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PROUDLY PRESENTS

# SPECTRA

## CURRENT CRISIS

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# Welcome to PhysicsQuest: Spectra's Current Crisis

## Your Mission

You are about to go on an adventure learning about electricity and color as Spectra and her gang try to figure out who's been sabotaging the town's new *Magno-Go-Round*. Can you solve the mystery of the mysterious man in the white suit before they do?

## 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 enthusiastically received 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.

This year, APS is pleased to present this eleventh kit, ***PhysicsQuest: Spectra's Current Crisis***.

In the past, each *PhysicsQuest* kit has followed a mystery-based storyline and has required 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 defeat of General Relativity, the evil antics of Maxwell's Demon, a descent into the competitive madness of Henri Toueaux, the unfortunate adventures of the Quantum Mechanic, and a second round of Miss Alignments antics.

In this edition of *PhysicsQuest*, the Terminal Twins, Andy and Cathy, come into town promising to build an amazing ride whose profits will fund a new science lab for the school. As usual, nothing goes according to plan. Spectra and her team use their powers—and physics—to save the town and catch some crooks.

Students will learn about color, conduction, resistance, magnetism, and electricity.

## 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 (www.physicscentral.com), a website aimed at communicating the excitement and importance of physics to the general public.

At 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, and her swim team's coach with his unusual and destructive coaching methods. 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 four 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 up with other teachers and classes, there is now a Facebook group, *PhysicsQuest*. It's a great way to talk with other *PhysicsQuest* groups or learn helpful tips and tricks.

## About the PhysicsQuest Competition

If you would like to submit your answers online for a chance at prizes, you may do so before November 25th. We will draw names from those submitting answers for first, second, and third place prizes.

## PhysicsQuest Materials

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

## Comic Book

Each activity is preceded by several comic book pages that 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 save the town from the Terminal Twins.

Many of the *PhysicsQuest* experiments are part of the comic book plot; you are encouraged to discuss these with your class.

## 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.

## 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, contact Educational Innovations, 203-229-0730 or www.TeacherSource.com.

### Included in this kit:

- PhysicsQuest manual/comic book
- Beads
- Coin batteries
- Craft dough
- Magnet
- Nail
- Wire
- AA battery
- Cocktail umbrella
- Red, green, and blue LEDs
- Pencil

### Not included in this kit:

- Water
- Scissors
- Plastic cups
- Styrofoam
- Lots of tape
- Paper
- Permanent marker

### 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 up 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, websites, 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 your 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 provides 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.

### 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 all the 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!

### 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 or as an 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 those corresponding units.

### PhysicsQuest as an all-school activity

Some schools set up *PhysicsQuest* activity stations around the school gym for one afternoon. 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 carry out the activities


## APS PhysicsQuest Publication Staff

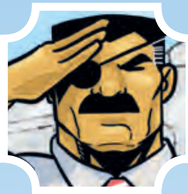
Coordinated, Researched, and Written by Rebecca Thompson, Ph.D.
Teacher Manual graphics by James Roche
Comic Art by David Ellis and Amanda J. Ellis

**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.

**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.

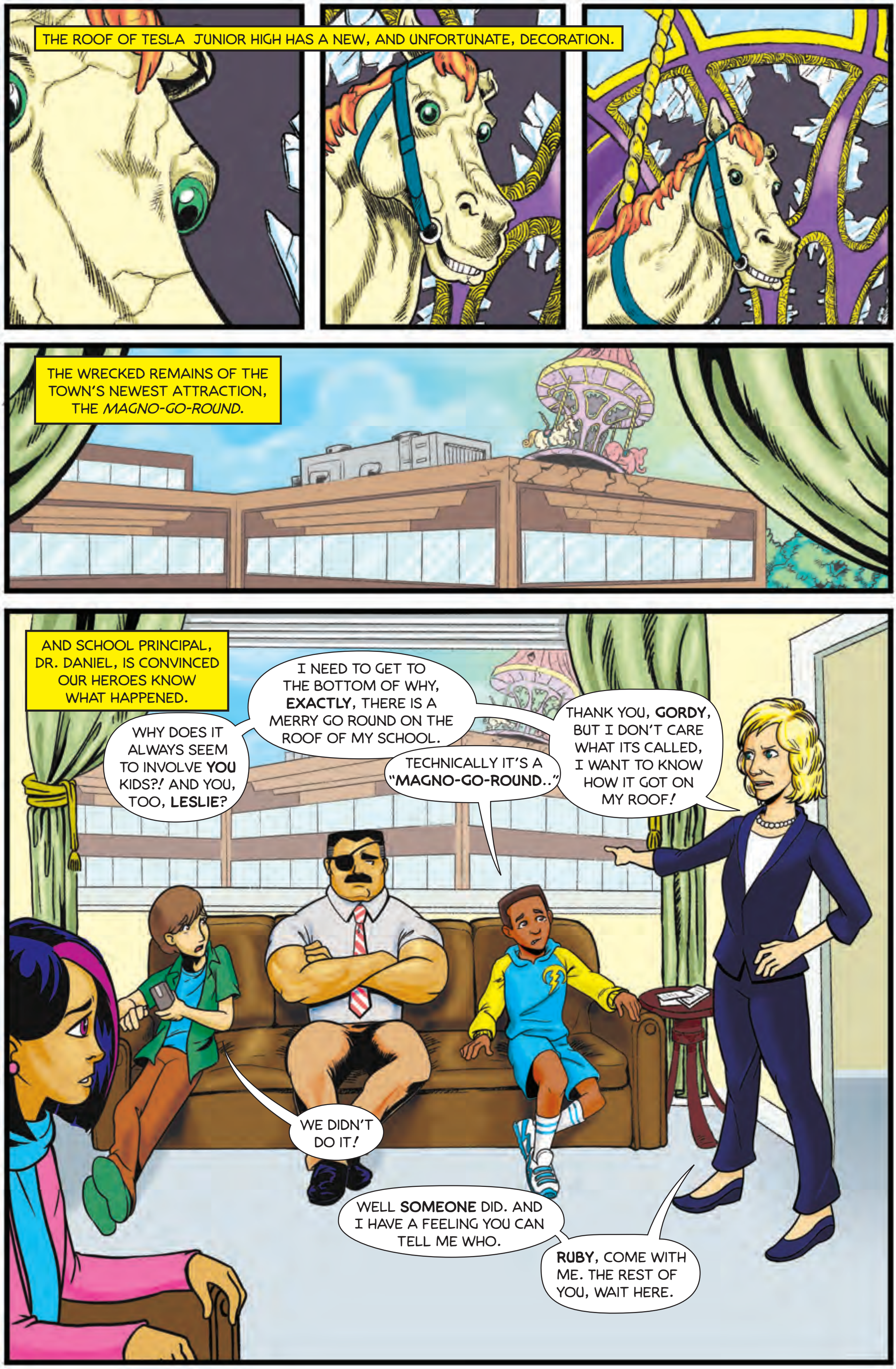
**KAS**:  Lead guitarist of garage band "The Ultraviolet Catastrophe" and Spectra's biggest fan. His greatest ambition is to go on tour with One Republic and rock out all over the world.



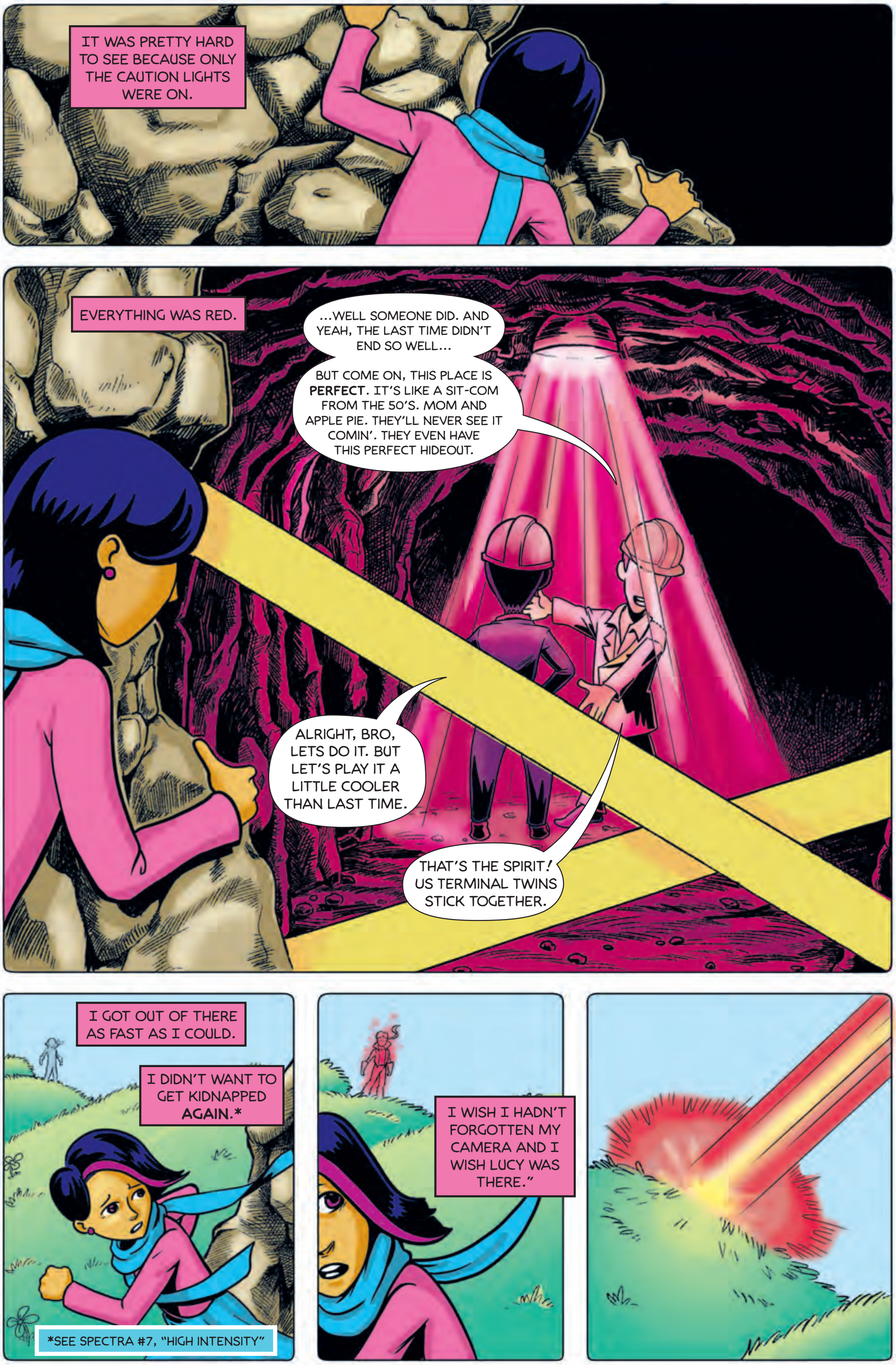
**GENERAL LESLIE J. RELATIVITY**:  Former army General turned high school physics teacher, don't let his gruff exterior fool you. Actually, yes, his gruff exterior is pretty accurate. He does have a soft spot for his beloved niece, Ruby, who doesn't seem to understand why everyone else is so scared of him.

**ANDY and CATHY TERMINAL**:  These swindlers move town to town trying to make a buck with their curious current machines. Their heroes include P.T. Barnum and Harold Hill. Its easy to fall for their hype, as Spectra's town soon finds out in...

# SPECTRA'S CURRENT CRISIS


THE ROOF OF TESLA JUNIOR HIGH HAS A NEW, AND UNFORTUNATE, DECORATION.
THE WRECKED REMAINS OF THE TOWN'S NEWEST ATTRACTION, THE *MAGNO-GO-ROUND.*
AND SCHOOL PRINCIPAL, DR. DANIEL, IS CONVINCED OUR HEROES KNOW WHAT HAPPENED.
I NEED TO GET TO THE BOTTOM OF WHY, **EXACTLY**, THERE IS A MERRY GO ROUND ON THE ROOF OF MY SCHOOL.
WHY DOES IT ALWAYS SEEM TO INVOLVE **YOU** KIDS?! AND YOU, TOO, **LESLIE**?
TECHNICALLY IT'S A "**MAGNO-GO-ROUND**.."
THANK YOU, **GORDY**, BUT I DON'T CARE WHAT ITS CALLED, I WANT TO KNOW HOW IT GOT ON MY ROOF!
WE DIDN'T DO IT!
WELL **SOMEONE** DID. AND I HAVE A FEELING YOU CAN TELL ME WHO.
**RUBY**, COME WITH ME. THE REST OF YOU, WAIT HERE.


PLEASE HAVE A SEAT, RUBY. NOW WHAT CAN YOU TELL ME?
I DON'T KNOW... I DIDN'T DO ANYTHING WRONG.
JUST TELL ME WHAT YOU KNOW. DID **ANYTHING** SEEM ODD THESE PAST FEW WEEKS?
I WAS OUT AT MISS ALIGNMENT'S OLD CON CAVE...
THAT PLACE IS **DANGEROUS!** YOU SHOULDN'T BE UP THERE, ESPECIALLY ALONE!
I KNOW...
"...BUT THE LIGHTING WAS SO PERFECT AND THERE ARE THESE BEAUTIFUL FLOWERS.
FOR RENT
Pefect for the budding Super Villain!
Contact Agent S. Skolnick
I HEARD VOICES COMING FROM THE CON CAVE. I DIDN'T HAVE MY PHONE WITH ME TO TEXT LUCY, SO I DECIDED TO INVESTIGATE ON MY OWN.
YOU DIDN'T HAVE YOUR PHONE WITH YOU!? WHAT IF SOMETHING HAPPENED TO YOU!?
I'LL BE MORE CAREFUL NEXT TIME, I JUST FORGOT. ANYWAY, I HEARD SOME VOICES COMING FROM THE CAVE.
I DECIDED TO MOVE CLOSER AND SEE IF I COULD OVERHEAR ANYTHING.
NOTHING GOOD HAS **EVER** HAPPENED IN THAT CAVE.


IT WAS PRETTY HARD TO SEE BECAUSE ONLY THE CAUTION LIGHTS WERE ON.
EVERYTHING WAS RED.
...WELL SOMEONE DID. AND YEAH, THE LAST TIME DIDN'T END SO WELL...
BUT COME ON, THIS PLACE IS **PERFECT**. IT'S LIKE A SIT-COM FROM THE 50'S. MOM AND APPLE PIE. THEY'LL NEVER SEE IT COMIN'. THEY EVEN HAVE THIS PERFECT HIDEOUT.
ALRIGHT, BRO, LETS DO IT. BUT LET'S PLAY IT A LITTLE COOLER THAN LAST TIME.
THAT'S THE SPIRIT! US TERMINAL TWINS STICK TOGETHER.
I GOT OUT OF THERE AS FAST AS I COULD.
I DIDN'T WANT TO GET KIDNAPPED **AGAIN**.*
*SEE SPECTRA #7, "HIGH INTENSITY"
I WISH I HADN'T FORGOTTEN MY CAMERA AND I WISH LUCY WAS THERE."

# Teacher's Guide

## ACTIVITY 1: MAGNETIC MERRY-GO-ROUND

### Intro

Generally students learn about electricity and magnetism as separate things. If they've had a chance to play with simple motors, they may have seen that the two can work together to make things move. When electricity flows, it creates a magnetic field. In this experiment your students will look at how the magnetic field created by a current interacts with the magnetic field of a permanent magnet.

### Key Question

How can Andy and Cathy and you make a merry-go-round turn using a magnet and a battery?

### Key Terms

**Current:** Flow of positive charges. When a complete circuit is created with a battery, current flows.

**Force:** Objects move only when a force is applied to them.

**Magnetic field:** A field produced by either a permanent magnet or a current. At every point it has both a strength and a direction.

**Permanent magnet:** A substance suchas iron that produces a magnetic field. A refrigerator magnet is a good example of this type of magnet.

**Radius:** Line from the center of a circle to the outer edge of the circle.

### Materials

AA battery
Nail
Cocktail umbrella
Magnet
Insulated wire

* Tape
* Paper clip
* Cup of water
* Small piece of styrofoam

* **not** included in the PhysicsQuest kit

# Teacher's Guide

## Before the activity students should know

• When materials such as iron come in contact with a strong magnet they also become magnets.

• When things move, it is because they feel a force.

• Current is the motion of positive charges.

## After the activity students should know

• When charges move in a magnetic field, they feel a force.

• The direction of the force they feel is related to the direction of the magnetic field and the direction in which the charges are moving.

## The science behind

When the motor is connected and current is flowing, there are positive charges flowing through the magnet. During the activity the direction of current will change. Sometimes it will be flowing down the nail, through the magnet and to the outside edge of the magnet. Sometimes it will flow from the outside edge through to the middle and back up the nail. Either way, the direction of the current flow will be along the radius of the magnet. The magnetic field points from one flat side of the magnet to the other. The only direction that is perpendicular to both the magnetic field and the direction of the current is the direction of the force. This force is so strong that is causes the magnet to turn. During this activity the students will set up the motor in various configurations and see which way the magnet turns.

Apart from the main physics in this activity, there is a little extra piece shown when the nail is hung from the battery. When a strong magnet is attached to certain metals, it makes the metal object magnetic as well. In this case the neodymium magnet is attached to the head of a nail and then the nail itself becomes magnetic. Your students have probably stumbled across this before with paper clips. If they are touching a magnet, they also become magnets and can pick up more paper clips.

Because the end of a battery is made of a metal that magnets can stick to, when the magnet is attached to the head of the nail and nail becomes a magnet, it can hang from the end of the battery. If your students have had a chance to make electromagnets, they may realize that when current is flowing, it creates a magnetic field.

# Teacher's Guide

In this experiment we are going to see what happens when current flows through a permanent magnet. The magnetic field created by the current is going to get in the way of the magnetic field of the permanent magnet. Because of the two magnetic fields repelling, the motor will turn.

