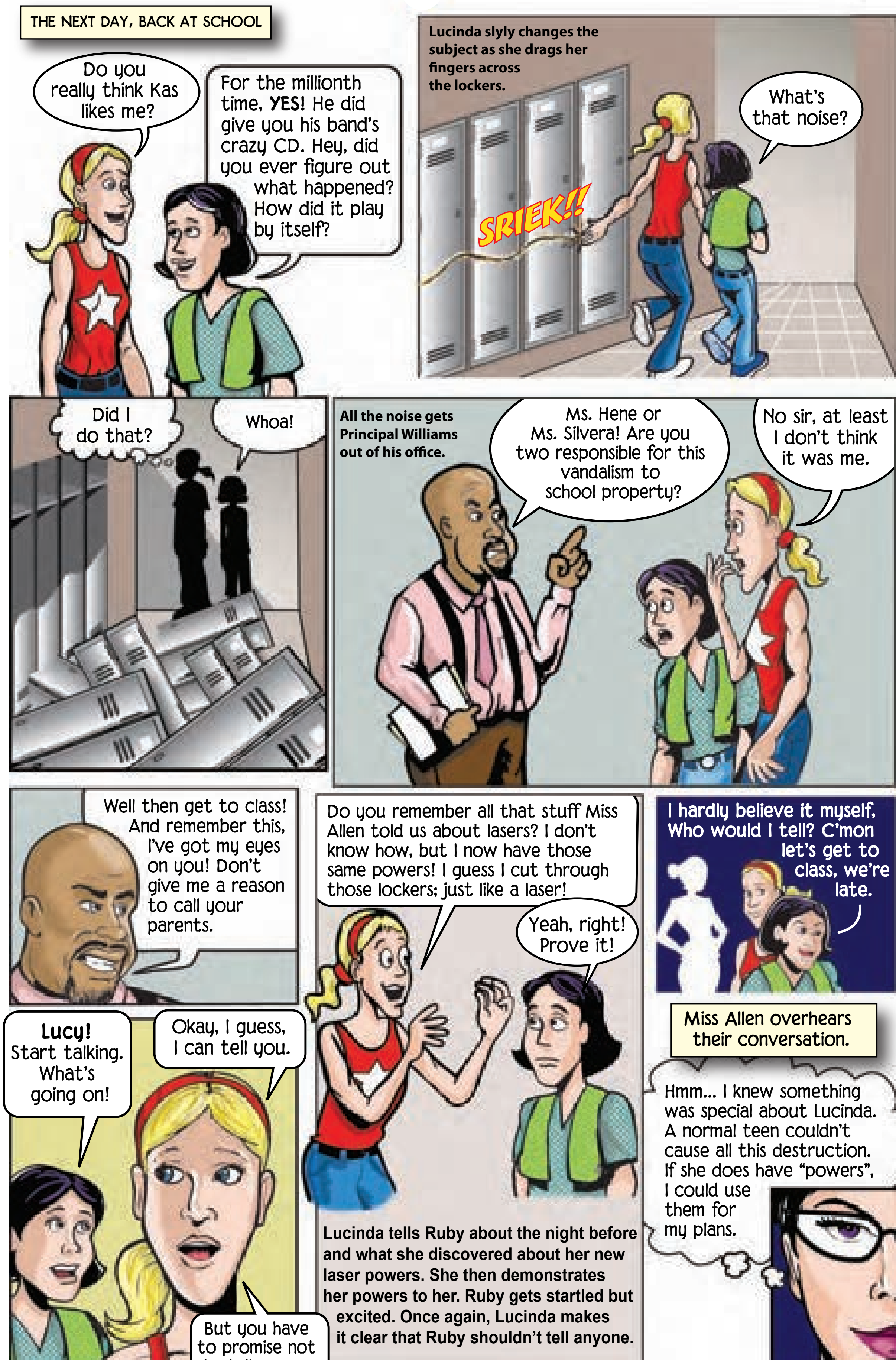
(Circle one)

