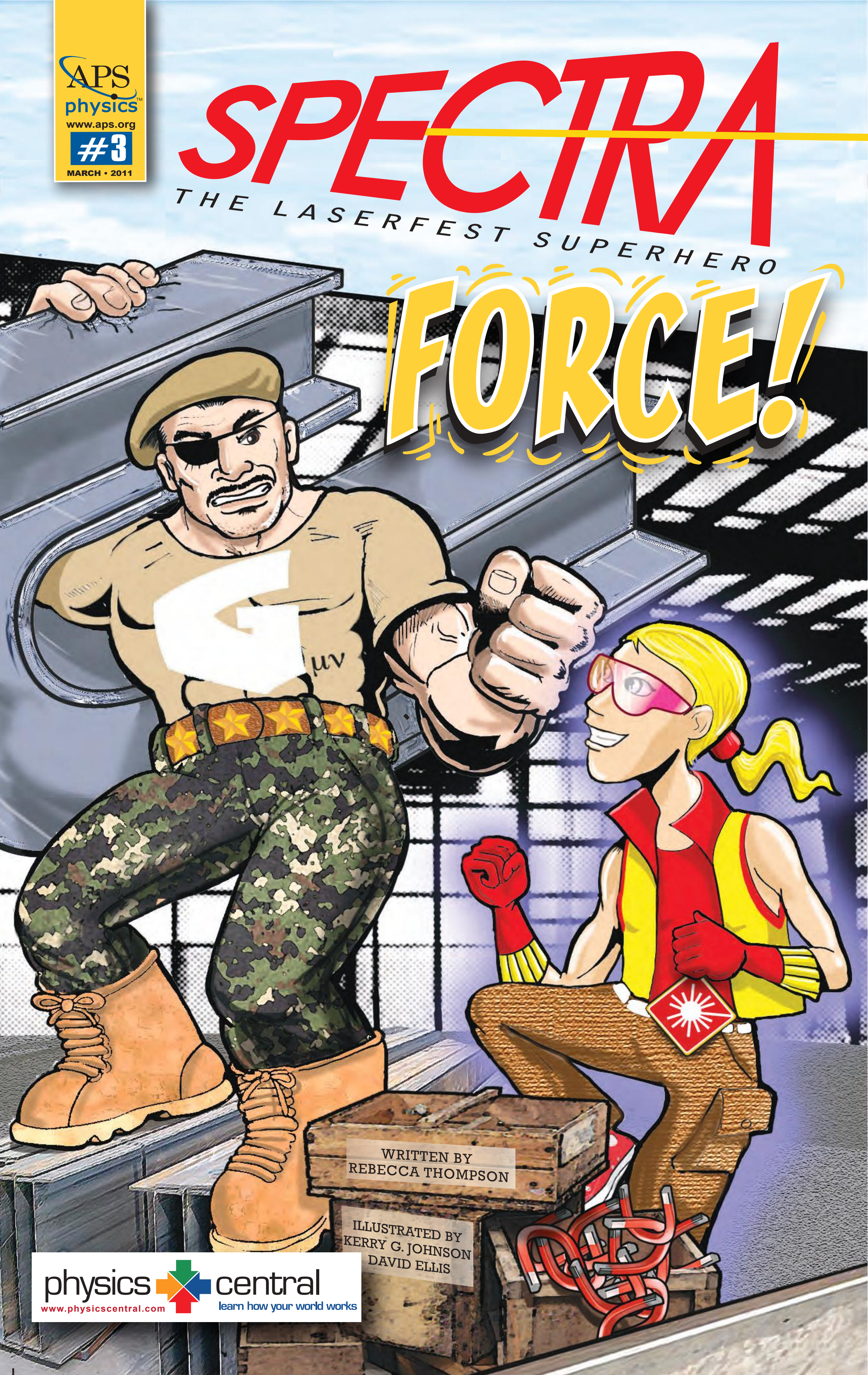

APS physics
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SPECTRA
THE LASERFEST SUPERHERO
FORCE!
G
μν
WRITTEN BY
REBECCA THOMPSON
ILLUSTRATED BY
KERRY G. JOHNSON
DAVID ELLIS
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FAYE DANIEL

June 27, 1950 - December 24, 2010

DEDICATED TO MY MA,
WHO WAS THE GREATEST TEACHER
I HAVE EVER KNOWN,
BOTH IN A CLASSROOM
AND IN MY LIFE.

– Rebecca Thompson

Written by Rebecca Thompson
Art direction and coloring by Kerry G. Johnson
Illustrations by Kerry G. Johnson *(Part 1)* **and David Ellis** *(Part 2)*
Activity illustrations by Nancy Bennett-Karasik

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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 sixth kit, *PhysicsQuest 2010: Spectra's Force.*

In the past each PhysicsQuest kit has followed a mystery-based storyline and requires students to correctly complete four activities in order to solve the mystery and be eligible for a prize drawing. For the second year in a row students will be following laser superhero Spectra. Last year saw the downfall of the evil Miss Alignment. This year students will learn about force and motion as the help unravel the plot of the hard-nosed General Leslie J. Relativity.

THE AMERICAN PHYSICAL SOCIETY (APS)

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

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

MATERIALS LIST

Included in this kit:
- One white tube
- Two yo-yos
- Two sets of chopsticks
- Six rubber bands
- Four differently sized wooden balls

Not included in this kit:
- Two cans of "gravity testing material"
- Masking tape
- Stop watch
- Ruler

For more information on these items and where they can be purchased, please visit the PhysicsQuest website.

If your kit is missing any of these materials, please contact Educational Innovations, www.teachersource.com - (203)229-0730

ABOUT PHYSICSQUEST

PhysicsQuest is a set of four activities designed to engage students in scientific inquiry. The 2010-2011 activities are linked together via a storyline and comic book that follows Spectra, a laser superhero and her work with the hard-nosed General Relativity. 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 through 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.