Current is moving charges. Because of Ben Franklin's convention we always assume it is positive charges moving, even though we really now know it is negatively charged electrons. From now on, we are just going to assume that the positive charges are moving. Thank you, Ben.

The tricky thing about electro-magnetism is that charges that are sitting still don't interact with a magnetic field that isn't changing. So an electron could happily sit next to a refrigerator magnet forever and feel nothing at all. But electricity starts affecting magnetism and vice versa as soon as one starts changing. This activity will look at what happens when charges move in a magnetic field that is not changing (Fig. 1). The magnetic field is produced by the neodymium magnet so it won't be changing, but there will be a current produced by a battery which means that charges will be moving (Fig 2.).

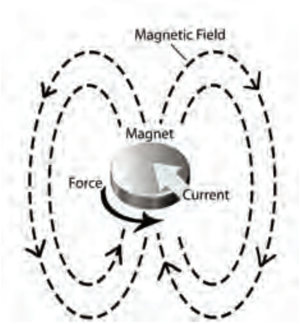



*Figure 1*

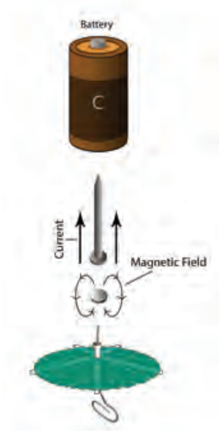



*Figure 2*

The direction of the force depends on which way the positive charge is moving and which way the magnetic field is going. One interesting thing is that the force the positive charge feels is not in the direction of the magnetic field or of the particle's motion—it is perpendicular to both.

## Safety

If the wire is held for too long, it may get hot. Only touch the wire to the magnet long enough to observe the direction of the spinning pinwheel.

## Suggested Resources

- *http://www.evilmadscientist.com/*
- *2006/how-to-make-the-simplest-electric-motor/*
- *https://phet.colorado.edu/en/simulation/faraday*
- *http://science.howstuffworks.com/electromagnet.htm*

# Student Guide

## ACTIVITY 1: MAGNETIC MERRY-GO-ROUND

### Intro

Andy and Cathy Terminal are all set to swindle the town with their magnetic Merry-Go-Round. But how does it work? Is it something that could actually be built? In this experiment you'll make a small version of the Terminal Twins' fantastic ride.

Because it's hard to send you a small Merry-Go-Round, you'll be using a tiny umbrella, but it's still fun. Enjoy seeing exactly how Andy and Cathy pulled off their magic amusement park ride!.

### Key Question

How can Andy and Cathy and you make a merry-go-round turn using a magnet and a battery?

### Getting Started

What types of motors can you think of? What do they have in common?

### Setting Up the Experiment

1. First you need to figure out which is the north side of your magnet and which is the south side.

### Materials

AA battery
Nail
Cocktail umbrella
Magnet
Insulated wire

* Tape
* Paper clip
* Cup of water
* Small piece of styrofoam

* **not** included in the PhysicsQuest kit

2. Embed the magnet in the small piece of styrofoam and float it in the cup of water. If you can't find styrofoam, you can use any material that floats and can hold the magnet (Fig. 1).

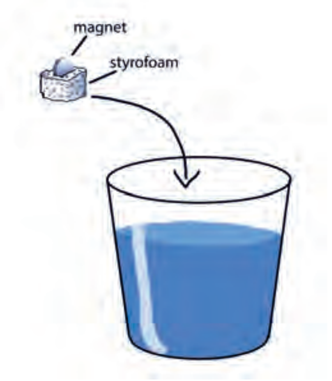



*Figure 1*

3. It should immediately align with the Earth's magnetic field and one flat side will face north while the other faces south.

4. The side of the magnet facing south is the side of the magnet attracted to magnetic south. Since north is attracted to south, this means it's the north side of the magnet. Use a marker to label it with an "N."

5. Push the stick through the top of the cocktail umbrella so you have just the top of the umbrella with a hole in the middle (Fig. 2).

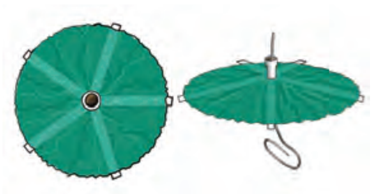


*Figure 2*

6. Stick the paper clip through the hole and bend the bottom so the umbrella top is hanging off the paper clip.

7. Put the magnet on the head of the nail with the "N" side against the head.

8. Hang the paper clip/umbrella top contraption off the other side of the magnet.

9. The nail will now be magnetic thanks to the magnet. Hang the nail by its point from the negative side of the battery.

10. Hold the battery so the nail is hanging and free to move.

## Collecting Data

1. Put the south end of the magnet against the head of the nail.

2. Draw your set up, indicating where the north and south ends of the magnet are as well as the positive and negative ends of the battery.

3. Now touch the wire to both the positive end of the battery and the side of the magnet.

4. What happens?

# Student Guide

5. Put the south end of the magnet against the head of the nail.

6. Draw your set up, indicating where the north and south ends of the magnet are as well as the positive and negative ends of the battery.

7. Now touch the wire to both the positive end of the battery and the side of the magnet.

8. What happens?

9. Now hang the magnet and nail from the positive end of the battery and touch the wire to the negative end and the side of the magnet.

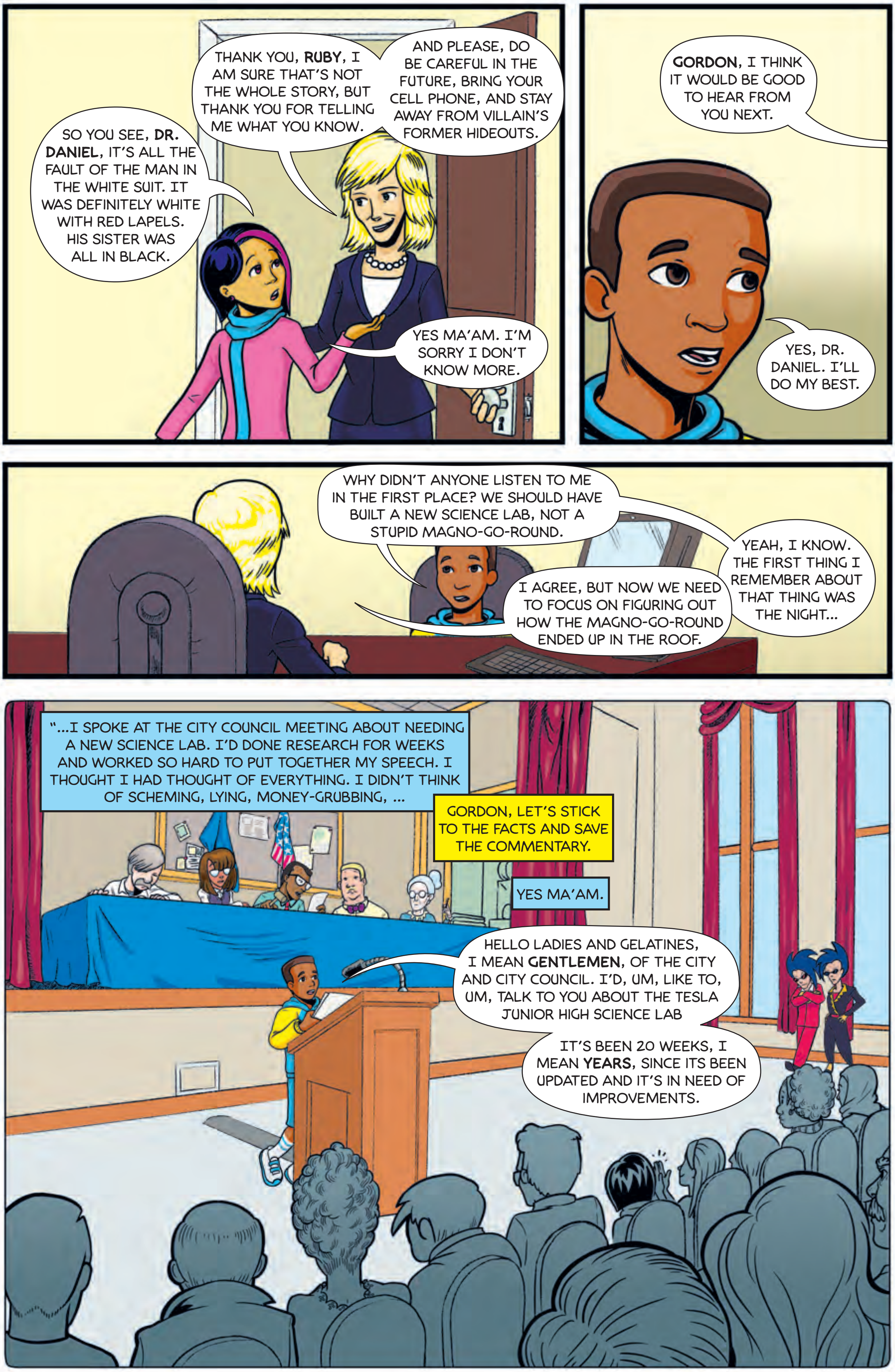
10. What happened? How does this compare to what happened before?

11. Repeat steps 2-6 with the north side of the magnet against the head of the nail.

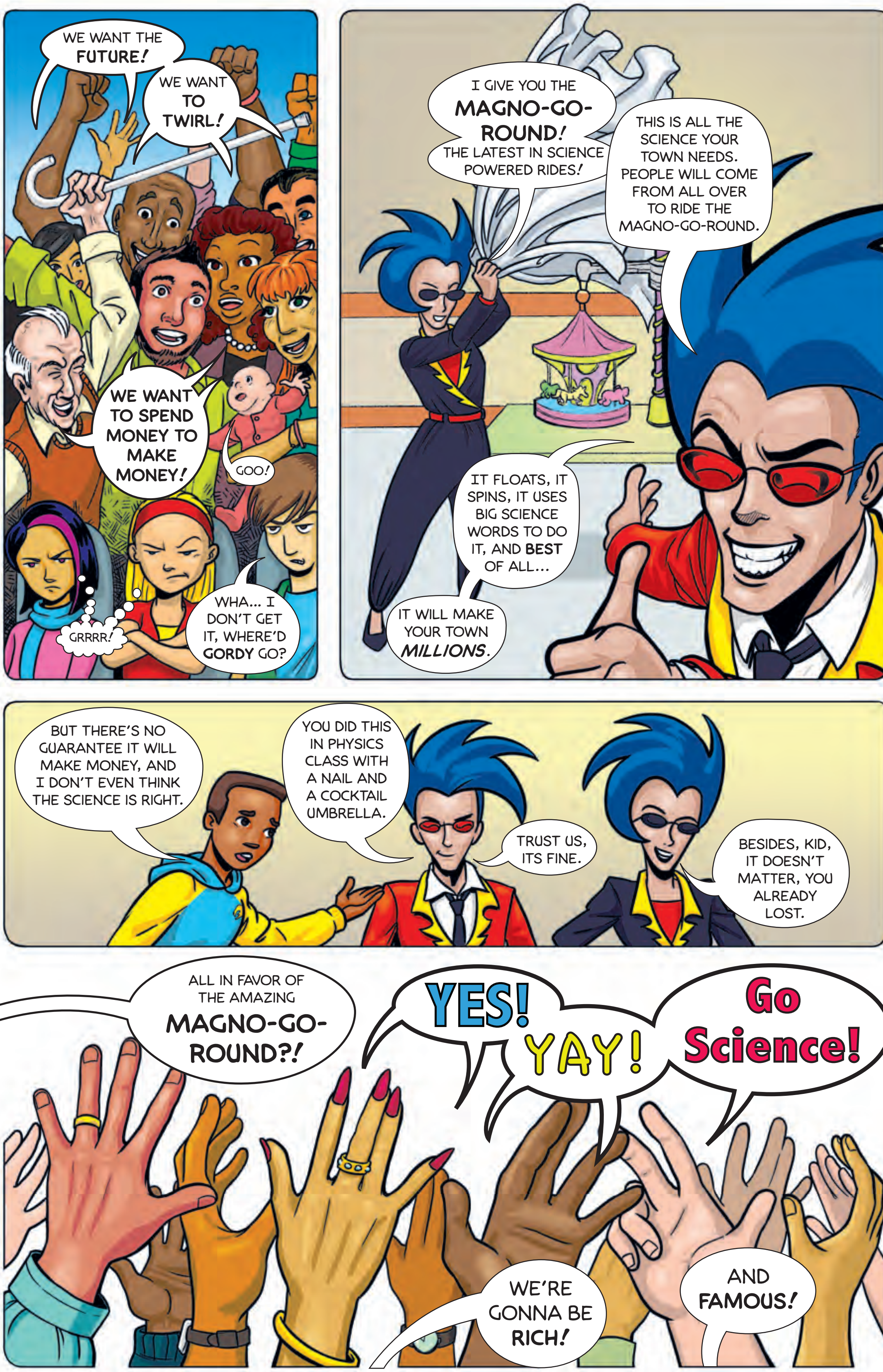
## Analyzing Your Results

Draw the two set ups that made the pinwheel turn clockwise.

Draw the two set ups that made the pinwheel turn counterclockwise.


SO YOU SEE, DR. DANIEL, IT'S ALL THE FAULT OF THE MAN IN THE WHITE SUIT. IT WAS DEFINITELY WHITE WITH RED LAPELS. HIS SISTER WAS ALL IN BLACK.
THANK YOU, RUBY, I AM SURE THAT'S NOT THE WHOLE STORY, BUT THANK YOU FOR TELLING ME WHAT YOU KNOW.
AND PLEASE, DO BE CAREFUL IN THE FUTURE, BRING YOUR CELL PHONE, AND STAY AWAY FROM VILLAIN'S FORMER HIDEOUTS.
YES MA'AM. I'M SORRY I DON'T KNOW MORE.
GORDON, I THINK IT WOULD BE GOOD TO HEAR FROM YOU NEXT.
YES, DR. DANIEL. I'LL DO MY BEST.
WHY DIDN'T ANYONE LISTEN TO ME IN THE FIRST PLACE? WE SHOULD HAVE BUILT A NEW SCIENCE LAB, NOT A STUPID MAGNO-GO-ROUND.
I AGREE, BUT NOW WE NEED TO FOCUS ON FIGURING OUT HOW THE MAGNO-GO-ROUND ENDED UP IN THE ROOF.
YEAH, I KNOW. THE FIRST THING I REMEMBER ABOUT THAT THING WAS THE NIGHT...
"...I SPOKE AT THE CITY COUNCIL MEETING ABOUT NEEDING A NEW SCIENCE LAB. I'D DONE RESEARCH FOR WEEKS AND WORKED SO HARD TO PUT TOGETHER MY SPEECH. I THOUGHT I HAD THOUGHT OF EVERYTHING. I DIDN'T THINK OF SCHEMING, LYING, MONEY-GRUBBING, ...
GORDON, LET'S STICK TO THE FACTS AND SAVE THE COMMENTARY.
YES MA'AM.
HELLO LADIES AND GELATINES, I MEAN GENTLEMEN, OF THE CITY AND CITY COUNCIL. I'D, UM, LIKE TO, UM, TALK TO YOU ABOUT THE TESLA JUNIOR HIGH SCIENCE LAB
IT'S BEEN 20 WEEKS, I MEAN YEARS, SINCE ITS BEEN UPDATED AND IT'S IN NEED OF IMPROVEMENTS.


I WAS A LITTLE NERVOUS AT FIRST BUT HIT MY STRIDE BY THE FINISH...
...YOU SEE, THE BUDGET SURPLUS SHOULD BE SPENT ON HELPING YOUR CHILDREN, MY FRIENDS, LEARN SCIENCE. THERE HAVE BEEN SO MANY ADVANCES IN TEACHING METHODS AND IN SCIENCE AND WE CAN'T AFFORD FOR OUR STUDENTS TO FALL BEHIND.
STEM IS THE FUTURE AND WE NEED TO BE READY.
IN CONCLUSION...
YO, GORDY, I'M REALLY HAPPY FOR YOU AND IMMA LET YOU FINISH, WHO AM I KIDDING, NO I'M NOT, BUT WE HAVE ONE OF THE BEST IDEAS OF ALL TIME.
BEST IDEAS OF ALL TIME!
MOVE OVER, KID.
MY SIS, CATHY, AND I JUST HAPPEN TO HAVE A WAY THAT YOU CAN HAVE YOUR SCIENCE LAB AND SO MUCH MORE.
WHY SPEND MONEY WHEN YOU CAN SPEND MONEY TO MAKE MONEY??
DO YOU WANT TO BE THE KIND OF TOWN THAT'S STUCK IN THE PAST OR ARE YOU READY TO TWIRL INTO THE FUTURE?
BECAUSE WE HAVE THE FUTURE!
WE CAN PUT THIS TOWN ON THE MAP.
HEARD OF ANAHEIM? YEAH, WE WERE THERE.
THAT'S RIGHT! WE CAN PUT THIS TOWN ON THE MAP.
JUST IMAGINE PEOPLE FROM ALL OVER SPENDING MONEY RIGHT HERE.
YOU'LL BE THE VACATION DESTINATION OF THE MIDWEST.


WE WANT THE FUTURE!
WE WANT TO TWIRL!
WE WANT TO SPEND MONEY TO MAKE MONEY!
GOO!
GRRRR!
WHA... I DON'T GET IT, WHERE'D GORDY GO?
I GIVE YOU THE MAGNO-GO-ROUND! THE LATEST IN SCIENCE POWERED RIDES!
THIS IS ALL THE SCIENCE YOUR TOWN NEEDS. PEOPLE WILL COME FROM ALL OVER TO RIDE THE MAGNO-GO-ROUND.
IT FLOATS, IT SPINS, IT USES BIG SCIENCE WORDS TO DO IT, AND BEST OF ALL...
IT WILL MAKE YOUR TOWN MILLIONS.
BUT THERE'S NO GUARANTEE IT WILL MAKE MONEY, AND I DON'T EVEN THINK THE SCIENCE IS RIGHT.
YOU DID THIS IN PHYSICS CLASS WITH A NAIL AND A COCKTAIL UMBRELLA.
TRUST US, ITS FINE.
BESIDES, KID, IT DOESN'T MATTER, YOU ALREADY LOST.
ALL IN FAVOR OF THE AMAZING MAGNO-GO-ROUND?!
YES!
YAY!
Go Science!
WE'RE GONNA BE RICH!
AND FAMOUS!