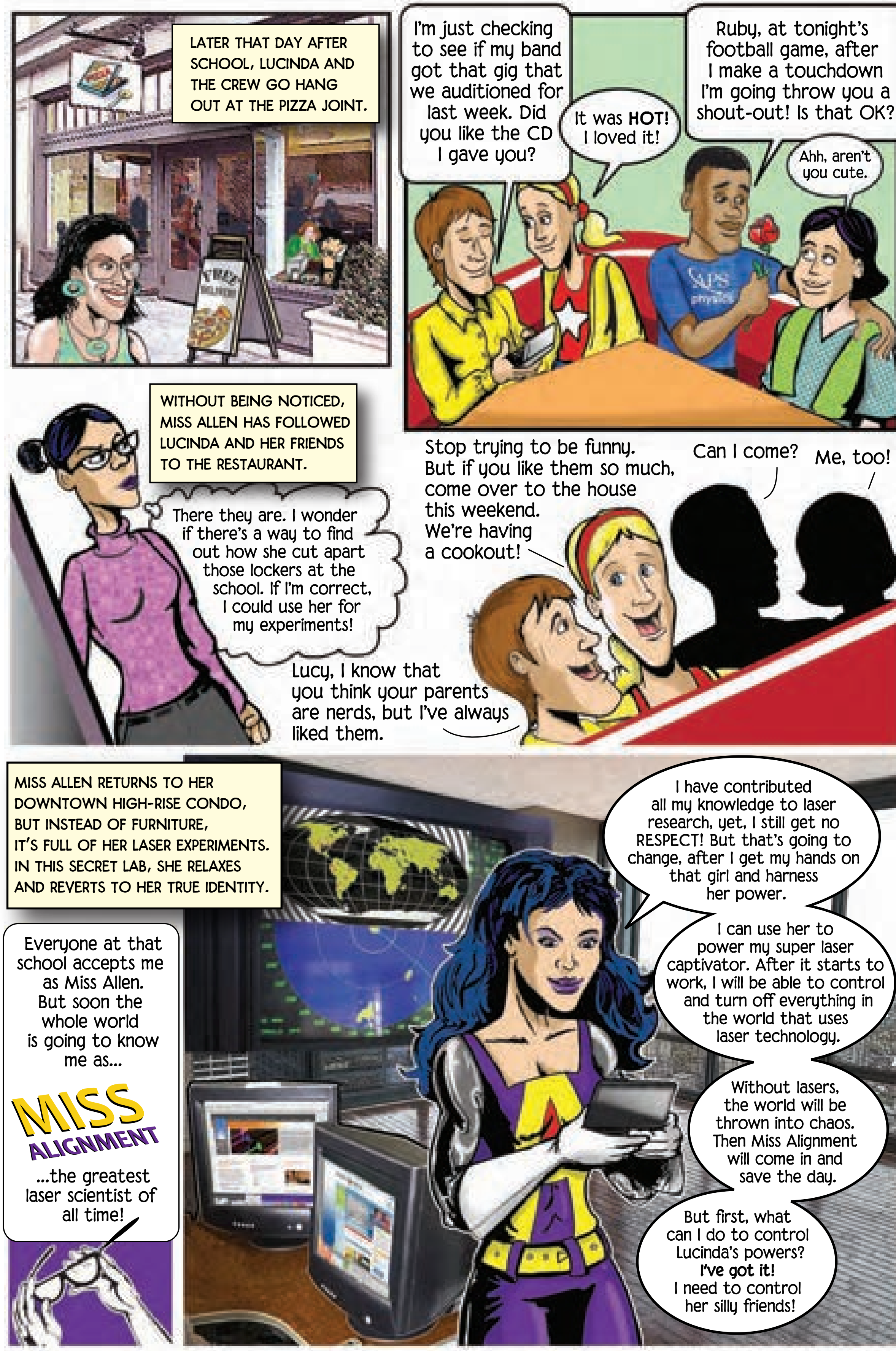
A. 100-400 nanometers

B. 1-4 micrometers

C. 30-200 micrometers

D. 300-1,000 micrometers


THE NEXT DAY, BACK AT SCHOOL
Do you really think Kas likes me?
For the millionth time, YES! He did give you his band's crazy CD. Hey, did you ever figure out what happened? How did it play by itself?
Lucinda slyly changes the subject as she drags her fingers across the lockers.
What's that noise?
SRIEK!!
Did I do that?
Whoa!
All the noise gets Principal Williams out of his office.
Ms. Hene or Ms. Silvera! Are you two responsible for this vandalism to school property?
No sir, at least I don't think it was me.
Well then get to class! And remember this, I've got my eyes on you! Don't give me a reason to call your parents.
Do you remember all that stuff Miss Allen told us about lasers? I don't know how, but I now have those same powers! I guess I cut through those lockers; just like a laser!
Yeah, right! Prove it!
I hardly believe it myself. Who would I tell? C'mon let's get to class, we're late.
Miss Allen overhears their conversation.
Hmm... I knew something was special about Lucinda. A normal teen couldn't cause all this destruction. If she does have "powers", I could use them for my plans.
Lucy! Start talking. What's going on!
Okay, I guess, I can tell you.
But you have to promise not to tell anyone.
Lucinda tells Ruby about the night before and what she discovered about her new laser powers. She then demonstrates her powers to her. Ruby gets startled but excited. Once again, Lucinda makes it clear that Ruby shouldn't tell anyone.


LATER THAT DAY AFTER SCHOOL, LUCINDA AND THE CREW GO HANG OUT AT THE PIZZA JOINT.
I'm just checking to see if my band got that gig that we auditioned for last week. Did you like the CD I gave you?
It was HOT! I loved it!
Ruby, at tonight's football game, after I make a touchdown I'm going throw you a shout-out! Is that OK?
Ahh, aren't you cute.
WITHOUT BEING NOTICED, MISS ALLEN HAS FOLLOWED LUCINDA AND HER FRIENDS TO THE RESTAURANT.
There they are. I wonder if there's a way to find out how she cut apart those lockers at the school. If I'm correct, I could use her for my experiments!
Stop trying to be funny. But if you like them so much, come over to the house this weekend. We're having a cookout!
Can I come?
Me, too!
Lucy, I know that you think your parents are nerds, but I've always liked them.
MISS ALLEN RETURNS TO HER DOWNTOWN HIGH-RISE CONDO, BUT INSTEAD OF FURNITURE, IT'S FULL OF HER LASER EXPERIMENTS. IN THIS SECRET LAB, SHE RELAXES AND REVERTS TO HER TRUE IDENTITY.
Everyone at that school accepts me as Miss Allen. But soon the whole world is going to know me as...
MISS ALIGNMENT
...the greatest laser scientist of all time!
I have contributed all my knowledge to laser research, yet, I still get no RESPECT! But that's going to change, after I get my hands on that girl and harness her power.
I can use her to power my super laser captivator. After it starts to work, I will be able to control and turn off everything in the world that uses laser technology.
Without lasers, the world will be thrown into chaos. Then Miss Alignment will come in and save the day.
But first, what can I do to control Lucinda's powers? I've got it! I need to control her silly friends!