# Teacher's Guide

## ACTIVITY 2: ONE GOES OUT & THEY ALL GO OUT

### Intro

This activity is about series and parallel circuits, a standard topic for middle school students. Usually it starts with well-drawn and easy-to-follow diagrams that soon devolve into a bird's nest of wires that don't look a darn thing like the original diagram. In our version, instead of wires that never look like the pictures, students will be using Fun Dough. Normal Fun Dough is fairly conductive. It doesn't conduct nearly as well as wire, but it can adequately light LEDs in simple circuits. Using Fun Dough, students can draw a circuit on paper and then trace it out with the Fun Dough. No more trying to guess where wires are going or figuring out if the connections are good. (Also, Fun Dough is infinitely more fun!)

### Key Question

What's the difference between a parallel circuit and a series circuit and what happens when you break a connection in each?

### Materials

- 3 LEDs
- 2 Coin batteries
- Fun Dough

### Key Terms

**Circuit:** A circuit is a complete path for current to flow. It needs a power source, conductors, and a circuit element such as a light or buzzer.

**Current Resistance:** Resistance to the flow of current. Resistors slow down electrical current much like rocks in a stream slow the flow of water.

**LED:** Light Emitting Diode. An LED emits mostly one color of light and only allows current to flow in one direction. When current is flowing, the LED lights up.

**Parallel:** When two things are parallel, they are alongside each other and won't cross. In a parallel circuit, two circuit elements are next to each other—not lined up one after another. Current can flow through one or the other, but not both.

**Series:** When things are in series, they come one right after another. In a series circuit, the circuit elements come right after each other. If current flows through one, it must also flow through the other.

## Before the activity students should know

• What it means to create a complete circuit.

• That to make an LED light up, they need a complete circuit.

## After the activity students should know

• Discuss the difference between parallel and series circuits.

• Describe what a "complete circuit" is.

The science behind circuits
Current is moving electric charge. Current in a river is moving water; current in a wire is moving charge. In some materials, such as metal or Fun Dough, it is very easy for current to flow. These materials are called conductors. When all charges are moving in the same direction in the conductor, there is a current.

To make things super complicated, it is really the electrons moving. However, the direction of electrical current is the opposite direction of the moving electrons. If you need to draw an arrow in the direction of the current, you draw the arrow pointing "upstream" of the electron movement.

It's kind of confusing, but you can thank Ben Franklin for that. He chose to label the direction of current in this way and we've had to deal with his choices ever since. When you've made a complete circuit, current will be flowing through all the circuit elements (LEDs and "wires" made of Fun Dough).

If you want to get charges moving, you need to have something to push them. That something is called the power source. In the circuits your students will be building, the power source is the two 3v coin batteries. Inside each battery, a chemical reaction creates a build-up of positive charges on the (+) end of the battery and negative charges on the (–) end of the battery.

Because negative charges want to be near positive charges and away from other negative charges, as soon as there is a path for electrons from the (+) end of the battery to travel to the (–) end of the battery, the electrons will feel a push to move and—as a result—current will flow. Creating a circuit is just creating a path for those positive charges to get to the negative charges.

It's possible for a circuit to have more than one path, but there has to be at least one. If there is more than one possible path to get from one end of the power source to the other, the current can choose which path to take.

When trying to figure out a path in the circuit, look at the connections and ask yourself, “What would an electron do?”

Conductors such as wires allow current to flow easily. Insulators such as rubber stop current from flowing. Halfway between conductors and insulators are **resistors**. Resistors allow current to flow but slow it down, kind of like rocks in a river. In these circuits, the LEDs have small resistors inside them. The higher the resistance of something, the more it slows down the current.

It’s always important to have at least a bit of resistance in a circuit. If there isn’t anything to slow down the current, it can go too fast and will burn out the battery and cause overheating. This is called a **short circuit**.

When your students touch the two ends of the Fun Dough “wires” together, they are creating a short circuit. The current doesn’t want to flow through the LED anymore because it has more resistance than the Fun Dough. Because there’s no current, the LED turns off.

This activity has two types of circuits: series and parallel. **Series circuits** are made with all the LEDs arranged on the same path.

**Parallel circuits** have LEDs on multiple paths, making it possible for the current to flow through one of several possible loops.

When a resistor is added to a series circuit, it slows down the current. When more resistors are added, the current is slowed down even more. That’s why the LEDs in a series circuit become dimmer if more are added.

If one of those LEDs were to burn out, the loop of the circuit would be broken and all of the other LEDs would go out, too. Instead, in a parallel circuit, if one LED goes out, it’s no big deal—the current can just take a different path.
The final circuit your students will create is a combination of a series and parallel circuit.

Pay attention to polarity. You will see a (+) symbol on the one side of your coin battery. The unmarked side is the negative (-). LEDs only allow current to flow in one direction. The current (flowing positive charges) must go in through the long leg and out through the short leg. Make sure the long leg is always closest to the (+) of the battery.

Your students will be tracing out circuit diagrams with Fun Dough. Circuit diagrams are used in all electronics to identify what’s connected to what and how current will flow. It can be extremely difficult, even for the pros, to look at a circuit diagram and recreate it with wires.

Wires are hard to manipulate sometimes and it can be really hard to look at a bird’s nest of wires and understand that it looks like the diagram. Hopefully by tracing it directly with Fun Dough, your students will have a better understanding of how to translate a circuit diagram into an actual circuit.

## Safety

Though Fun Dough is non-toxic, it should not be eaten.

Be careful with the LEDs, as the leads can be sharp.

## Suggested Resources

- *https://phet.colorado.edu/en/simulation/circuit-construction-kit-dc*
- *https://www.khanacademy.org/science/physics/circuits-topic*
- *https://learn.sparkfun.com/tutorials/*
- *series-and-parallel-circuits*

If you are interested in an educational class game based on these concepts:

- *http://www.thinkfun.com/products/circuit-maze/*

# Student Guide

## ACTIVITY 2: ONE GOES OUT & THEY ALL GO OUT

### Intro

Circuits are fun to build and Fun Dough is fun to play with. In this experiment, you will combine the two: make circuits out of Fun Dough. When you are asked to set up a circuit, you usually have to follow a circuit diagram using wires and light bulbs. In this experiment, you can trace the circuit diagram out with Fun Dough and watch the lights light up. You'll explore the difference between series and parallel circuits.

### Key Question

What's the difference between a parallel circuit and a series circuit and what happens when you break a connection in each?

### Getting Started

1. What does it mean for something to be a conductor? An insulator?

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2. Do you think Fun Dough is an insulator or a conductor?

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### Materials

- 3 LEDs
- 2 Coin batteries
- Fun Dough

3. What does it mean for two things to be parallel?

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4. What does it mean for two things to be in series?

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5. What do you need to make a circuit?

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6. What do you think is meant by a parallel circuit?

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7. What do you think is meant by a series circuit?

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# Student Guide

## Setting Up the Experiment

1.  Put a small amount of Fun Dough between the positive (+) side of one battery and the negative (-) side of the other battery.

2.  Place the long leg of one LED on the positive (+) side of the battery combo and place the short leg on the negative (-) side.  Does it light up?  If so, great!  If not, make sure you have positive to negative with the batteries and the long leg is on the positive side.

3.  Create two “snakes” with the Fun Dough.  These are your wires.

4.  Attach one snake to the positive end of the battery and the other one to the negative end.  Make sure the snakes don’t touch each other.

5.  Put the long leg of the LED into the Fun Dough snake attached to the positive side of the battery and the LED’s short leg into the snake attached to the negative side.  (Fig. 1)

6.  What happens?

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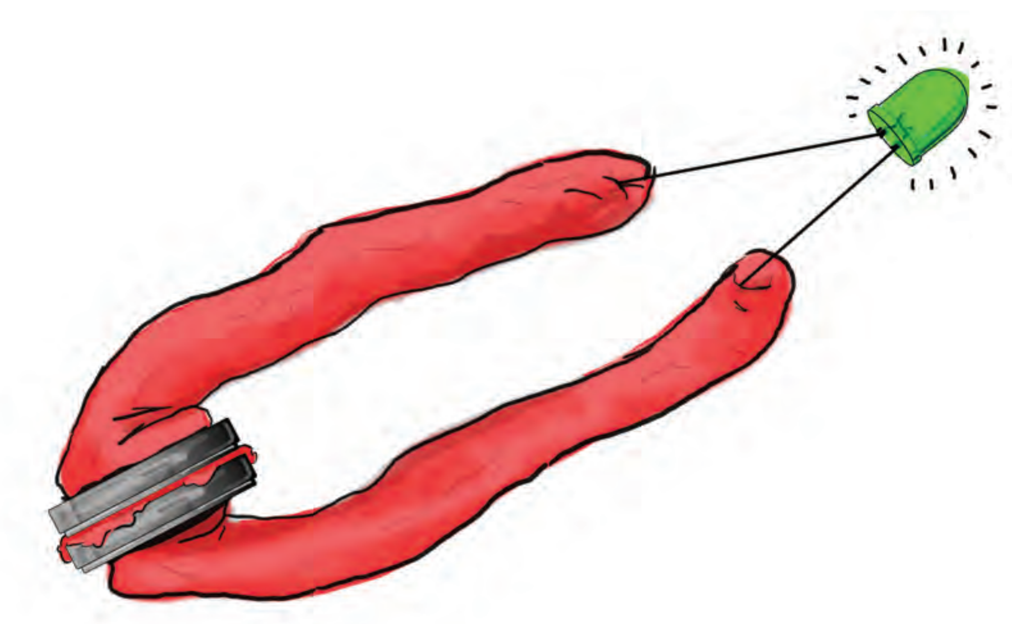

*Figure 1*

## Collecting Data

In the "Setting Up the Experiment" section, you made a very simple circuit with a battery, LED and Fun Dough. In this section, you are going to make two types of circuits: parallel and series. You are also going to work with a circuit diagram.

Is Fun Dough an insulator or a conductor?

### Simple circuit:

1. Trace out the lines on Circuit Diagram 1 (below) using Fun Dough. A circuit diagram shows all the element of your circuit and how they are connected. Usually you would use wires to create a circuit from the circuit diagram, but Fun Dough works pretty well, too.

2. Place the stuck-together batteries in the area on the diagram marked "batteries" and attach to the Fun Dough "wires."

3. Use an LED to bridge the gap, making sure the long leg is closest to the positive (+) side of the battery.

4. What happens to the LED?

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5. Touch the two "wires" of Fun Dough together. What happens to the LED?

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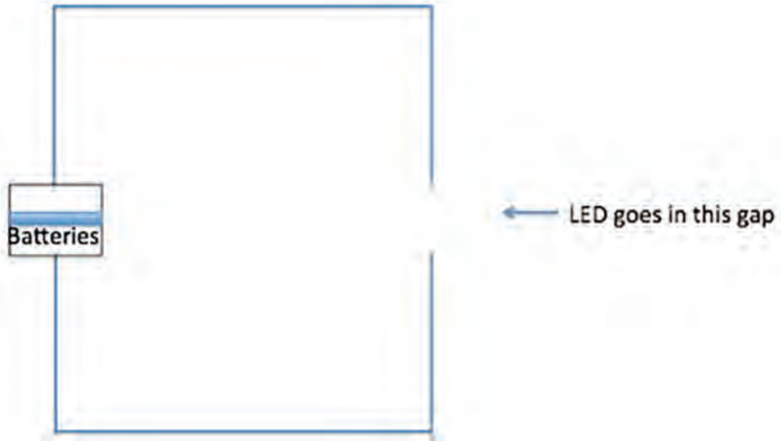


*Circuit Diagram 1*

## More interesting circuits

Look at circuit diagrams 2, 3, and 4 below and on the next few pages. You will be making and discussing these three circuits.

### Circuit diagram 2

1. Circuits can be built as series circuits, parallel circuits, or a combination of the two. What type of circuit do you think this is?

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2. As with the simple circuit, use the Fun Dough to trace out the wires, connect the battery and bridge the gaps with LEDs as shown in the circuit diagram below. Make sure the long legs of the LEDs are close to the positive (+) side of the battery.

3. The LEDs should light up.

4. Take out one of the three LEDs. What happens to the other two?

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5. Replace the LED. What happens?

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6. Remove one of the other LEDs. What happens?

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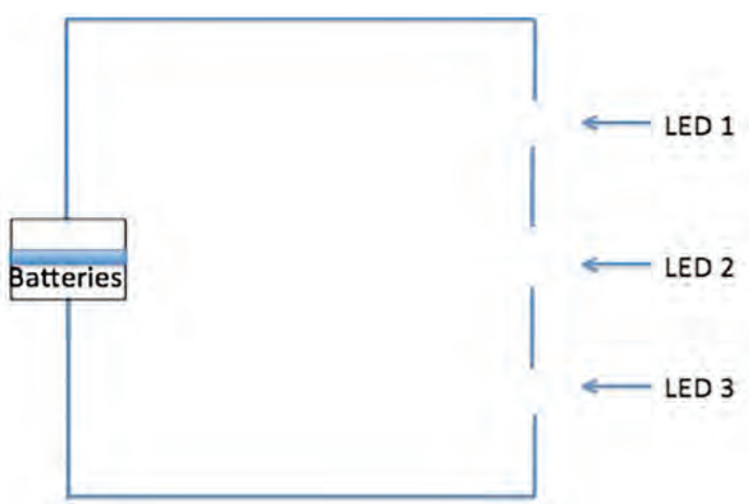


*Circuit Diagram 2*

## Circuit Diagram 3

1. Circuits can be series circuits, parallel circuits, or a combination of the two. What type of circuit do you think this is?

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2. As with the simple circuit, use the Fun Dough to trace out the wires, connect the battery and bridge the gaps with LEDs as shown in the circuit diagram below. Make sure the long legs of the LEDs are close to the positive (+) side of the battery.

3. The LEDs should light up.

4. 4. Take out one of the three LEDs. What happens to the other two? ______________________
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5. Replace the LED.
What happens?
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6. Remove a second LED. What happens?
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7. Replace the LED and then remove a third LED.
What happens?
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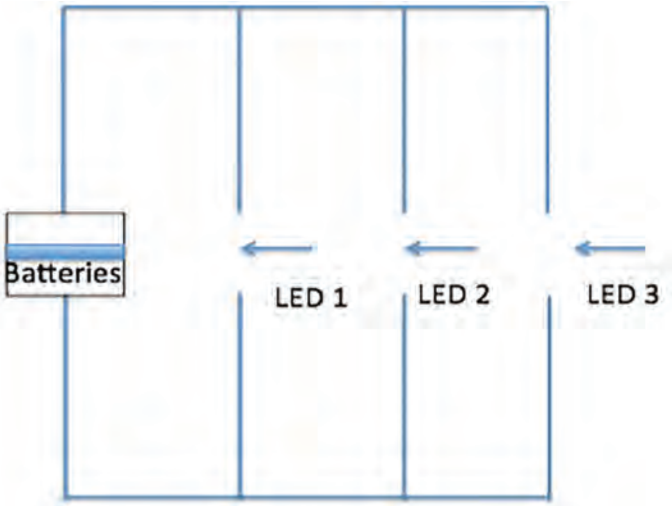


*Circuit Diagram 3*

## Circuit Diagram 4

1. Circuits can be series circuits, parallel circuits, or a combination of the two. What type of circuit do you think this is?

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2. As with the simple circuit, use the Fun Dough to trace out the wires, connect the battery and bridge the gaps with LEDs as shown in the circuit diagram below. Make sure the long legs of the LEDs are close to the positive (+) side of the battery.

3. The LEDs should light up.

4. Take out the LED labeled "LED 1" on the circuit diagram. What happens to the other two?

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5. Replace the LED.
What happens?

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6. Remove LED 2.
What happens?

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7. Replace the LED and then remove LED 3. What happens?

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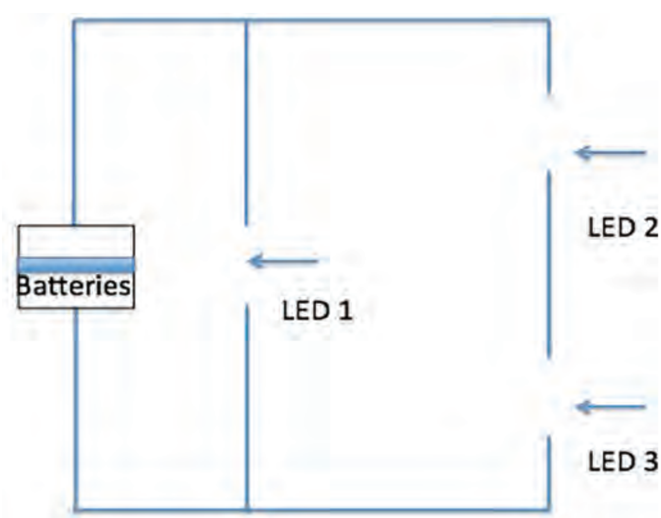


*Circuit Diagram 4*

## Analyzing Your Results

Current flows from the positive side of the battery and through the circuit to the negative side of the battery. When there is a complete path from the positive side to the negative side, current can flow. If there isn't, it can't.

1. In circuit 1, what was the path of the current in the circuit?

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2. Thinking about the path of the current, explain why the light went out when you touched the two Fun Dough wires together.

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3. In circuit 2, what is the path of the current? Is there just one path or are there different paths?

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4. In circuit 2, when you removed one LED, the other two didn't light. Using the idea of current flowing through a complete circuit, can you explain why the other two LEDs went out?

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5. In circuit 3, what is the path of the current? Is there just one path or are there different paths?

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6. In circuit 3, you could remove an LED and the other ones stay lit. Again talking about current flowing through the circuit, can you say why the other two could stay lit?