EXPERIMENT 3

Light and Dark

TEACHER'S GUIDE

■ **INTRODUCTION:** This is a neat and surprising little experiment. Everyone has seen polarization in there everyday lives. Many people know that if you cross two polarizers no light will be able to pass through. But the real fun starts when three polarizers are put in a row. This gives shocking and counter intuitive results but once the phenomenon is understood the students will have a much deeper understanding of the nature of polarization.

■ **KEY QUESTION:** What happens when you put three polarizers in a row and look at an LED through all three?

■ **MATERIALS:**
- LED flashlight (not laser pointer)
- Tape
- Marker
- Polarizers (3)
- Binder clips (3)
- Protractor

■ **BEFORE THE ACTIVITY, STUDENTS SHOULD KNOW:**
- Polarizers select light who's electric field is going in a particular direction
- When two polarizers are crossed, no light can get through.
- Polarizers are used in many things such as sunglasses.
- A vector is a way if indication both a magnitude and a direction.

■ **AFTER THE ACTIVITY, STUDENTS SHOULD BE ABLE TO:**
- Understand and explain why no light can pass through polarizers that are crossed.
- Understand and explain what happens to light when it passes through three polarizers in a row.
- Polarizers are used in many things such as sunglasses.
- Explain this phenomenon using vectors.

■ **THE SCIENCE BEHIND POLARIZATION**

If you have done the two previous experiments you have learned a bit about the wave nature of light. But light is a wave of what exactly? How does that something interact with its surroundings? Picture an electron. It creates an electric field. You have probably seen a drawing with arrows coming out of an electron.

The arrows are vectors that tell you the direction of the electric field and how strong it is. You can do the same thing with a magnet and a magnetic field. Light is a combination of the two types of fields. The electric field is pointing in one direction and the magnetic field is pointing 90 degrees to that. But where does the wave come in? Normally when you see pictures of electric fields they are just sitting there, not moving. But with light, the electric field is moving like a wave and so is the magnetic field. Notice we haven't said how the fields are actually created. Who cares!

They are there now and that is all that matters. If you must know, it comes from electrons jiggling around and there are many ways to make electrons jiggle.

■ **KEY TERMS:**

LED: Stands for "light emitting diode." A diode is a part of a circuit that only allows current to go in one direction. Some types of diodes will glow when current passes through them. Many lasers are made out of LEDs, though all LEDs are not lasers.

Polarizer: A polarizer is a sheet made up of long chains of polymers that only allow electric fields of one direction to pass through.

Polarized: Light is made of both an electric and magnetic field. When the electric field of all the light rays is going in the same direction it is said to be "polarized light." To polarize light it is passed though a polarizer.

Vector: An arrow that can indicate both direction and magnitude.

Most of the time the electric field of different light rays are going in different directions. If you could see the direction of the electric fields of the light all the light rays all around you right now, they would all be going in different directions.

When this is the case, the light is said to be "unpolarized." When light is polarized, it means that the electric field of every light ray is moving in the same direction. To make this happen, unpolarized light can be passed through a polarizer.
A polarizer picks out the light rays with electric fields going in one particular direction.

A polarizer acts like a filter and only allows light rays in one direction to pass through. The polarizers in you kit are actually clear plastic coated with a film of long chains of polymers. When light hits this, only light that has some part of its electric field vectors going in the direction of the polymer chains in the polarizer will pass through. This means that the light that comes out of a polarizer has electric fields all going in one direction.

Note that we said that light that has some part of its electric field vector in the direction of the polarizer can pass though. This is a bit of a tricky statement, but like all tricky ideas it is also the most interesting part. Imagine an arrow pointing at 45 degrees. If you were to draw this arrow on an x, y plot, you would need to know how much is going in the x direction and how much is going in the y direction. So the arrow has some x and some y components. Now think of this arrow as describing the direction of the electric field of a ray of light. Next think of the polarizer as being in the x direction, so that only light with some x component can go through. Even though our 45 degree light ray isn't completely in the x direction, it has some amount in the x direction. Because it has a little bit in the x, that part can pass through the polarizer. The light that comes out the other side has all of its electric field in the x direction.