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7. In circuit 4, what is the path of the current? Is there just one path or are there different paths?

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8. In circuit 4, even after you took out LED 1, LED 2 and 3 both stayed lit. When you took out LED 2, only LED 1 stayed lit. Can the path of the current describe why this happened?

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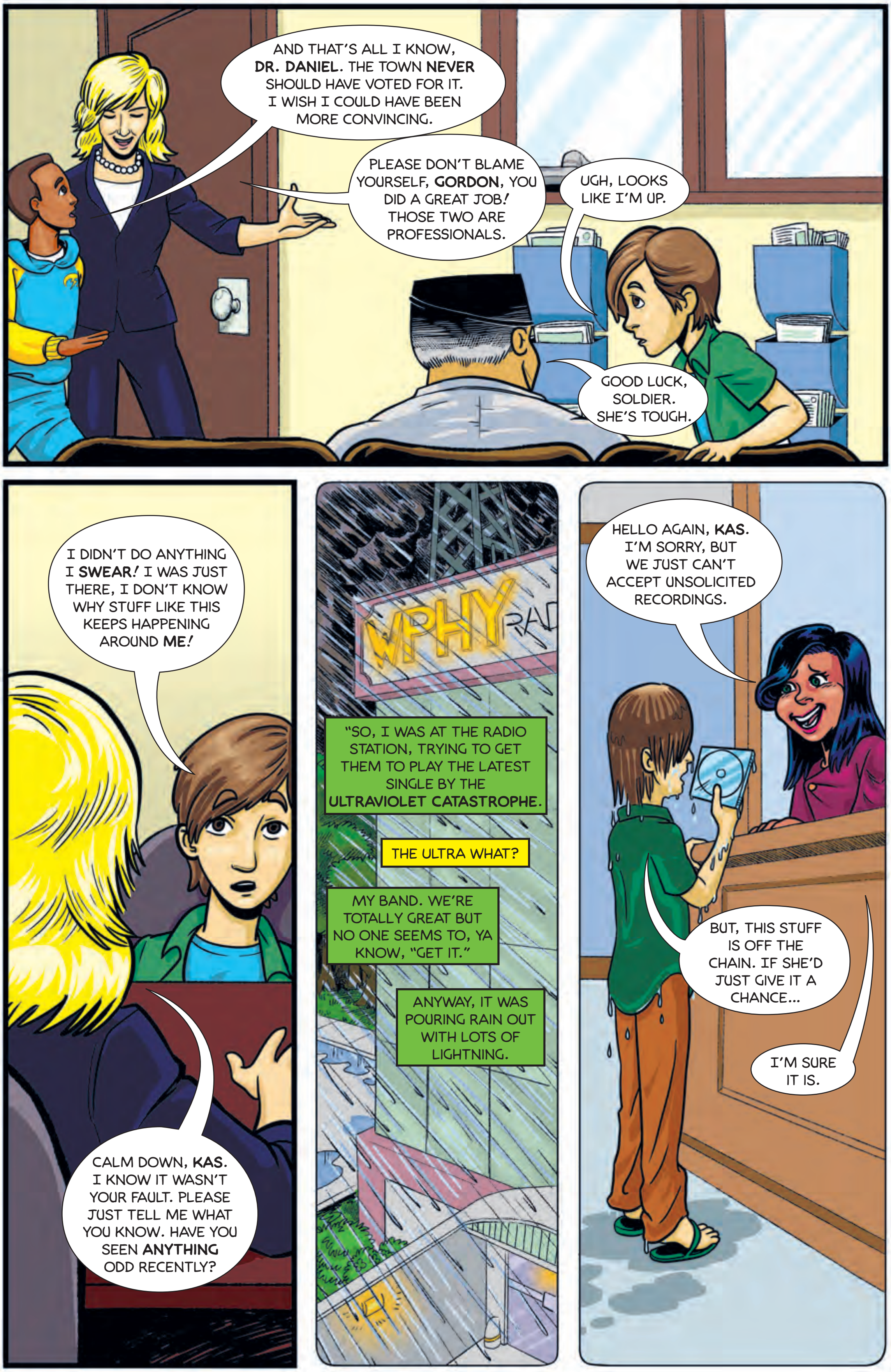
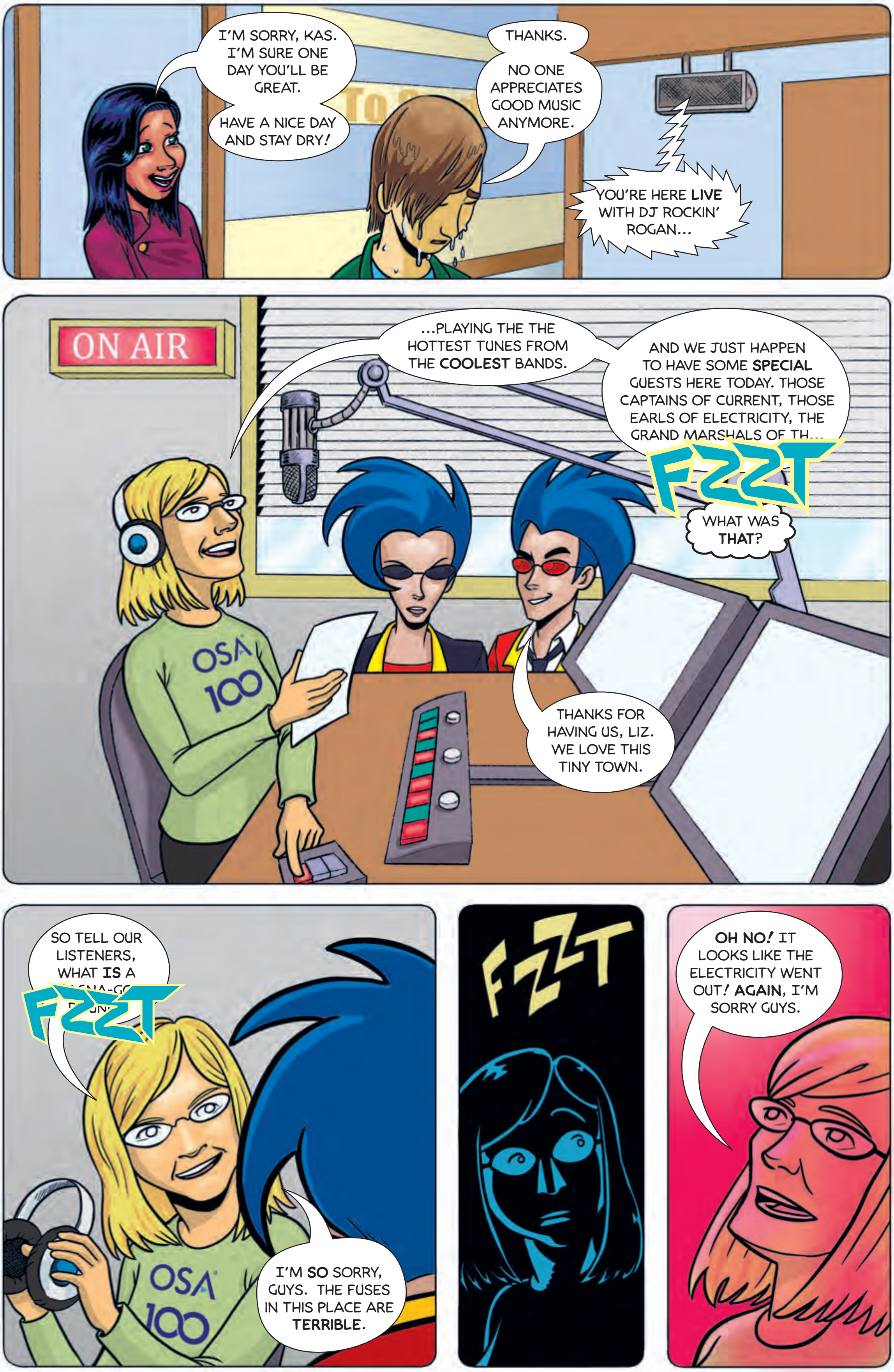
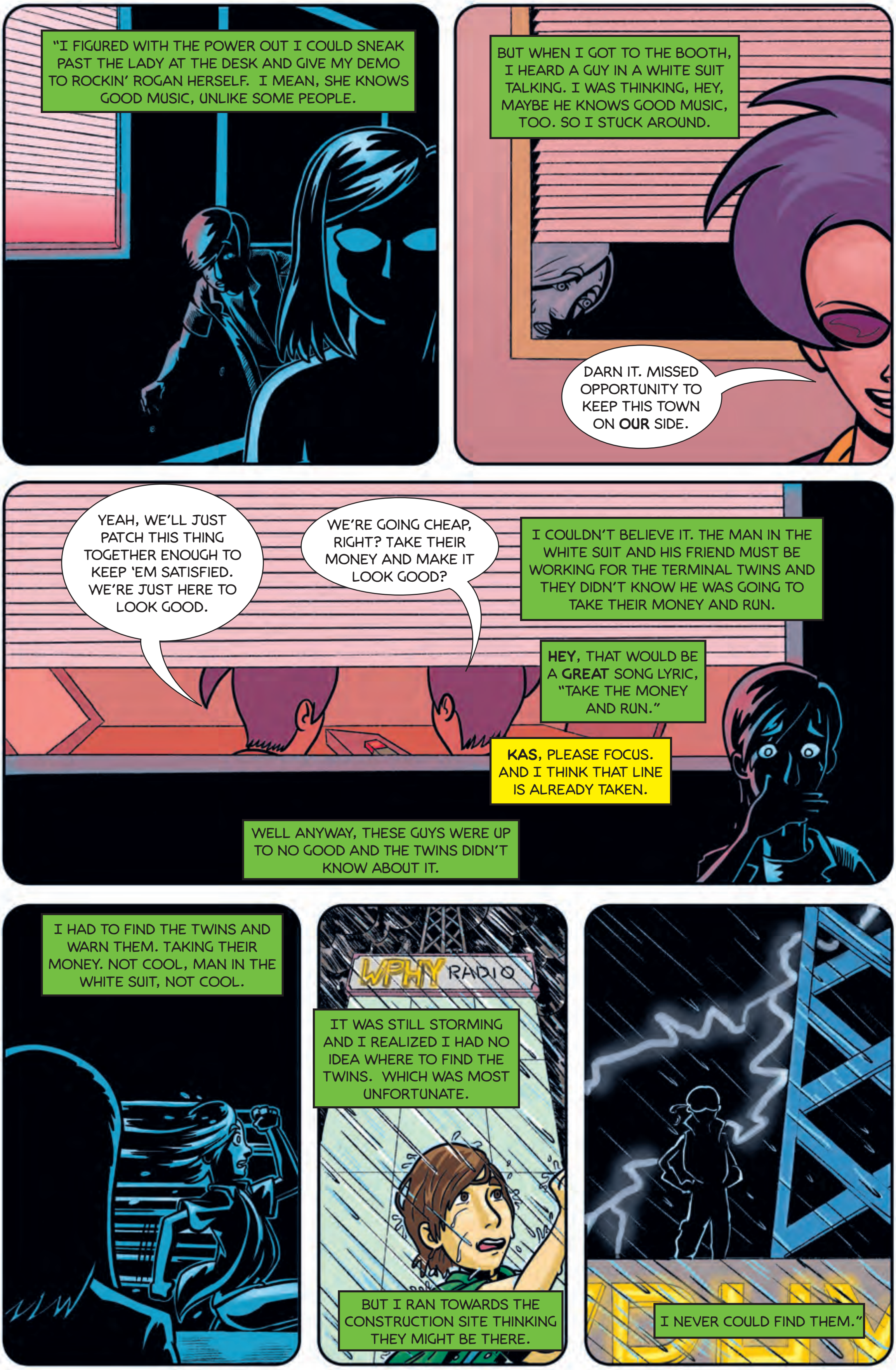

AND THAT'S ALL I KNOW, DR. DANIEL. THE TOWN NEVER SHOULD HAVE VOTED FOR IT. I WISH I COULD HAVE BEEN MORE CONVINCING.
PLEASE DON'T BLAME YOURSELF, GORDON, YOU DID A GREAT JOB! THOSE TWO ARE PROFESSIONALS.
UGH, LOOKS LIKE I'M UP.
GOOD LUCK, SOLDIER. SHE'S TOUGH.
I DIDN'T DO ANYTHING I SWEAR! I WAS JUST THERE, I DON'T KNOW WHY STUFF LIKE THIS KEEPS HAPPENING AROUND ME!
CALM DOWN, KAS. I KNOW IT WASN'T YOUR FAULT. PLEASE JUST TELL ME WHAT YOU KNOW. HAVE YOU SEEN ANYTHING ODD RECENTLY?
WPHY
"SO, I WAS AT THE RADIO STATION, TRYING TO GET THEM TO PLAY THE LATEST SINGLE BY THE ULTRAVIOLET CATASTROPHE.
THE ULTRA WHAT?
MY BAND. WE'RE TOTALLY GREAT BUT NO ONE SEEMS TO, YA KNOW, "GET IT."
ANYWAY, IT WAS POURING RAIN OUT WITH LOTS OF LIGHTNING.
HELLO AGAIN, KAS. I'M SORRY, BUT WE JUST CAN'T ACCEPT UNSOLICITED RECORDINGS.
BUT, THIS STUFF IS OFF THE CHAIN. IF SHE'D JUST GIVE IT A CHANCE...
I'M SURE IT IS.


I'M SORRY, KAS. I'M SURE ONE DAY YOU'LL BE GREAT.
HAVE A NICE DAY AND STAY DRY!
THANKS.
NO ONE APPRECIATES GOOD MUSIC ANYMORE.
YOU'RE HERE **LIVE** WITH DJ ROCKIN' ROGAN...
ON AIR
...PLAYING THE THE HOTTEST TUNES FROM THE **COOLEST** BANDS.
AND WE JUST HAPPEN TO HAVE SOME **SPECIAL** GUESTS HERE TODAY. THOSE CAPTAINS OF CURRENT, THOSE EARLS OF ELECTRICITY, THE GRAND MARSHALS OF TH...
FZZT
WHAT WAS **THAT**?
OSA 100
THANKS FOR HAVING US, LIZ. WE LOVE THIS TINY TOWN.
SO TELL OUR LISTENERS, WHAT **IS** A
FZZT
OSA 100
I'M **SO** SORRY, GUYS. THE FUSES IN THIS PLACE ARE **TERRIBLE**.
FZZT
**OH NO!** IT LOOKS LIKE THE ELECTRICITY WENT OUT! **AGAIN**, I'M SORRY GUYS.



"I FIGURED WITH THE POWER OUT I COULD SNEAK PAST THE LADY AT THE DESK AND GIVE MY DEMO TO ROCKIN' ROGAN HERSELF. I MEAN, SHE KNOWS GOOD MUSIC, UNLIKE SOME PEOPLE.
BUT WHEN I GOT TO THE BOOTH, I HEARD A GUY IN A WHITE SUIT TALKING. I WAS THINKING, HEY, MAYBE HE KNOWS GOOD MUSIC, TOO. SO I STUCK AROUND.
DARN IT. MISSED OPPORTUNITY TO KEEP THIS TOWN ON **OUR** SIDE.
YEAH, WE'LL JUST PATCH THIS THING TOGETHER ENOUGH TO KEEP 'EM SATISFIED. WE'RE JUST HERE TO LOOK GOOD.
WE'RE GOING CHEAP, RIGHT? TAKE THEIR MONEY AND MAKE IT LOOK GOOD?
I COULDN'T BELIEVE IT. THE MAN IN THE WHITE SUIT AND HIS FRIEND MUST BE WORKING FOR THE TERMINAL TWINS AND THEY DIDN'T KNOW HE WAS GOING TO TAKE THEIR MONEY AND RUN.
**HEY**, THAT WOULD BE A **GREAT** SONG LYRIC, "TAKE THE MONEY AND RUN."
**KAS**, PLEASE FOCUS. AND I THINK THAT LINE IS ALREADY TAKEN.
WELL ANYWAY, THESE GUYS WERE UP TO NO GOOD AND THE TWINS DIDN'T KNOW ABOUT IT.
I HAD TO FIND THE TWINS AND WARN THEM. TAKING THEIR MONEY. NOT COOL, MAN IN THE WHITE SUIT, NOT COOL.
WPHY RADIO
IT WAS STILL STORMING AND I REALIZED I HAD NO IDEA WHERE TO FIND THE TWINS. WHICH WAS MOST UNFORTUNATE.
BUT I RAN TOWARDS THE CONSTRUCTION SITE THINKING THEY MIGHT BE THERE.
I NEVER COULD FIND THEM."

# Teacher's Guide

## ACTIVITY 3: DIM THE LIGHTS

### Intro

In most of the circuits students work with, they have some wires, an object they are trying to power—such as a light or a buzzer—and a battery. Using these circuits they talk about insulators versus conductors and come up with lists of each. In this activity, students will use an LED, a battery, and a pencil to build a rheostat, a device that can change resistance. They can use the rheostat to come up with some ideas about what changes an object's resistance.

### Key Question

How does the amount of graphite (pencil lead) affect how much current flows through it?

### Key Terms

**Circuit:** A circuit is a closed loop through which charges move.

**Current:** Current is the flow of positive charges. It flows from the positive end of the battery to the negative end of the battery. To make something like an LED light up, current must flow through it.

**Resistance:** Resistance slows current down. The more resistance something has, the less current flows through it.

**Rheostat:** A rheostat is a circuit element that can change its resistance. Things like volume control knobs and light dimmer switches are examples of rheostats

### Materials

**Pencil**
**Coin battery**
**Red LED**

* **Dimly lit room**
* **White paper**
* **Pencil sharpener**
* **Ruler**

* **not** included in the PhysicsQuest kit

# Teacher's Guide

## Before the activity students should know

• How a simple circuit works.
• The difference between resistance and conductivity.

## After the activity students should be able to

• Discuss how size and length affect resistance.
• Discuss the conductivity of graphite (pencil lead).

## The science behind resistance

In general when talking about circuits, things are divided into insulators—which won't allow current to flow—and conductors, which allow current to flow easily.

In reality, most things are resistors. Resistors, which are very smartly named, resist the flow of current. They allow some current to flow but not infinite current. Most electronics need to prevent too much current from flowing so they use resistors to regulate it. Most of the resistors in your electronics are made from ceramic. Pencil lead, or graphite, is also great resistor.

For an LED to light up, it must have current flowing through it. The more current there is, the brighter the LED will light. In a circuit, the amount of current flowing depends on a few things. It depends on the voltage of the battery—the higher the voltage, the more current. That's why the AA battery can't power something meant for a 9v battery: because the AA battery can't create enough current.

Current also depends on the amount of resistance in the circuit. Things like lights and buzzers have resistance and they slow down the current. The more resistance, the less current. The relationship between current, voltage, and resistance is called Ohm's Law. You can find more information about Ohm's Law in the first link under "suggested resources."

Ohm's law describes a linear relationship. This means that when resistance is increased, the current decreases by the same amount. Your students will see this when they make a graph of the distance from the battery versus the brightness of the LED.

In this experiment, students are creating a circuit with a battery, an LED, and a whole lot of graphite. Graphite is not very conductive so you will need to get quite a few layers of it on the paper for the experiment to work. If there isn't enough graphite, there will be too much resistance and current won't be able to flow at all.

# Teacher's Guide

The more graphite there is in a given area, the less resistance there is in the circuit.  Current can flow through more easily.  (Fig. 1)

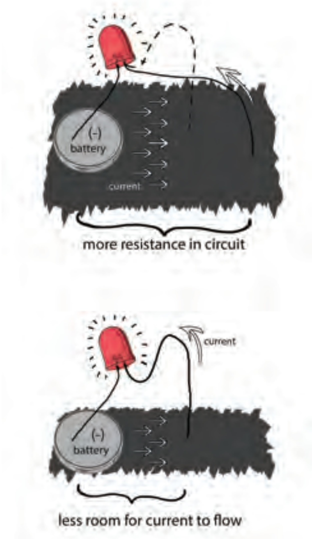



*Figure 1*

The more graphite there is in a given length, the easier it is for current to flow.  At the same time, however, the longer the distance the current has to travel through the graphite, the more resistance it will encounter.

In the circuit your students have created, they'll be looking at what happens to a light as they change the length of graphite that the current must flow through.  When the length of graphite in the circuit is longer, there is more resistance, so current doesn't flow as easily.  As a result, the light is dimmer.

But what happens if there is more graphite in a given length?  What happens if we draw the graphite "wire" a bit thicker on the page?  Because there is now more graphite in a given length, current will be able to flow more easily and the light will be brighter.

This idea of changing resistance by increasing or decreasing the length or size of a resistor is exactly how dimmer light switches and volume control knobs work.  As you slide the dimmer light switch up and down, it's exactly like sliding the leg of the LED down the length of the graphite and causing it to dim.  In a volume control knob, as the volume is turned down the resistance is increased; as it is turned up, the resistance is decreased and the music gets louder.

## Safety

Be careful with the LEDs, as the leads can be very sharp.

## Suggested Resources

- *https://learn.sparkfun.com/tutorials/voltage-current-resistance-and-ohms-law.*
- *https://enlightenme.com/rheostat/*

NOTE:  In this example coiled wire is used instead of pencil graphite.

- *https://phet.colorado.edu/en/simulation/battery-resistor-circuit*
- *https://phet.colorado.edu/en/simulation/ohms-law*

# ACTIVITY 3: DIM THE LIGHTS

## Intro

Have you ever wondered how the volume control knob on an old radio works or how it's possible to lower a switch and dim your lights without turning them off? The reason resistance. This activity will look at how resistance can be changed. If you want to make a volume control, you can try this experiment with a buzzer instead of an LED!

## Materials

**Pencil**
**Coin battery**
**Red LED**

- * **Dimly lit room**
- * **White paper**
- * **Pencil sharpener**
- * **Ruler**

* **not** included in the PhysicsQuest kit

## Key Question

How does the amount of graphite (pencil lead) affect how much current flows through it?

## Getting Started

1. What is "resistance"? What is conductance?

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2. What types of things are resistors? What types of things are conductors?

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3. What things do you think affect how conductive an object is? What things probably don't matter?

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4. Can you think of places you might use changing resistance such as dimmer light switches?

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5. What are the benefits of changing the resistance in a circuit?

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# Student Guide

## Setting Up the Experiment

This should be done in a dimly lit room.

1. Sharpen both ends of your pencil.

2. Make a circuit with the wire, the pencil, the battery, and the LED. Does the pencil conduct? How do you know?

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3. On the white sheet of paper, use the pencil to draw two very dark rectangles using the pencil. One rectangle should be 1” x 4” and the other should be 0.5” x 4.” (Fig. 1)

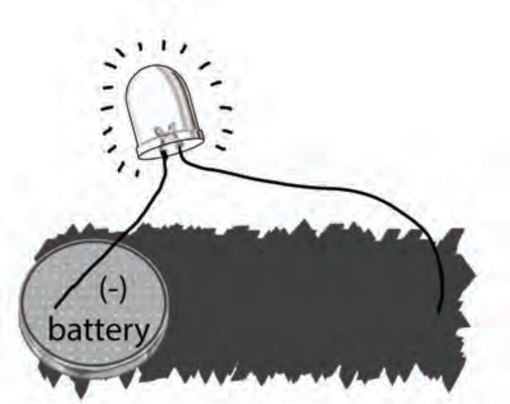


*Figure 1*

4. Place the battery with the “+” side down on one end of the larger rectangle.

5. Put the shorter leg of the LED on the side of the battery that is facing up and tape it in place.

6. Put the longer leg of the LED about half an inch down on the rectangle. Does it light up? If not, get out your pencil and make the rectangle even darker. It might takes several layers of pencil lead to make this work.

7. Repeat steps 4-6 for the smaller rectangle to make sure you can make the LED light up.

## Collecting Data

**Qualitative**

1. Turn off the room’s lights.

2. Start with the larger rectangle. Light up the LED as you did in the previous section.

3. Slide the shorter leg along the rectangle. What happens to the LED?

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4. Do the same for the smaller rectangle. What happens?

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# Student Guide

## Collecting Data

**Quantitative**

1. Again, make the LED light up on the big square. The shorter leg should start 0.5” from the battery.

2. On a scale from 1-10, with 1 being the dimmest and 10 being the brightest, how bright is the LED? Record it in the chart.

3. Move the leg 0.5” down the square, so the leg is now 1” away from the battery. On a scale from 1-10, how bright is the LED now? Record it in the chart.

4. Continue steps 1-3 until the entire chart is filled.

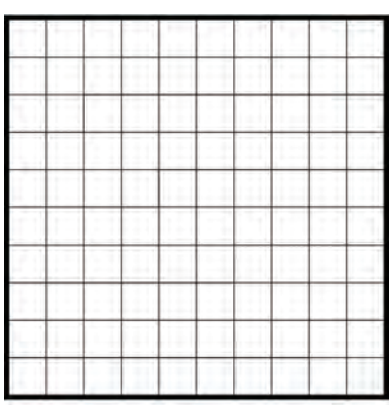
5. Repeat for the smaller rectangle

| | 0.5" | 1" | 1.5" | 2" | 2.5" | 3" | 3.5" | 4" |
|---|---|---|---|---|---|---|---|---|
| Large Rectangle | | | | | | | | |
| Small Rectangle | | | | | | | | |

## Analyzing Your Results

1. What happened to the brightness of the LED when the leg of the LED got farther away from the battery?

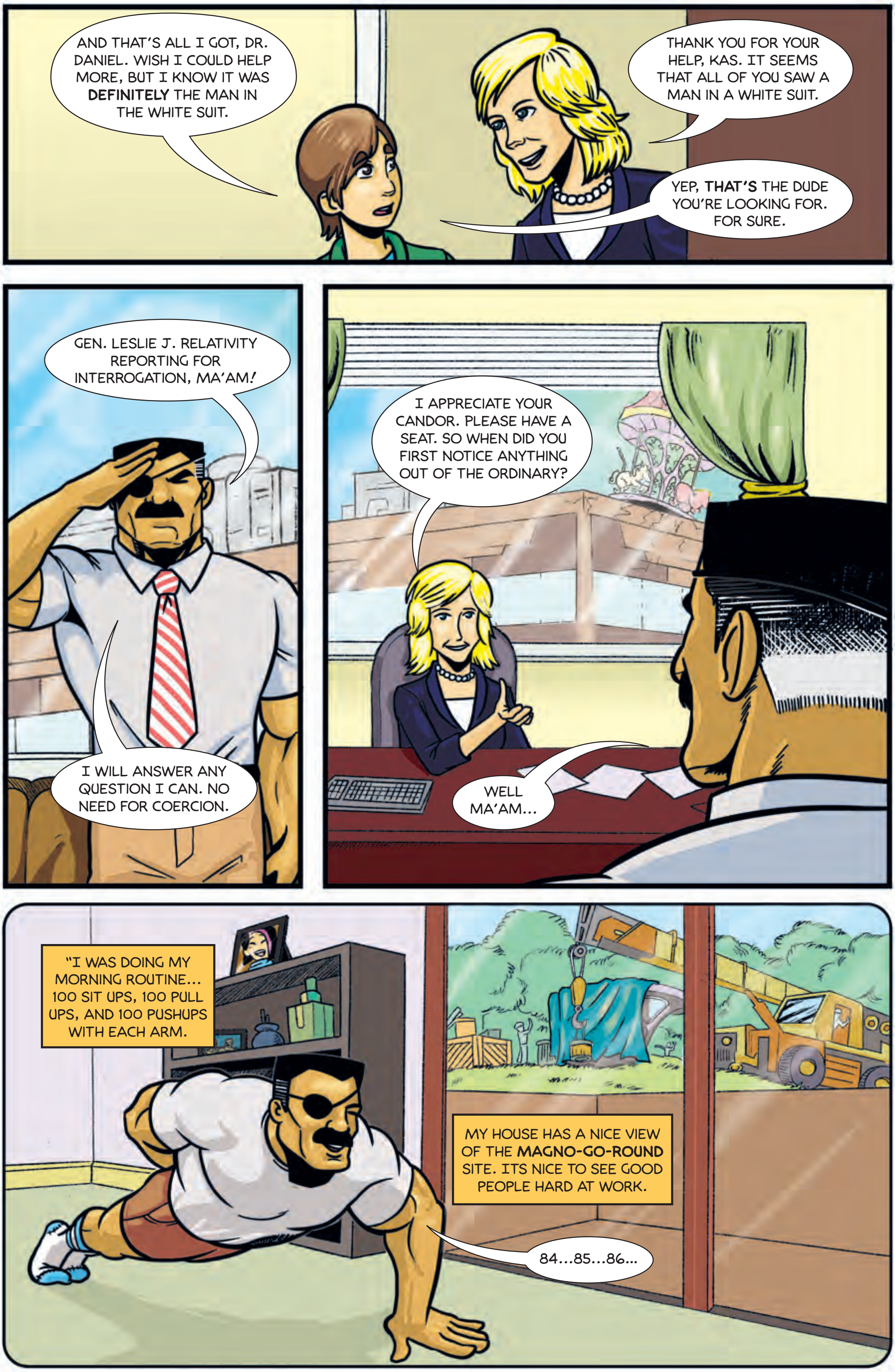
2. In the space below, graph the brightness of the distance from the battery versus the brightness of the LED for both the large rectangle and the small rectangle on the same graph



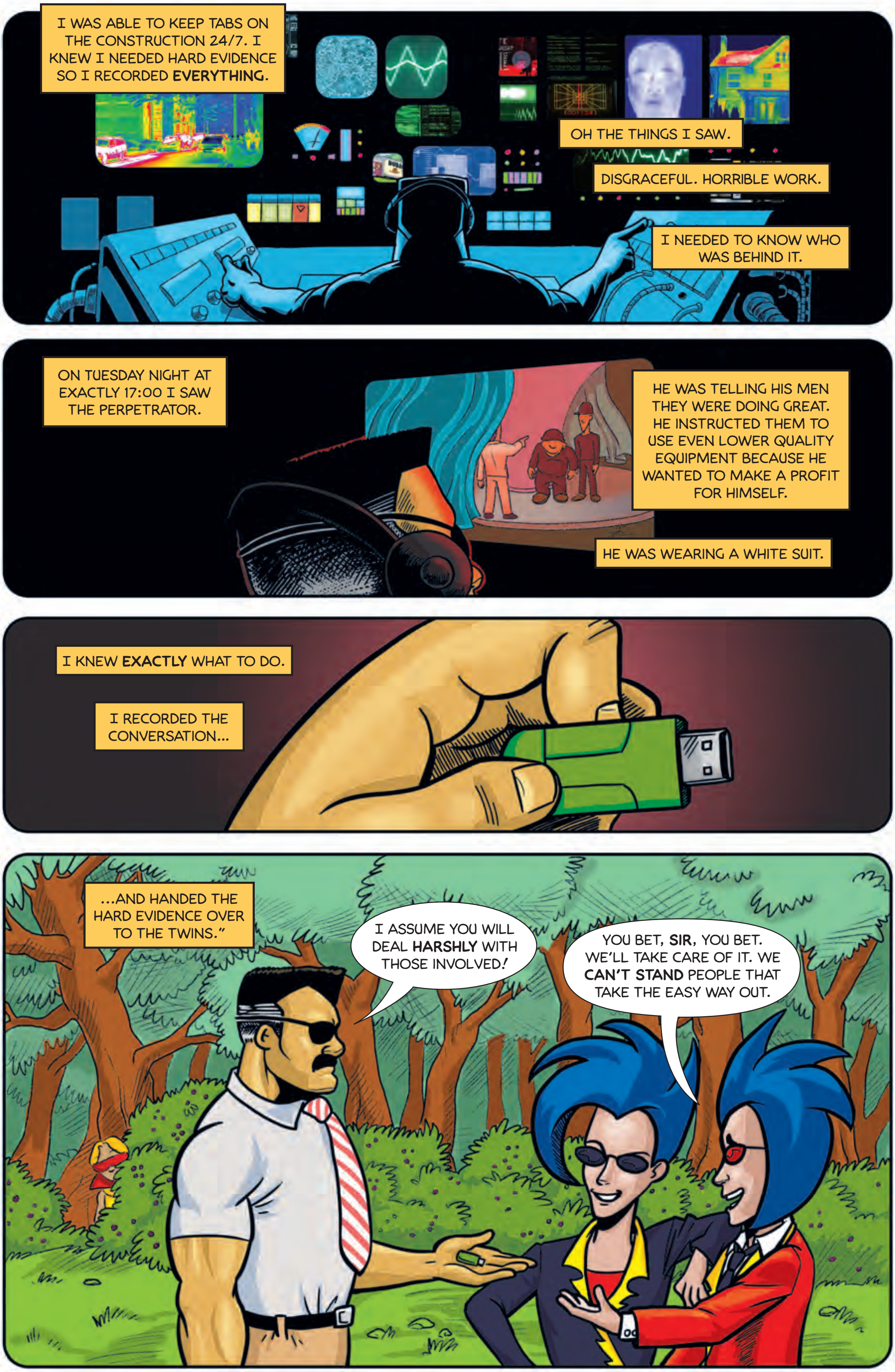
3. What does the graph look like?

4. How does the graph of the small rectangle compare to the graph of the large rectangle? Do they change at the same rate? Do they end at the same brightness level?

5. From looking at your graphs and your answers to the previous questions, what can you say about how resistance changes as you have more pencil graphite in the circuit made by the battery, LED, and graphite?


AND THAT'S ALL I GOT, DR. DANIEL. WISH I COULD HELP MORE, BUT I KNOW IT WAS **DEFINITELY** THE MAN IN THE WHITE SUIT.
THANK YOU FOR YOUR HELP, KAS. IT SEEMS THAT ALL OF YOU SAW A MAN IN A WHITE SUIT.
YEP, **THAT'S** THE DUDE YOU'RE LOOKING FOR. FOR SURE.
GEN. LESLIE J. RELATIVITY REPORTING FOR INTERROGATION, MA'AM!
I WILL ANSWER ANY QUESTION I CAN. NO NEED FOR COERCION.
I APPRECIATE YOUR CANDOR. PLEASE HAVE A SEAT. SO WHEN DID YOU FIRST NOTICE ANYTHING OUT OF THE ORDINARY?
WELL MA'AM...
"I WAS DOING MY MORNING ROUTINE... 100 SIT UPS, 100 PULL UPS, AND 100 PUSHUPS WITH EACH ARM.
MY HOUSE HAS A NICE VIEW OF THE **MAGNO-GO-ROUND** SITE. ITS NICE TO SEE GOOD PEOPLE HARD AT WORK.
84...85...86...

BUT THEN I STARTED LOOKING CLOSER. I DIDN'T LIKE THE LOOK OF THOSE PEOPLE. I NEVER HEARD OF "DUBIOUS SHIPPING" OR "SHADY ENTERPRISES" AND I KNOW MY CONSTRUCTION COMPANIES!
SHADY ENT. PROJECT
DUBIOUS BROTHERS SHIPPING
AND THEY HAD SPRAY PAINT ON THEIR TRUCK. **SPRAY PAINT!**
NO WORK ETHIC AT ALL! **NONE!** I CAN'T TOLERATE SLACKERS AND DO-NOTHING WORKERS. THEY NEED A FEW YEARS IN THE ARMY TO STRAIGHTEN THEM OUT. I SHOULD HAVE...
YES **LESLIE**, I'M SURE THEY WERE HORRIBLE. BUT LET'S MOVE ON. WHAT ELSE DID YOU NOTICE?
FUN DOUGH
THEY HAD NO IDEA WHAT THEY WERE DOING. NO DIRECTION! THEY NEEDED A LEADER!
PLANS
I WAS SURE THE TWINS HAD NO IDEA. GOOD PEOPLE, THE TWINS, GOOD PEOPLE.
I HAD TO SHOW THE TWINS WHAT WAS GOING ON SO I GOT OUT SOME SUPPLIES TO RECORD THEIR ABHORRENT BEHAVIOR.
YOU KNOW, THE NORMAL STUFF...
ARMY SPY GEAR
PARABOLIC RECEIVER, INFRARED CAMERA, NIGHT VISION. JUST WHAT I HAD AROUND THE HOUSE, OF COURSE.