EXPERIMENT 3

Light and Dark

TEACHER'S GUIDE

Now what if this light were to try and go through a polarizer that was in the y direction it couldn't. Because the light has no component in the y direction it would be completely blocked. This is why light can't go through crossed polarizers. This experiment puts three polarizers in a line and looks at what happens when the middle on of the three is turned. The first and third polarizers are crossed but the middle one is free to move. You might assume that because the first and third polarizers are crossed that no light will make it to the end, but when you preform the experiment it becomes clear this is not the case. So what is happening here?

Lets follow the light one step at a time. First light of all polarizations hits the first polarizer which picks out light in one direction, lets call that x. So when the light gets to the second polarizer it is all going in the x direction. This second polarizer is moved around during the experiment. When the polarizer is turned so that it is a least pointing a little bit in the x direction, so of the light can get through it. So now we move on to the third polarizer.

At this point all the light is going in whatever direction the second polarizer is pointing. The third polarizer is pointing in the y direction. If the light coming out of the second polarizers is going even a little bit in the y direction then some of it will pass through the third polarizer and you can see it at the very end. So, basically, if the third polarizer's direction is pointing in a way that gives it both some x and y direction then light can get all the way through. The most light gets through when the second polarizer has the same amount of x and y.

What does all this have to do with lasers? Well it turns out, not much. Many people think that laser light must be polarized, but that isn't true. As long as laser light is all "in phase" (see activity 1) then it is laser light. However, most laser light is polarized. Look at your laser through the polarizer and see if it is polarized.

CORRESPONDING EXTENSION ACTIVITIES

- Polarization All Around You
- Polarize a Slinky
- Glaring Polarization

EXPERIMENT 3

Light and Dark

STUDENT'S GUIDE

INTRODUCTION:

Polarizers are all around us, but most of us usually see them in sunglasses. But why are they used in sunglasses and what exactly do they do? Do they just block some light or is there something special about them? This experiment will look at some of the properties of polarizers and hopefully give you some surprising results!

MATERIALS:

- LED flashlight (not laser pointer)
- Tape
- Marker
- Polarizers (3)
- Binder clips (3)
- Protractor

KEY QUESTION:

What happens when you put three polarizers in a row and look at an LED through all three?

GETTING STARTED:

- What do you think it means for light to be "polarized"?
- Where have you seen polarization before?
- Why do you think a polarizer looks dark?

SETTING UP THE EXPERIMENT:

1. Place a small piece of masking tape on the side of all three polarizers.

2. Line up the polarizers so that they are all facing the same direction. This means you will be able to see a lot of light if you look through all three.

3. Draw an upward arrow on each of the polarizers. This will let you know which was the light is being polarized. (Fig. 1)

4. Attach a binder clip to each polarizer so that when placed on a table the stand up facing in the same direction. (Fig. 2)

5. Lay the LED on top of a book so that you can look through the polarizers and see the LED (Fig. 3)

COLLECTING DATA

- Set up two polarizers so that the arrows are pointing perpendicular. Look at the LED through the two polarizers. You should not be able to see much light at all.

- While looking at the LED, turn the polarizer closest to the LED 10 degrees to the right. On a scale of one to ten, where one is no light a ten is full brightness, how bright does the LED appear?

- Continue to turn the polarizer in 10-degree increments and ranking the brightness until you have turned the polarizer a full 180 degrees. (Fig. 4)

- Start with the set up in step one but this time put the third polarizer in between the first and second. The polarizer should be in the same direction as the polarizer closest to the LED.

- This time you will turn the middle polarizer in 10-degree increments and rank the brightness of the LED as viewed through the polarizers. Make sure you turn the polarizer a full 180 degrees.

KEY TERMS:

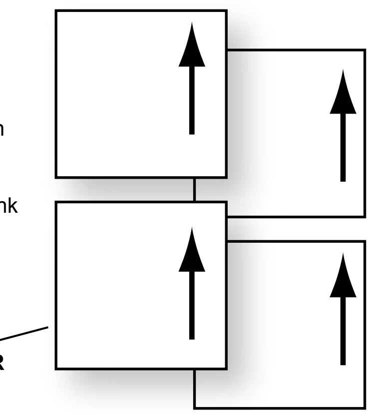
LED: Stands for "light emitting diode." A diode is a part of a circuit that only allows current to go in one direction. Some types of diodes will glow when current passes through them. Many lasers are made out of LEDs, though all LEDs are not lasers.

Polarizer: A polarizer is a sheet made up of long chains of polymers that only allow electric fields of one direction to pass through.

Polarized: Light is made of both an electric and magnetic field. When the electric field of all the light rays is going in the same direction it is said to be "polarized light." To polarize light it is passed though a polarizer.

Vector: An arrow that can indicate both direction and magnitude.

Figure 1



POLARIZER

EXPERIMENT 3
Light and Dark

STUDENT'S GUIDE

ANALYZING YOUR DATA

1. What happened to the brightness of the LED as you rotated the polarizer in the first experiment? What this what you expected? Why?

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2. How bright did the LED appear in the as you rotated the polarizer in the second experiment? Was that what you expected?

3. Create two graphs, one for each experiment. Graph your results putting degrees rotated on the x-axis and brightness on the y-axis.

4. In experiment 2, why do you think there are points where you can see the LED through all three polarizers, but when there are two crossed polarizers you can't? What is it about the third polarizer that allows you to see light?