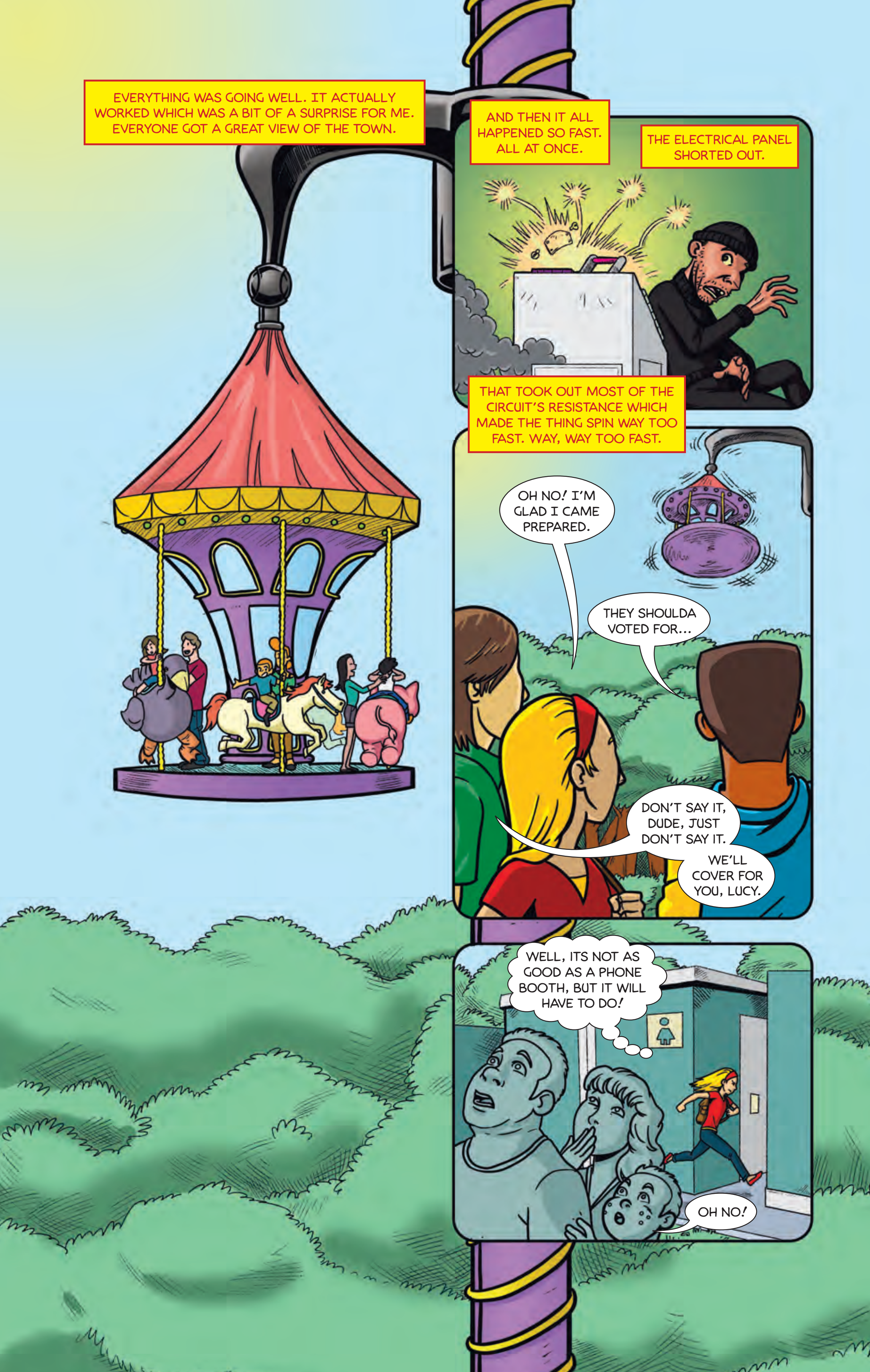


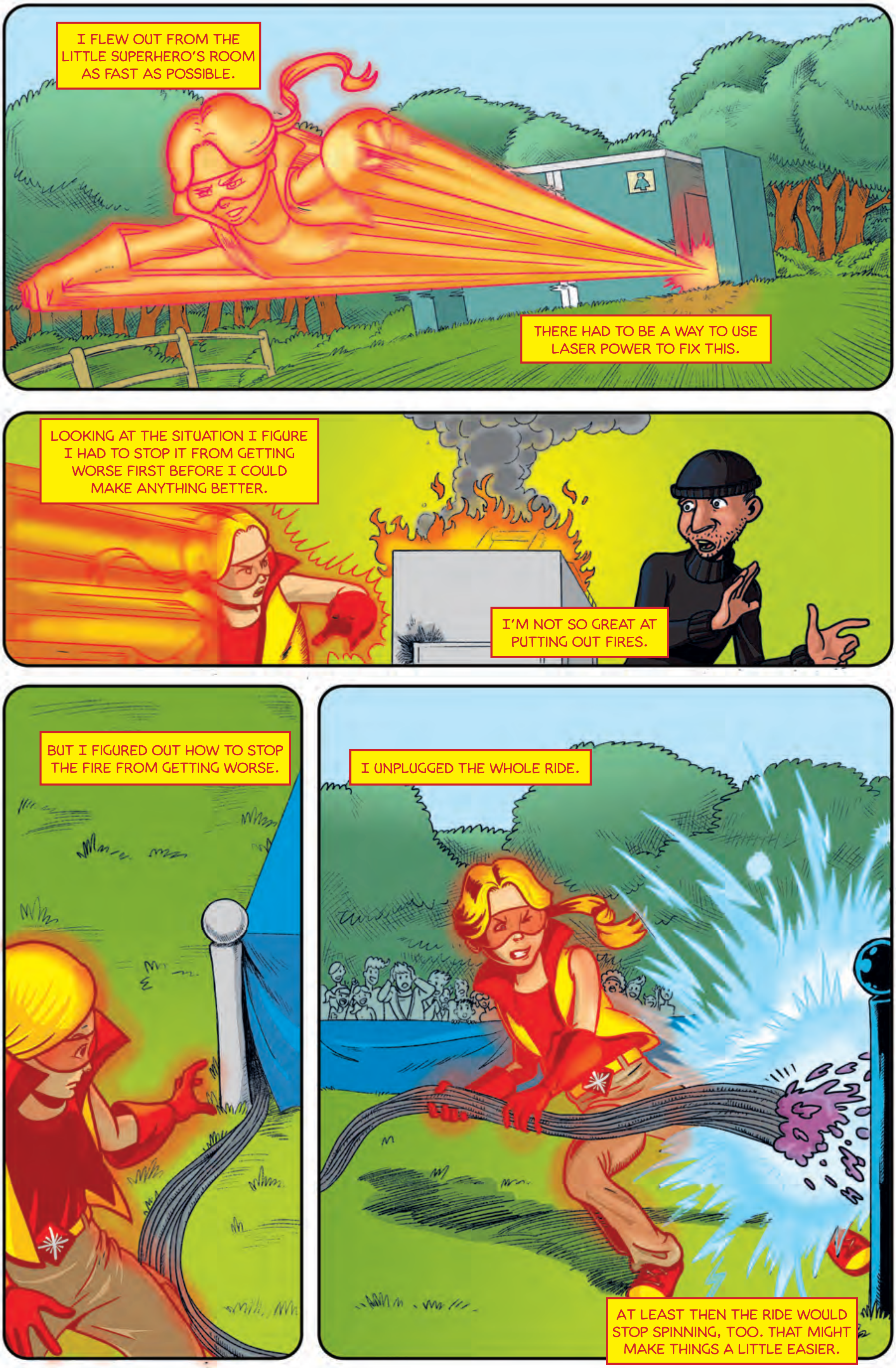
I WAS ABLE TO KEEP TABS ON THE CONSTRUCTION 24/7. I KNEW I NEEDED HARD EVIDENCE SO I RECORDED **EVERYTHING**.
OH THE THINGS I SAW.
DISGRACEFUL. HORRIBLE WORK.
I NEEDED TO KNOW WHO WAS BEHIND IT.
ON TUESDAY NIGHT AT EXACTLY 17:00 I SAW THE PERPETRATOR.
HE WAS TELLING HIS MEN THEY WERE DOING GREAT. HE INSTRUCTED THEM TO USE EVEN LOWER QUALITY EQUIPMENT BECAUSE HE WANTED TO MAKE A PROFIT FOR HIMSELF.
HE WAS WEARING A WHITE SUIT.
I KNEW **EXACTLY** WHAT TO DO.
I RECORDED THE CONVERSATION...
...AND HANDED THE HARD EVIDENCE OVER TO THE TWINS."
I ASSUME YOU WILL DEAL **HARSHLY** WITH THOSE INVOLVED!
YOU BET, **SIR**, YOU BET. WE'LL TAKE CARE OF IT. WE **CAN'T STAND** PEOPLE THAT TAKE THE EASY WAY OUT.


I ASSUMED THEY WOULD **FIRE** THOSE INVOLVED AND PER-FORM A **THOROUGH** INSPECTION OF THE WORK ALREADY COMPLETED.
I TOLD THEM ALL ABOUT THE 5 KEYS TO A PRODUCTIVE WORKFORCE.
**1.** ALWAYS...
**HI, GUYS!**
WHO THE..?
SORRY I'M LATE, I NEEDED TO GO AND GET SOME THINGS FIRST. I THINK **I** CAN SHED SOME LIGHT ON THIS NEGATIVE SITUATION.
**SPECTRA!**
I HOPE **YOU** CAN, NO ONE ELSE HAS BEEN MUCH HELP. THEY ALL KEEP SAYING IT WAS A MAN IN A WHITE SUIT BUT NO ONE KNOWS SOMEONE THAT WEARS **THAT** MUCH WHITE!
DON'T WORRY, I GOT THIS.
YOU GUYS DIDN'T SEE ME MUCH, BUT I WAS THERE THROUGH ALL OF THIS STUFF, TOO. AFTER THE **MISS ALIGNMENT** FIASCO* I'VE BEEN RANDOMLY KEEPING AN EYE ON THE TOWN.
OH, AND I WOULDN'T HAVE MISSED GORDY'S CITY COUNCIL SPEECH FOR **ANYTHING!** WAY TO GO, BUDDY!
I SAW THE MAN IN THE WHITE SUIT, BUT NOT THE WAY YOU ALL DID.
SO I GUESS NOW ITS TIME FOR YOU TO CALL **ME** INTO YOUR OFFICE DR. DANIEL?
I THINK WE'D **ALL** LIKE TO HEAR THIS. WHAT DO YOU REMEMBER?
*SEE SPECTRA #7, "HIGH INTENSITY"

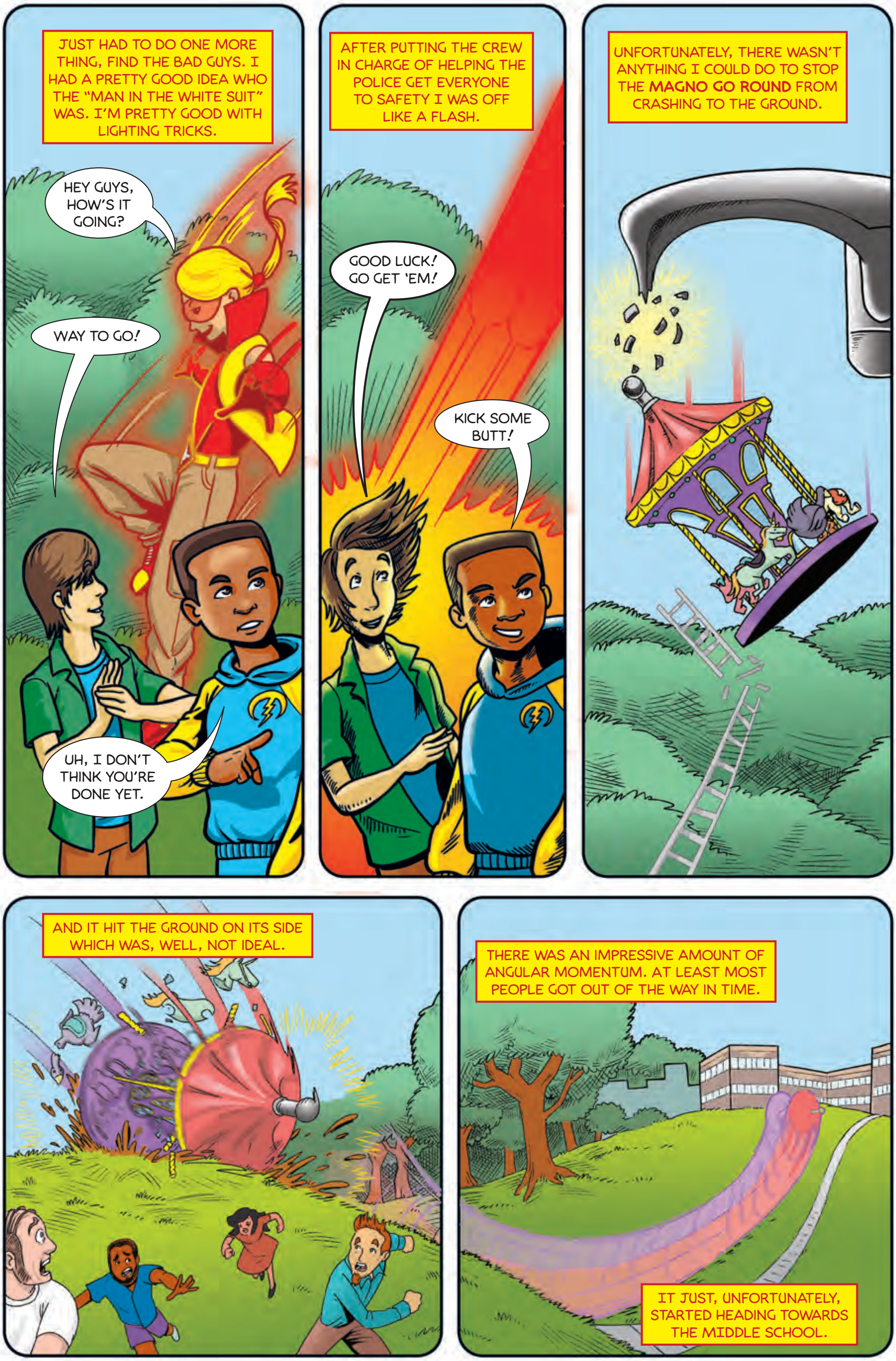

"WELL, I WENT TO THE BIG GRAND OPENING BECAUSE I WAS SURE **SOMETHING** WOULD GO WRONG. NO ONE BELIEVED MY WARNINGS AND I COULDN'T PROVE ANYTHING, I JUST HAD A FEELING.
THESE TWO SEEMED **TOO** LIKABLE FOR ME. AND BESIDES, I'D SEEN ENOUGH SHADY STUFF FROM THEM AROUND TOWN.
AFTER SO MANY ADVENTURES I HOPED I COULD FIX A PROBLEM ...**IF** I SAW ONE.
WELCOME ONE AND ALL TO OUR IRRESISTIBLE CREATION, OUR CURRENT CONTRAPTION, OUR AMPED ATTRACTION...
CHECK IT OUT!
WE WANT TO FLY!
THE MAGNIFICENT MAGNO-GO-ROUND!
COME ONE COME ALL TO RIDE THE FLYING ELEPHANTS OF THE SKY!
SEE THE UNICORN? I WANT TO RIDE THE UNICORN!
ZZZZ
I CAN'T BELIEVE THEY BUILT IT!
WISH THEY WERE PLAYING **MY** MUSIC, NOT THIS CIRCUS STUFF.
I'D RATHER BE AT THE WATER PARK.
I'M SORRY, GORDY, THE TOWN SHOULD HAVE GONE WITH YOUR IDEA. WAY TO BE A GOOD SPORT ABOUT IT ALL. I'M SURE RUBY IS GLAD YOU CAME.
GRUMBLE.. SCIENCE LAB... GRUMBLE.!

OHM MY GOODNESS, HERE WE GO! LOOK AT THE POTENTIAL!
GET READY TO RIDE!!!
ZZZZZ
UM, SIR? AREN'T YOU SUPPOSED TO BE PAYING ATTENTION?
EVERYTHING LOOK FLASHY AND SHINY AND NEW, BUT WITH SLEEPING RIDE OPERATORS AND WHAT LOOKED LIKE BAD CONSTRUCTION, I KNEW WE NEEDED TO BE READY FOR SOMETHING TO GO WRONG.
MY SPECTRA SENSES ARE DEFINITELY TRIGGERED. I'M GOING TO BE READY JUST IN CASE.
YEAH, SOMETHING ISN'T RIGHT.
COME ON, MAN, GET OVER THE SCIENCE LAB, LETS HAVE SOME **FUN**.
LUCY, QUIT MAKING US WORRY.
EVERYONE GOT ON THE RIDE AND..
I WANTED TO RIDE THE UNICORN!
UH..YES, KAS, YOU DID. AS I WAS SAYING...
WHEN IT WENT INTO THE AIR I COULD HEAR CREAKING AND WHINING. IT SOUNDED LIKE THE WHOLE STRUCTURE WAS GOING TO CRACK AND THE WIRES WERE GOING TO BLOW.
IT WASN'T EASY TO HEAR OVER THE NOISE BUT IT WAS THERE.