5. Why might polarized sunglasses block glare? What can you say about glare and polarization?

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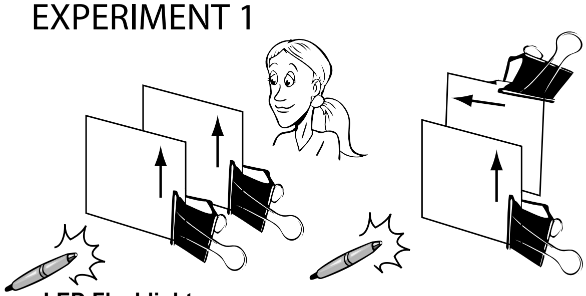
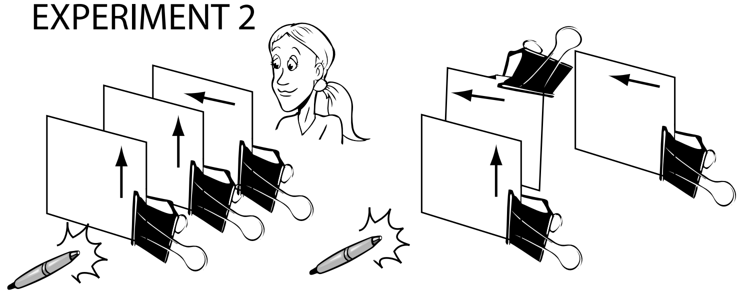
EXPERIMENT 1