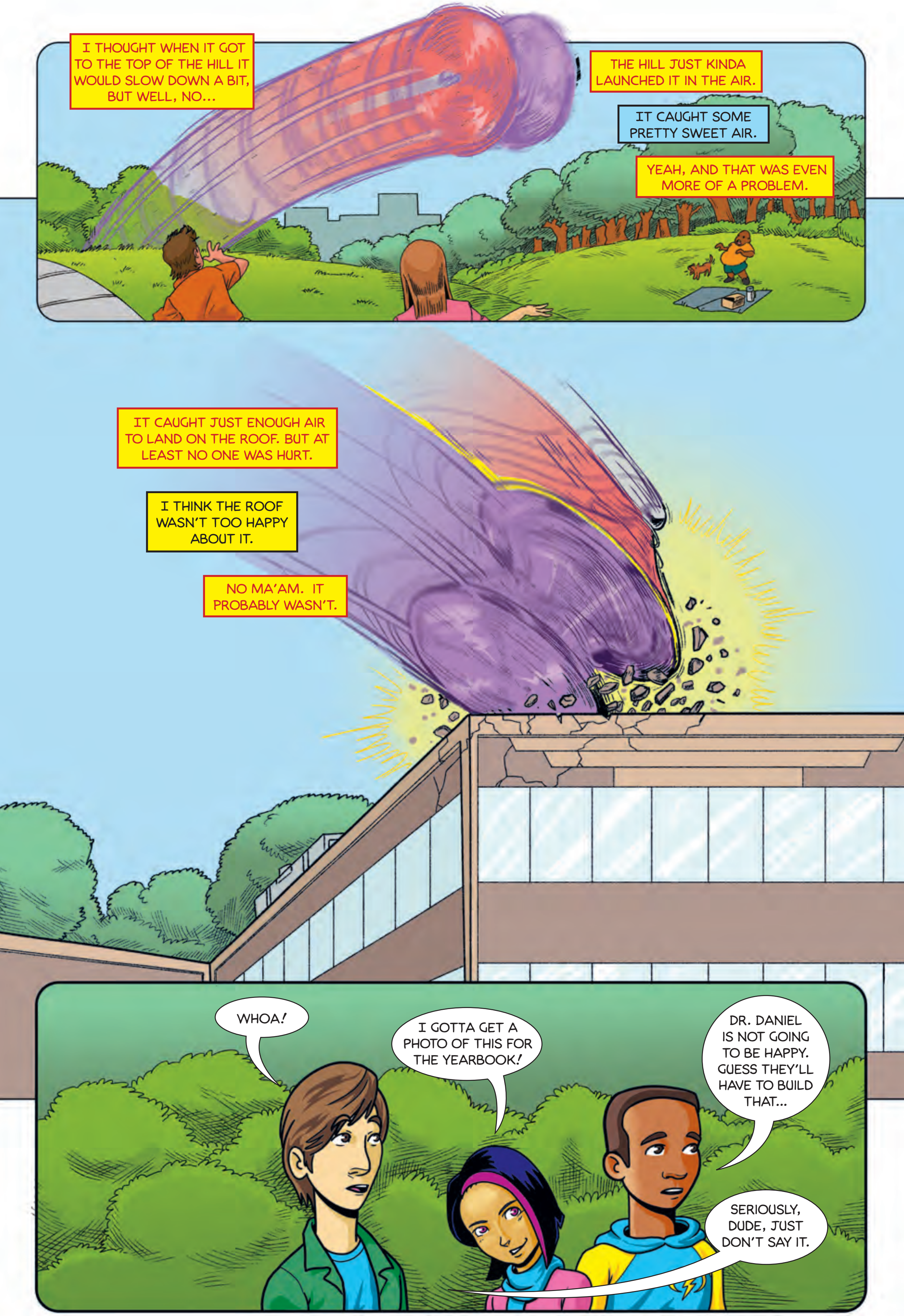

EVERYTHING WAS GOING WELL. IT ACTUALLY WORKED WHICH WAS A BIT OF A SURPRISE FOR ME. EVERYONE GOT A GREAT VIEW OF THE TOWN.
AND THEN IT ALL HAPPENED SO FAST. ALL AT ONCE.
THE ELECTRICAL PANEL SHORTED OUT.
THAT TOOK OUT MOST OF THE CIRCUIT'S RESISTANCE WHICH MADE THE THING SPIN WAY TOO FAST. WAY, WAY TOO FAST.
OH NO! I'M GLAD I CAME PREPARED.
THEY SHOULDA VOTED FOR...
DON'T SAY IT, DUDE, JUST DON'T SAY IT.
WE'LL COVER FOR YOU, LUCY.
WELL, ITS NOT AS GOOD AS A PHONE BOOTH, BUT IT WILL HAVE TO DO!
OH NO!


I FLEW OUT FROM THE LITTLE SUPERHERO'S ROOM AS FAST AS POSSIBLE.
THERE HAD TO BE A WAY TO USE LASER POWER TO FIX THIS.
LOOKING AT THE SITUATION I FIGURE I HAD TO STOP IT FROM GETTING WORSE FIRST BEFORE I COULD MAKE ANYTHING BETTER.
I'M NOT SO GREAT AT PUTTING OUT FIRES.
BUT I FIGURED OUT HOW TO STOP THE FIRE FROM GETTING WORSE.
I UNPLUGGED THE WHOLE RIDE.
AT LEAST THEN THE RIDE WOULD STOP SPINNING, TOO. THAT MIGHT MAKE THINGS A LITTLE EASIER.


THAT'S WHEN I REALIZED THE WHOLE RIDE WAS A MESS. IT WAS HELD TOGETHER WITH **FUN DOUGH!**
FUN DOUGH CONDUCTS ELECTRICITY? **COOL!**
GORDY! NOT NOW.
UNPLUGGING THE THING JUST MADE IT WORSE. WHEN IT STOPPED SPINNING IT GOT REALLY UNSTABLE. IT WAS ROCKING EVERYWHERE.
I HAD TO GET EVERYONE OFF AS FAST AS POSSIBLE.
AT FIRST I THOUGHT OF WELDING THE TOP TOGETHER, BUT THEN I FIGURED IF THEY USED FUN DOUGH FOR WIRES, THE MIGHT NOT HAVE USED A LOT OF REAL METAL IN THE CONSTRUCTION, EITHER.
I SAW SOME METAL RODS AND DECIDED I COULD WELD SOME TOGETHER TO MAKE A LADDER.
I JUST HOPED I COULD DO IT FAST ENOUGH.
IT WAS HARD TO GET THE LADDER UP TO THEM, BUT WITH HELP FROM EVERYONE, WE MADE IT WORK.
I AM SO IMPRESSED WITH HOW CALM EVERYONE WAS. AND WAY TO GO, KAS, FOR CALLING THE POLICE. WELL DONE.
WE GOT EVERYONE OFF THE RIDE SAFELY AND THE COPS KEPT EVERYTHING UNDER CONTROL.



JUST HAD TO DO ONE MORE THING, FIND THE BAD GUYS. I HAD A PRETTY GOOD IDEA WHO THE "MAN IN THE WHITE SUIT" WAS. I'M PRETTY GOOD WITH LIGHTING TRICKS.
HEY GUYS, HOW'S IT GOING?
WAY TO GO!
UH, I DON'T THINK YOU'RE DONE YET.
AFTER PUTTING THE CREW IN CHARGE OF HELPING THE POLICE GET EVERYONE TO SAFETY I WAS OFF LIKE A FLASH.
GOOD LUCK! GO GET 'EM!
KICK SOME BUTT!
UNFORTUNATELY, THERE WASN'T ANYTHING I COULD DO TO STOP THE **MAGNO GO ROUND** FROM CRASHING TO THE GROUND.
AND IT HIT THE GROUND ON ITS SIDE WHICH WAS, WELL, NOT IDEAL.
THERE WAS AN IMPRESSIVE AMOUNT OF ANGULAR MOMENTUM. AT LEAST MOST PEOPLE GOT OUT OF THE WAY IN TIME.
IT JUST, UNFORTUNATELY, STARTED HEADING TOWARDS THE MIDDLE SCHOOL.


I THOUGHT WHEN IT GOT TO THE TOP OF THE HILL IT WOULD SLOW DOWN A BIT, BUT WELL, NO...
THE HILL JUST KINDA LAUNCHED IT IN THE AIR.
IT CAUGHT SOME PRETTY SWEET AIR.
YEAH, AND THAT WAS EVEN MORE OF A PROBLEM.
IT CAUGHT JUST ENOUGH AIR TO LAND ON THE ROOF. BUT AT LEAST NO ONE WAS HURT.
I THINK THE ROOF WASN'T TOO HAPPY ABOUT IT.
NO MA'AM. IT PROBABLY WASN'T.
WHOA!
I GOTTA GET A PHOTO OF THIS FOR THE YEARBOOK!
DR. DANIEL IS NOT GOING TO BE HAPPY. GUESS THEY'LL HAVE TO BUILD THAT...
SERIOUSLY, DUDE, JUST DON'T SAY IT.

# Teacher's Guide

## ACTIVITY 4: BLUE & BLACK OR WHITE & GOLD?

### Intro

Why do we see the colors we do? Rods and cones and eyes and biology are one place to start, but this lesson is going to look at why the objects we see have a color at all. It's all based on light and how light is interacting with the objects we are looking at. Students will look at colored beads in different colors of light and talk about what colors they see. The results will be very, very surprising. This should also lead to a good discussion of why a dress can be blue and black but look white and gold in a picture.

### Key Question

What colors are beads in different colors of light?

### Materials

**Red, green, and blue LEDs**
**Coin battery**
**Beads**

* **Dark room**
* **4 sheets of white paper**
* **Pencil**
* **Tape**

* **not** included in the PhysicsQuest kit

### Key Terms

**Absorption:** When light hits an object the energy is absorbed by the object.

**Ambient Light:** Light that is all around us. It's not light that is being reflected from objects.

**LED:** Abbreviation for Light Emitting Diode. An LED emits mostly one color of light.

**Reflection:** When light bounces off an object, it is reflected. Mirrors do this very well, but all objects reflect some amount of light or you wouldn't be able to see them.

# Teacher's Guide

## Before the activity students should know

• We see objects because they reflect light.

• The color of an object is based on the color of light that is being reflected.

## After the activity students should know

• Explain why objects look different colors in different colors of light.

• Explain why a dress might look white and gold when it is really blue and black.

## The science behind how we see color

Seeing in color is no easy feat. It involves the biology of the retina, the brain, and the light around us. Many animals can't see in color at all, while others see many more colors than the human eye can see.

When we see something in color, our eyes are detecting the color of the light reflected from the object. Our brain takes that information—along with the color of the surrounding light—and processes it to determine what color the object is. Most of the time, this works fine because we are surrounded by white light. But when the color of the light around an object changes, problems can arise.

When a red bead is in white light, we see it as red. Why? Because only red light is being reflected; all the other colors of light are being absorbed. The same is true with blue beads and green beads, etc. Your brain says, "Look at that! The light all around is white and only red is being reflected. That means this bead is red!"

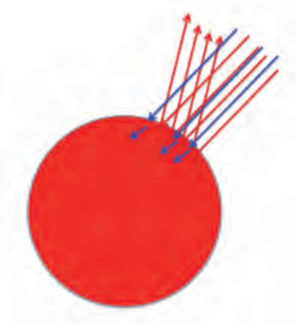


*Figure 1*

White things appear white because all the colors of the light around them are reflected. We perceive objects as black when all the colors of light are absorbed.

If you put that red bead into a room with only red light, it will reflect all the colors of the light around it. So your brain says, "Look at that! All the colors of the surrounding light are being reflected. The bead must be white!" You see the bead as white.

This explains the famous blue-and-black (or white-and-gold) dress:

it was a case of a blue dress being viewed in shaded blue light. Blue light reflecting off a blue dress made our eyes see white. Similarly, a green bead in a blue LED light will look grayish because the blue LED is producing a bit of green light, and that bit of green light is being reflected.

The LEDs you will use in this kit look like they produce red, blue, and green light. However, that's not entirely true. The red LED produces bits of orange and yellow light. The green LED produces a bit of yellow and blue light. The blue LED produces a bit of green and purple light.

Because it is important to know what colors are being produced by the LEDs, Figure 2 shows pictures of the LEDs as seen through a diffraction grating. The diffraction grating breaks up the light into its different colors so you can see what's actually being produced.

## Note:

If you'd like to take pictures on your own using your iPhone or iPad, you can download PhysicsCentral's free SpectraSnapp app, available at:

https://itunes.apple.com/us/app/spectrasnapp/id582838193

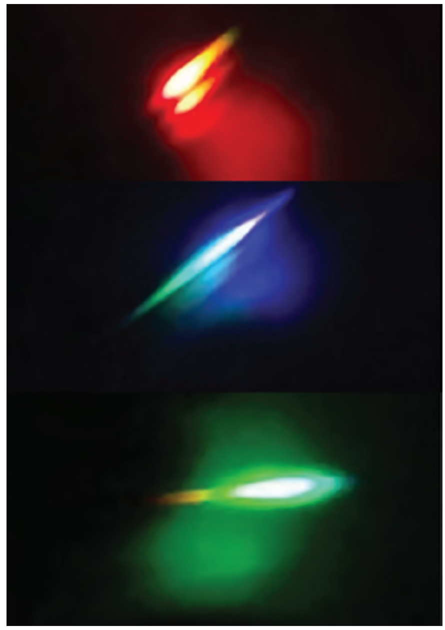


*Figure 2*

## Safety

Warn students very strongly about the dangers of looking directly into an LED. Small beads can be a choking hazard if swallowed.

## Suggested Resources

- http://www.nytimes.com/interactive/2015/02/28/science/white-or-blue-dress.html?_r=0
- http://www.wired.com/2015/02/science-one-agrees-color-dress/
- http://www.livescience.com/32559-why-do-we-see-in-color.html
- http://ed.ted.com/lessons/how-we-see-color-colm-kelleher

# Student Guide

## Intro

Were you one of the many people "tricked" by the blue and black dress that looked white and gold? Even after you knew it was blue and black did you swear it was white and gold? This activity will show you why it can sometimes be so hard to tell colors, particularly in interesting lighting.

### Materials

**Red, green, and blue LEDs**
**Coin battery**
**Beads**

- * **Dark room**
- * **4 sheets of white paper**
- * **Pencil**
- * **Tape**

* **not** included in the PhysicsQuest kit

*This picture of Cecilia Bleasdale's dress was initially posted on Tumblr by Caitlin McNeill. © 2015 Cecilia Bleasdale*

## Key Question

What colors are beads in different colors of light?

## Getting Started

1. When you look at a picture of "The Dress," what colors do you see?

_______________________________________
_______________________________________
_______________________________________
_______________________________________
_______________________________________

2. How do our eyes see color?

_______________________________________
_______________________________________
_______________________________________
_______________________________________
_______________________________________

3. Why do you think this dress is so confusing to our eyes and brain?

_______________________________________
_______________________________________
_______________________________________
_______________________________________
_______________________________________
_______________________________________

4. What do you think it would look like in only blue light? Only red? What about green?

_______________________________________
_______________________________________
_______________________________________
_______________________________________
_______________________________________
_______________________________________

## Setting Up the Experiment

1. Take your pile of beads and sort them into colors on a sheet of paper labeled “white light.” Draw a circle around each color category and label it with the color you see (Fig. 1).

2. Connect the green LED to the battery to light the LED (Fig. 2).

3. Turn off the classroom lights so that the only visible light is from the green LED.

4. Again, sort the LEDs into colors on a white sheet of paper labeled “green light,” using only the green light from the LED. The number of groups may be different from what you found on your “white light” paper.

5. Label each category with the color you see—not the color you think they are in white light, but the color you see in green light. These new colors may include things like gray and black.

6. Turn on the lights again. Write down what color beads appeared to be what colors in green light. So if you had a circle labeled “gray,” write down what color beads were in that circle when you turned on the lights.

7. Repeat steps 2 - 6 using the blue and red LEDs.

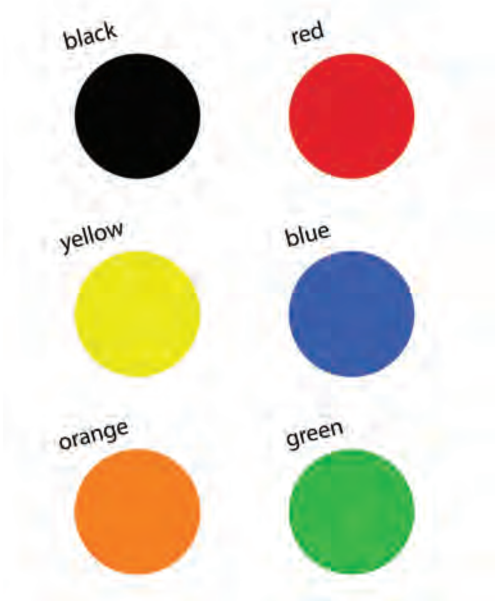


*Figure 1*

***Blue Light***


*Figure 2*

# Student Guide

## Collecting Data

Fill out the following chart with your group.  The bottom row should be the color of each bead in white light and the other rows should be the color that bead appeared in the different color LEDs.

| | | | | | | |
|---|---|---|---|---|---|---|
| Color seen in Green Light | | | | | | |
| Color seen in Blue Light | | | | | | |
| Color seen in Red Light | | | | | | |
| Color of beads in White Light | | | | | | |

## Analyzing Your Results

1.  Why do you think this dress is so confusing to our eyes and brain?

______________________________
______________________________
______________________________
______________________________

2.  In the blue light, what color beads looked white?  Black?  What other colors did you "see"?

______________________________
______________________________

3.  In the red light, what color beads looked white?  Black?  What other colors did you "see"?

______________________________
______________________________
______________________________

4.  What can you say about blue beads in blue light?  In red?  How does this related to the idea of colors reflecting certain colors of light?

______________________________
______________________________
______________________________
______________________________

5.  Look at the diffraction pictures of the blue LED.  What colors of light is it producing?  How does that relate to the colors you "saw" when you were looking at beads in the blue light?  What about for the red and green LEDs?