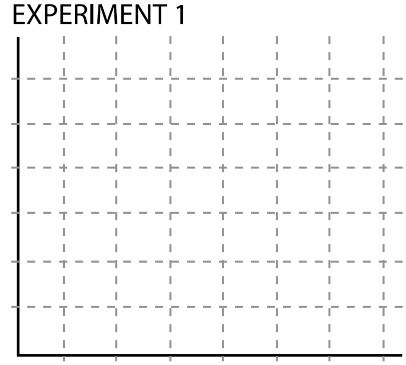
LED Flashlight

EXPERIMENT 2

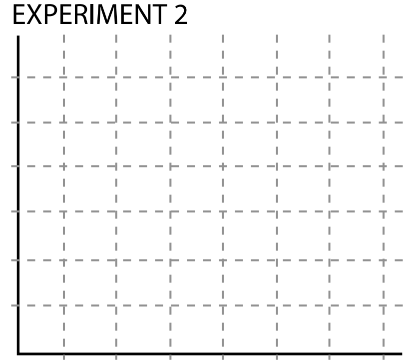


Draw your graphs below

EXPERIMENT 1

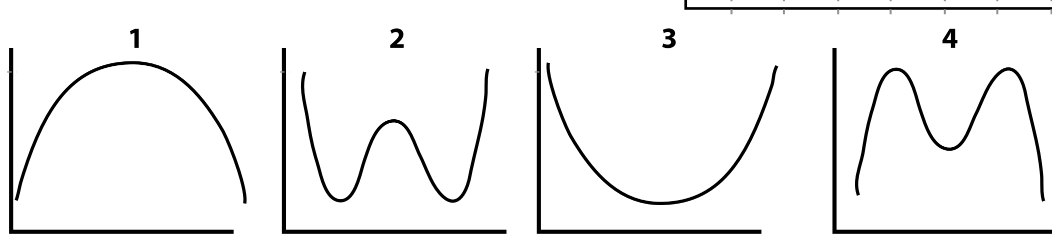


EXPERIMENT 2



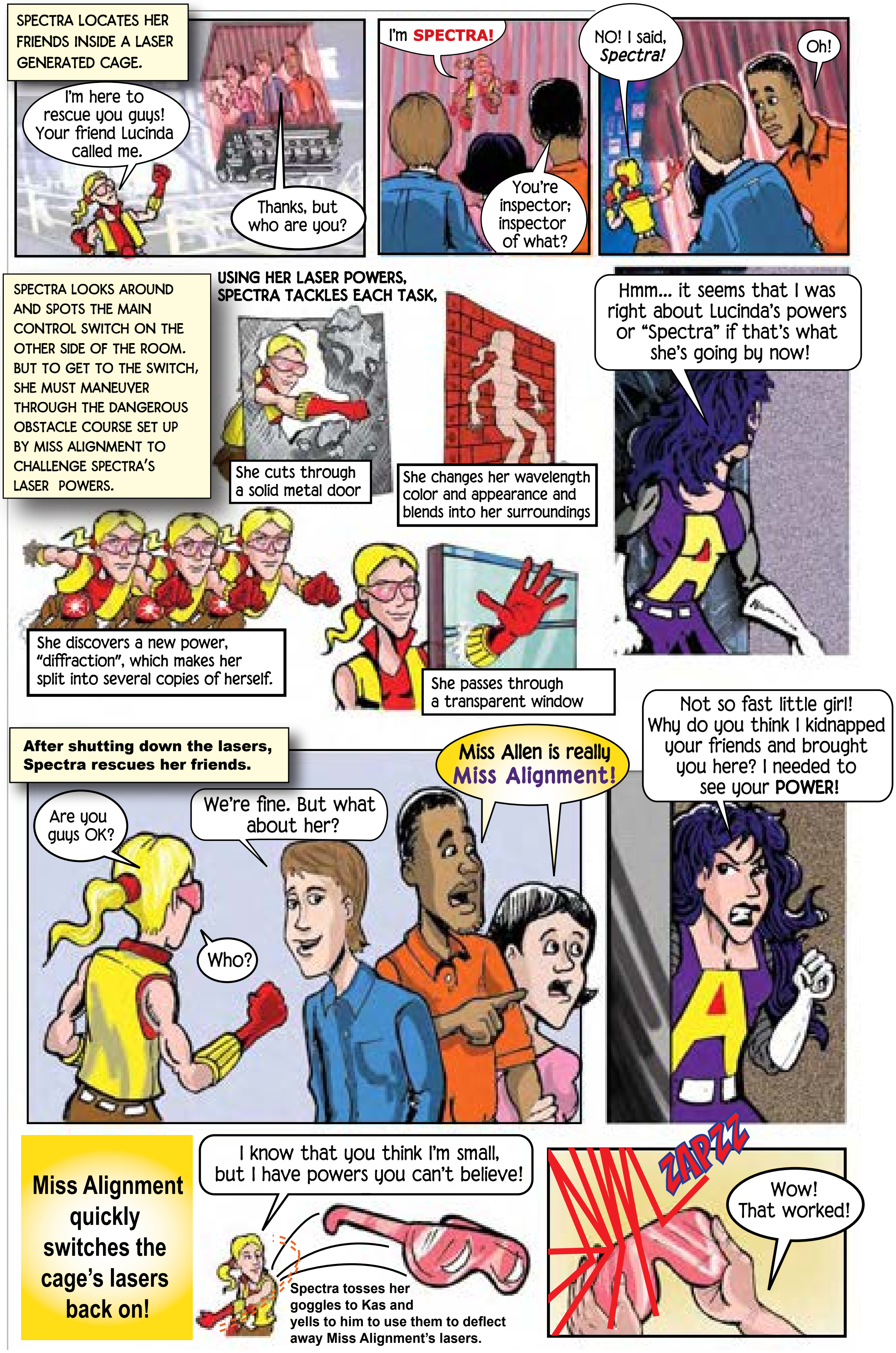
USING YOUR DATA TO HELP SPECTRA "MISALIGN" MISS ALIGNMENT

- Which graph looks like your graph for Experiment 2?




MISS ALIGNMENT AKA "MISS ALLEN" WORKS ON DEVELOPING HER RELATIONSHIPS WITH EACH OF LUCINDA'S BUDDIES AS A FRIEND AND MENTOR. THEY SLOWLY BEGIN TO TRUST HER.
SHE WEARS SOME OF RUBY'S CUSTOM FASHION DESIGNS.
SHE PRETENDS TO LIKE THE MUSIC BY KAS' BAND.
SHE HELPS GORDY DEVELOP A BETTER TOUCHDOWN PASS.
MISS ALLEN GETS TO BE KNOWN AS THE "COOL" TEACHER! ON THE DAY OF THE BIG SWIM MEET, SHE VOLUNTEERS TO GIVE THE UNSUSPECTING TRIO A RIDE TO GO WATCH LUCINDA COMPETE!
AFTER GETTING INTO THE SUV, MISS ALLEN LOCKS THE DOORS AND TELLS THEM TO MAKE CERTAIN TO PUT ON THEIR SEATBELTS. THE FRIENDS DO AS INSTRUCTED.
AFTER EACH CLICK OF THE BELT, THEY ARE ZAPPED BY THE RIGGED SEATBELTS.
CLICK!
CLICK!
CLICK!
ZAPZ!
THEY'RE UNCONSCIOUS! MISS ALIGNMENT KNOWS THAT HER PLAN HAS WORKED!
SHE HURRIEDLY TAKES HER "CAPTIVES" TO HER SECRET LABORATORY NEAR THE LAKE.
AFTER SHE ARRIVES, SHE MOVES THE SEDATED TRIO INTO A SPECIAL LASER-GENERATING CAGE.
MISS ALLEN KNOWS HOW MUCH LUCINDA CARES ABOUT HER FRIENDS, SO SHE SENDS HER A "FRIENDLY" TEXT MESSAGE.
I HAVE YOUR FRIENDS! LET'S SEE IF YOUR "LASER" POWERS CAN SAVE THEM! MEET ME @ THE CAVE BY THE LAKE! - MISS ALIGNMENT


AT FIRST LUCINDA THINKS RUBY IS PLAYING A PRANK ON HER. SHE CALLS HER BACK. SHE REPLIES TO MISS ALIGNMENT'S TEXT.
LUCINDA GETS A NEW "PHOTO" TEXT MESSAGE. IT'S HER FRIENDS.
It's not a joke!
And who is this "Miss Alignment?"
LUCINDA NOW REALIZES THAT SHE MUST SAVE HER FRIENDS. BUT SHE DOESN'T WANT ANYONE TO RECOGNIZE HER WHILE SHE'S LEARNING TO CONTROL HER NEW POWERS. SHE RUSHES HOME AND GOES DOWN TO HER PARENTS' LAB FOR ANYTHING SHE CAN GATHER TO HELP RESCUE HER FRIENDS.
SHE FINDS SOME OF HER OLD CAMPING GEAR!
SHE FINDS HER HIKING BOOTS.
SHE GETS A "LASER" DECAL FROM ONE OF HER MOM'S EXPERIMENTS.
AND LASTLY, SHE FIGURES OUT A WAY TO CONCEAL HER FACE.
NICE! I like it! But what do I call myself?
Wait a minute. I have the powers of a laser and light. I've got the perfect name!
Shooting Star? Nope, I don't even play basketball.
Laser Girl? Naw, that's dumb.
SuperGirl? Nope, that's already taken.
WATCH OUT WORLD, HERE COMES...
SPECTRA
THE ORIGINAL LASER SUPERHERO
SPECTRA FLIES TOWARD THE ADDRESS FROM THE TEXT MESSAGE. SHE QUICKLY DISCOVERS FLYING ISN'T AS EASY AS IT LOOKS IN COMIC BOOKS!
IT WAS A "BUMPY" RIDE. BUT SHE GETS THERE!
PLOP!
I hope that I'm not too late!
SPECTRA ENTERS THE CAVE.


SPECTRA LOCATES HER FRIENDS INSIDE A LASER GENERATED CAGE.
I'm here to rescue you guys! Your friend Lucinda called me.
Thanks, but who are you?
I'm SPECTRA!
You're inspector; inspector of what?
NO! I said, Spectra!
Oh!
SPECTRA LOOKS AROUND AND SPOTS THE MAIN CONTROL SWITCH ON THE OTHER SIDE OF THE ROOM. BUT TO GET TO THE SWITCH, SHE MUST MANEUVER THROUGH THE DANGEROUS OBSTACLE COURSE SET UP BY MISS ALIGNMENT TO CHALLENGE SPECTRA'S LASER POWERS.
USING HER LASER POWERS, SPECTRA TACKLES EACH TASK.
She cuts through a solid metal door
She changes her wavelength color and appearance and blends into her surroundings
Hmm... it seems that I was right about Lucinda's powers or "Spectra" if that's what she's going by now!
She discovers a new power, "diffraction", which makes her split into several copies of herself.
She passes through a transparent window
After shutting down the lasers, Spectra rescues her friends.
Are you guys OK?
We're fine. But what about her?
Who?
Miss Allen is really Miss Alignment!
Not so fast little girl! Why do you think I kidnapped your friends and brought you here? I needed to see your POWER!
Miss Alignment quickly switches the cage's lasers back on!
I know that you think I'm small, but I have powers you can't believe!
Spectra tosses her goggles to Kas and yells to him to use them to deflect away Miss Alignment's lasers.
ZAPZZ
Wow! That worked!

EXPERIMENT 4

Glow in the Dark

TEACHER'S GUIDE

INTRODUCTION: To demonstrate the energy of light and show that different wave lengths of light have different energies.

KEY QUESTION: What colors of light cause a glow in the dark square to glow?

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

KEY TERMS:
Wavelength: The distance from one wave peak to the next.

Intensity: The strength of something. *ex:* Brighter light has more intensity.

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

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 that we see.

THE SCIENCE BEHIND DIFFRACTION:

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. It will just sit right where it is and the red photon will simple 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 again. One really cool thing to realize is that this electron which needs a blue photon to jump up could be hit by hundreds, millions, 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.

EXPERIMENT 4

Glow in the Dark

TEACHER'S GUIDE

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's 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 an 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.

CORRESPODING EXTENSION ACTIVITES

- Glowing drinks
- Clean heat
- Painting particles

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

Figure 1

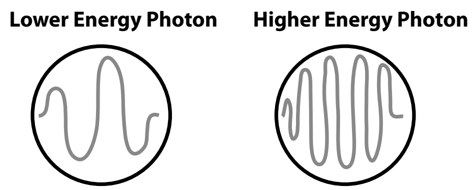
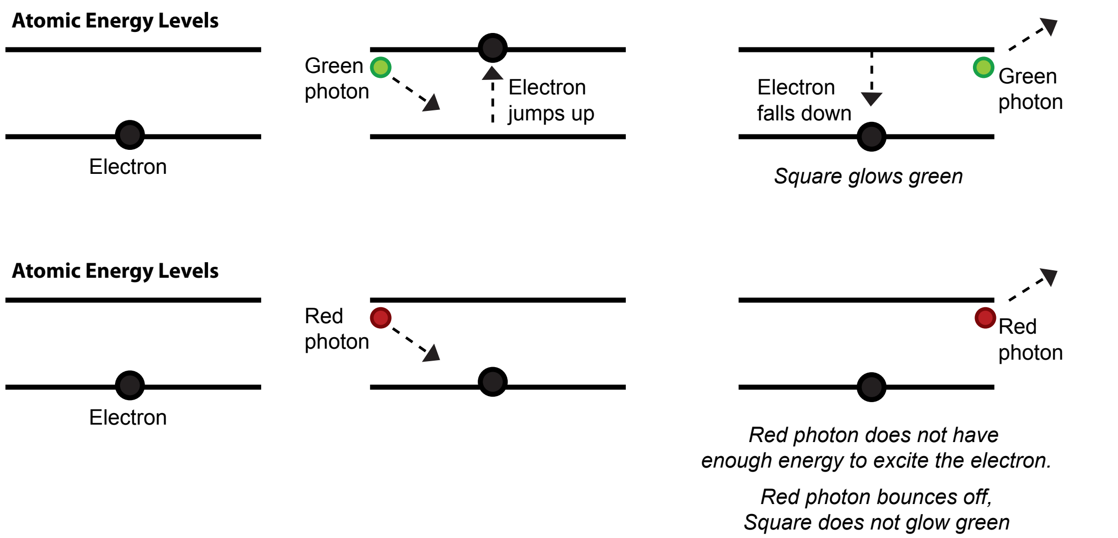