______________________________
______________________________
______________________________
______________________________

6.  In what color light do you think the blue black/white gold dress was photographed?  Why?

______________________________
______________________________
______________________________
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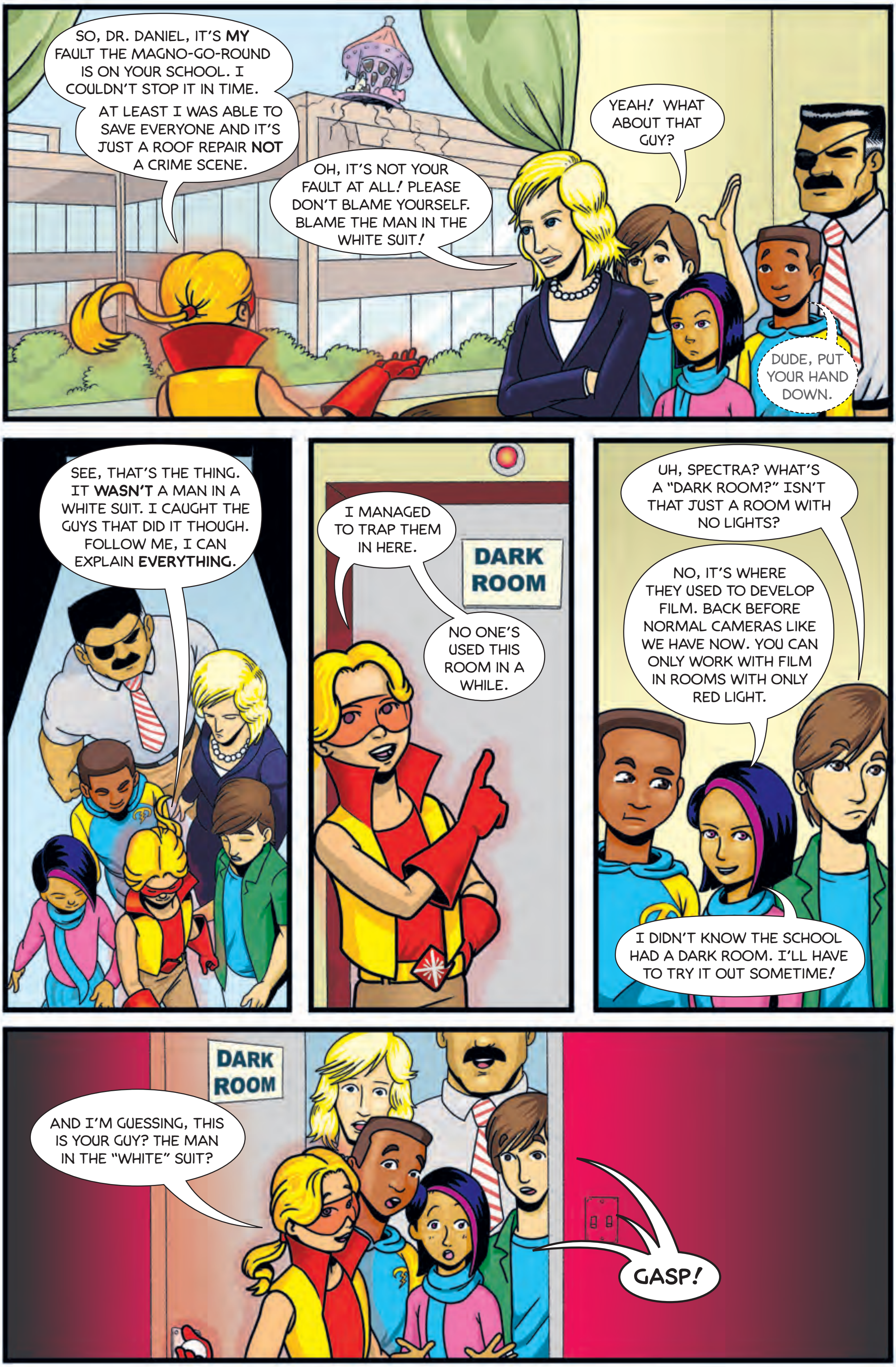
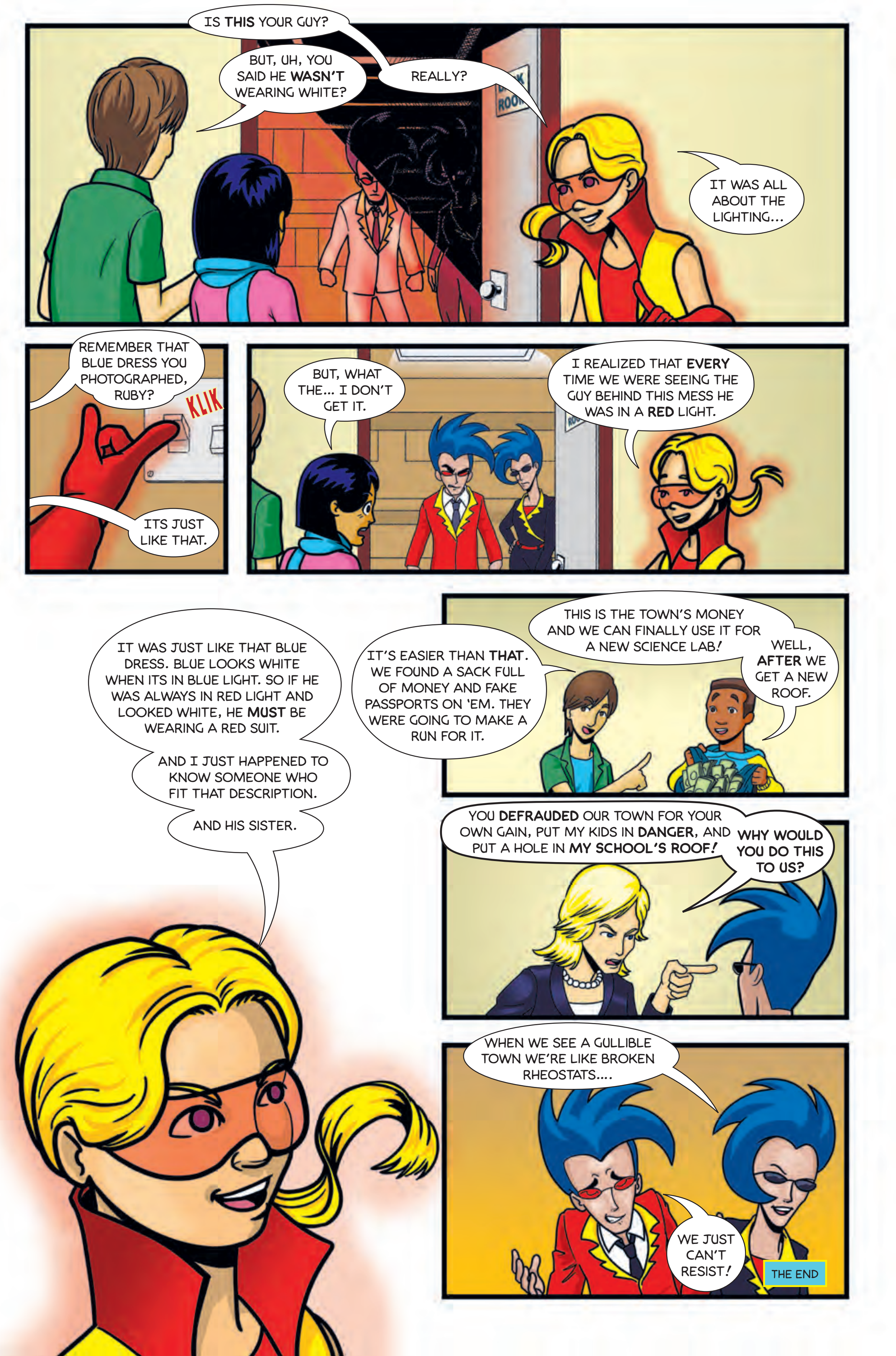
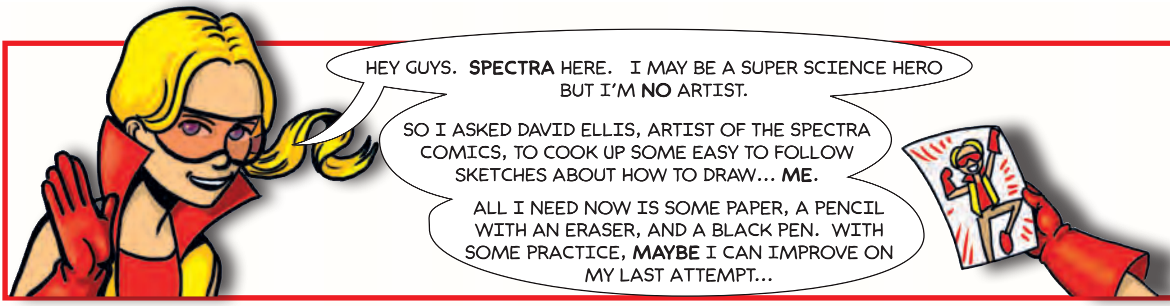
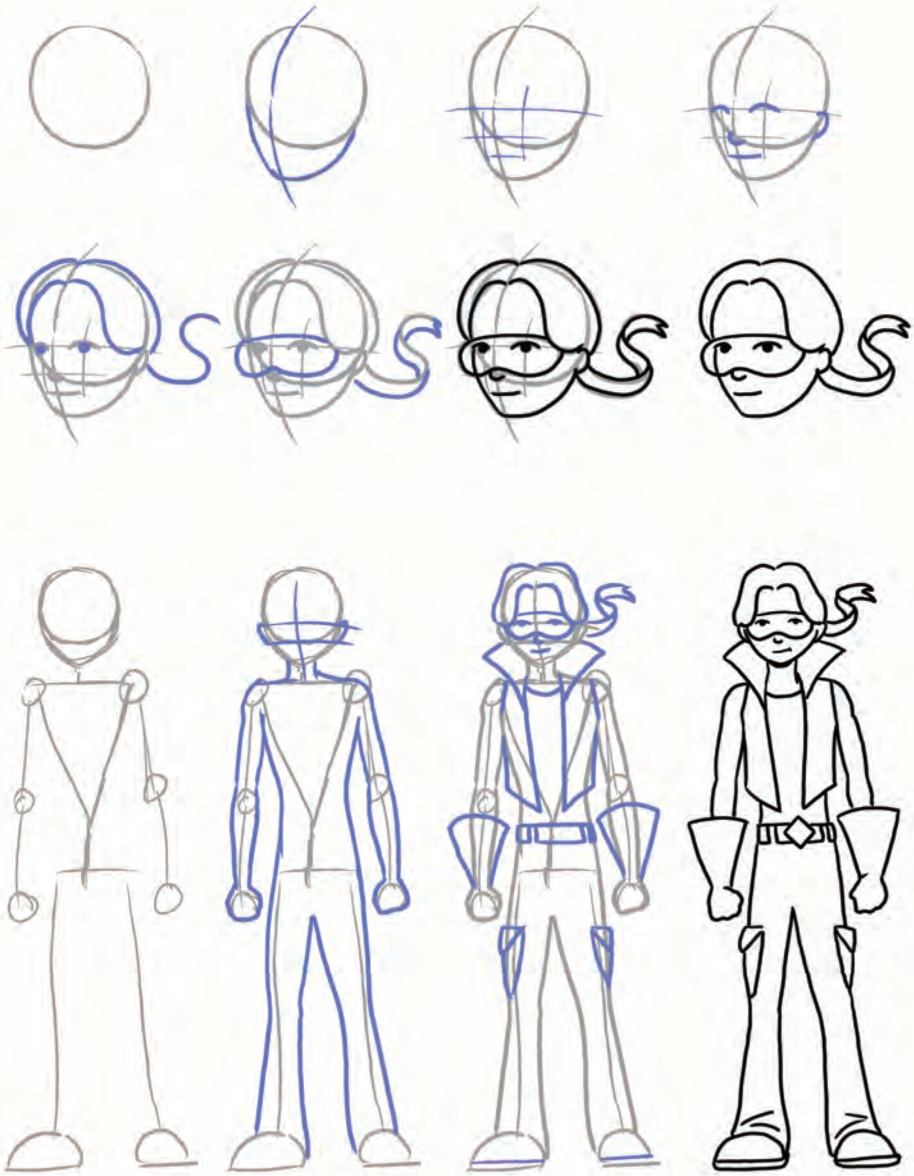
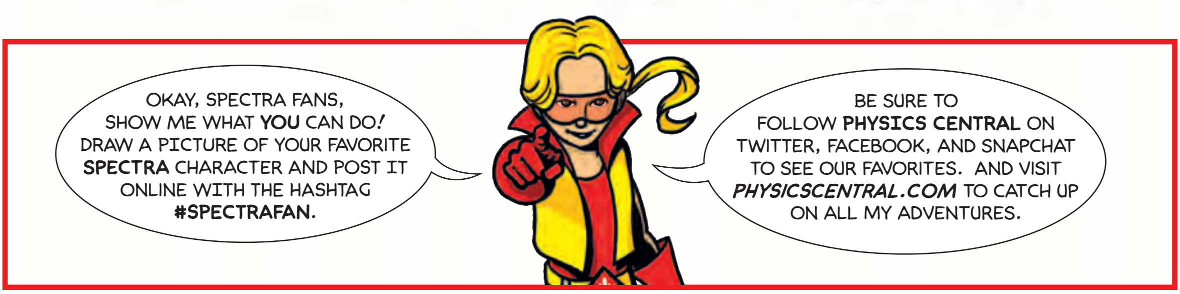

SO, DR. DANIEL, IT'S **MY** FAULT THE MAGNO-GO-ROUND IS ON YOUR SCHOOL. I COULDN'T STOP IT IN TIME.
AT LEAST I WAS ABLE TO SAVE EVERYONE AND IT'S JUST A ROOF REPAIR **NOT** A CRIME SCENE.
OH, IT'S NOT YOUR FAULT AT ALL! PLEASE DON'T BLAME YOURSELF. BLAME THE MAN IN THE WHITE SUIT!
YEAH! WHAT ABOUT THAT GUY?
DUDE, PUT YOUR HAND DOWN.
SEE, THAT'S THE THING. IT **WASN'T** A MAN IN A WHITE SUIT. I CAUGHT THE GUYS THAT DID IT THOUGH. FOLLOW ME, I CAN EXPLAIN **EVERYTHING**.
I MANAGED TO TRAP THEM IN HERE.
DARK ROOM
NO ONE'S USED THIS ROOM IN A WHILE.
UH, SPECTRA? WHAT'S A "DARK ROOM?" ISN'T THAT JUST A ROOM WITH NO LIGHTS?
NO, IT'S WHERE THEY USED TO DEVELOP FILM. BACK BEFORE NORMAL CAMERAS LIKE WE HAVE NOW. YOU CAN ONLY WORK WITH FILM IN ROOMS WITH ONLY RED LIGHT.
I DIDN'T KNOW THE SCHOOL HAD A DARK ROOM. I'LL HAVE TO TRY IT OUT SOMETIME!
DARK ROOM
AND I'M GUESSING, THIS IS YOUR GUY? THE MAN IN THE "WHITE" SUIT?
GASP!


IS THIS YOUR GUY?
BUT, UH, YOU SAID HE WASN'T WEARING WHITE?
REALLY?
DARK ROOM
IT WAS ALL ABOUT THE LIGHTING...
REMEMBER THAT BLUE DRESS YOU PHOTOGRAPHED, RUBY?
KLIK
ITS JUST LIKE THAT.
BUT, WHAT THE... I DON'T GET IT.
I REALIZED THAT EVERY TIME WE WERE SEEING THE GUY BEHIND THIS MESS HE WAS IN A RED LIGHT.
IT WAS JUST LIKE THAT BLUE DRESS. BLUE LOOKS WHITE WHEN ITS IN BLUE LIGHT. SO IF HE WAS ALWAYS IN RED LIGHT AND LOOKED WHITE, HE MUST BE WEARING A RED SUIT.
AND I JUST HAPPENED TO KNOW SOMEONE WHO FIT THAT DESCRIPTION.
AND HIS SISTER.
IT'S EASIER THAN THAT. WE FOUND A SACK FULL OF MONEY AND FAKE PASSPORTS ON 'EM. THEY WERE GOING TO MAKE A RUN FOR IT.
THIS IS THE TOWN'S MONEY AND WE CAN FINALLY USE IT FOR A NEW SCIENCE LAB!
WELL, AFTER WE GET A NEW ROOF.
YOU DEFRAUDED OUR TOWN FOR YOUR OWN GAIN, PUT MY KIDS IN DANGER, AND PUT A HOLE IN MY SCHOOL'S ROOF!
WHY WOULD YOU DO THIS TO US?
WHEN WE SEE A GULLIBLE TOWN WE'RE LIKE BROKEN RHEOSTATS....
WE JUST CAN'T RESIST!
THE END


HEY GUYS. **SPECTRA** HERE. I MAY BE A SUPER SCIENCE HERO BUT I'M **NO** ARTIST.
SO I ASKED DAVID ELLIS, ARTIST OF THE SPECTRA COMICS, TO COOK UP SOME EASY TO FOLLOW SKETCHES ABOUT HOW TO DRAW... **ME**.
ALL I NEED NOW IS SOME PAPER, A PENCIL WITH AN ERASER, AND A BLACK PEN. WITH SOME PRACTICE, **MAYBE** I CAN IMPROVE ON MY LAST ATTEMPT...




OKAY, SPECTRA FANS, SHOW ME WHAT **YOU** CAN DO*!* DRAW A PICTURE OF YOUR FAVORITE **SPECTRA** CHARACTER AND POST IT ONLINE WITH THE HASHTAG **#SPECTRAFAN**.
BE SURE TO FOLLOW **PHYSICS CENTRAL** ON TWITTER, FACEBOOK, AND SNAPCHAT TO SEE OUR FAVORITES. AND VISIT ***PHYSICSCENTRAL.COM*** TO CATCH UP ON ALL MY ADVENTURES.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