Figure 2



EXPERIMENT 4
Glow in the Dark

STUDENT'S GUIDE

INTRODUCTION:
Have you every wondered why your favorite glow in the dark t-shirt glows? Or ever wondered why you have to "charge it up" before you can impress your friends with its stunning glow? Every 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.

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

KEY TERMS:
Wavelength: The distance from one wave peak to the next.

Intensity: The strength of something. *ex:* Brighter light has more intensity.

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

GETTING STARTED:
1. To get a glow in the dark material to glow, what do you have to do to it first?

____

____

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

____

____

____

3. Why is a rainbow in the order that we see?

____

____

____

SETTING UP THE EXPERIMENT:
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 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 green by applying red light?

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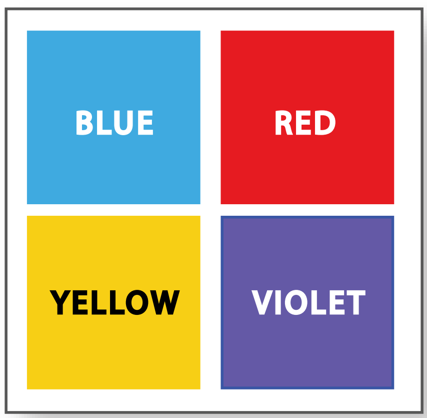

EXPERIMENT 4

Glow in the Dark

STUDENT'S GUIDE

ANALYZING YOUR DATA

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 cross out the colors that did not.

____

____

____

Do you see a pattern? **YES** **NO**

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 DATA TO HELP SPECTRA "MISALIGN" MISS ALIGNMENT

Which color gel filters allowed the vinyl to glow? *(Circle one)*

A. Blue and purple

B. Red and yellow

C. Red and blue

D. Red and blue


Nice trick, but your heroics have made you reveal yourself!
Lucinda!
Now, it all makes sense.
I knew it!
Yeah it's me. Hey guys!
Enough with the reunion show! You may have won this first round. But now I know what you can do with your powers.
Take my word for it. You and I will meet again. I need to use you to complete my ultimate laser experiment.
MISS ALIGNMENT SHINES A LASER POINTER INTO THE QUARTET'S EYES; TEMPORARILY BLINDING THEM AS SHE ESCAPES!
Don't be late for physics class! HA HA HA!
I'm glad that you guys are safe. Let's get out of here!
Lucy, you've got a lot of explaining to do.
You don't have to tell me twice.
Ruby knows a little, but let me tell you guys what has happened to me lately.
AS THEY HEAD HOME, LUCINDA TELLS THEM ABOUT HER POWERS.
But what do you think Miss Alignment meant when she said that she wants to use you?
I don't know?
AT AN UNDISCLOSED LOCATION.
Lucinda Hene and her laser powers are the final components needed for my super laser captivator to function! She passed all my tests, I now know her strengths and weaknesses! I can't wait until we meet again! I have special plans for SPECTRA!
HA! HA! HA!
To Be Continued...

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, which has supplemental material such as extension activities.

The 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 answers to help Spectra free her friends from the clutches of Miss Alignment.

The Teacher's 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, and some historical background. 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 that are provided in the kit are in bold type; you will need to provide the rest.

• Extension Activities
Extension activities related to each activity can be found on the PhysicsQuest website. This section gives a brief description of those related to the activity.

• Bibliography and 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's Guide for each activity includes:

• The Student Guide
Each activity has a Student Guide that you will need to copy and hand out to all of the students. In addition, you will need to copy the PhysicsQuest Challenge / Final Report and comic panel inserts and hand them out to your students when you first start the PhysicsQuest activities

• 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.

Materials List

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.

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.

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.

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.

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!

Using 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 winter break, or other such times. PhysicsQuest also works well as a science club activity and extra credit opportunity.

PhysicsQuest as a 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.

INCLUDED WITH KIT:

- PhysicsQuest manual
- Red Laser Pointer (1)
- Diffraction Grating Card Kit (1)
- LED Flashlight (1)
- 0.5 in. Binder Clips (3)
- Phosphorescent Vinyl Square (1)
- Blue transparency film (1)
- Violet transparency film (1)
- Red transparency film (1)
- Yellow transparency film (1)
- Polarizing Filters (3)

NOT included with kit: Tape, Meter stick, 3 x 5 index cards, Large sheet of blank paper, protractor, human hair

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