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 16th, 2011. 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 does not require the answers to all of the questions on the Final Report. If your class only has time to complete some of the activities, they can still submit their answers and receive a certificate of participation. 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 25, 2011.

THE PHYSICSQUEST MATERIALS

The PhysicsQuest kit includes this manual, an "emergency shut off switch" photocopy 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 prevent General Relativity from accidentally destroying the world.

THE TEACHER'S GUIDE

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.

- **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.

NEXT PAGE >>>>

Welcome to PhysicsQuest 2010

The Student's Guide

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

The Student Guide includes:

• **Key Question:** This question highlights the goal of the activity.

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

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

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

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

• **Using Your Results to help Spectra**
In this section students turn their results into information that will help them determine the secret code to a shut-off switch to rescue Spectra.

PhysicsQuest Website
The PhysicsQuest website, www.physicscentral.com/physicsquest, has supplemental material for teachers, such as extension activities. Periodic updates on the program will also be posted on this site.

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

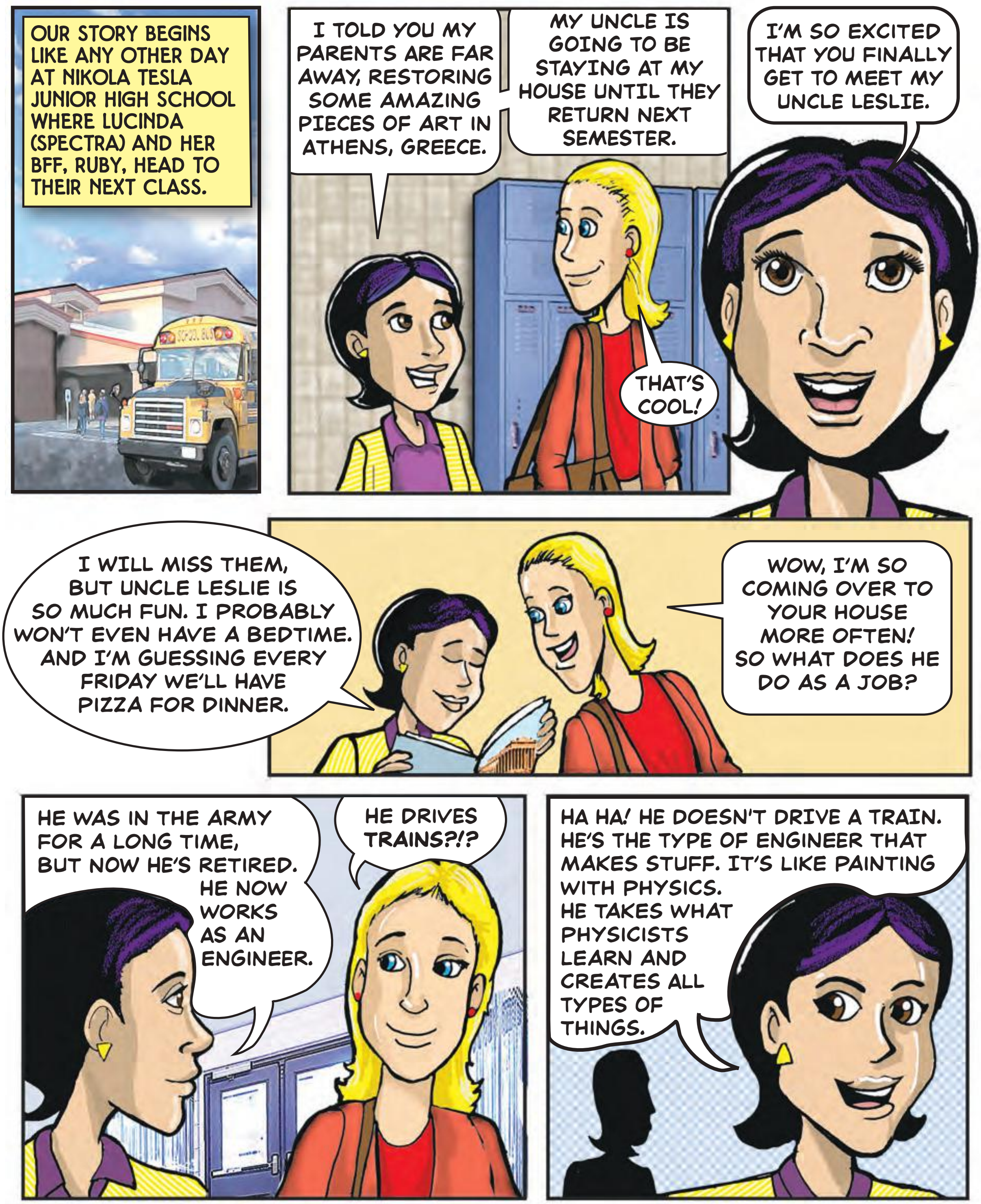
• PhysicsQuest as a fully integrated part of regular curriculum
The topics covered in PhysicsQuest are covered in many physical science classes, so you might have students do the PhysicsQuest activities during the corresponding units.

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

SPECTRA'S FORCE

PART 1

WRITTEN BY REBECCA THOMPSON • ILLUSTRATIONS BY KERRY G. JOHNSON




LOOK OVER THERE, IT'S THE GUYS.
KAS AND GORDY, WHERE ARE YOU TWO HEADED?
SAME PLACE YOU ARE, DARK ARTS WITH SLYTHERINE, BETTER KNOWN AS PHYSICS CLASS WITH A NEW TEACHER.
SEEMS LIKE WE CAN'T HANG ON TO A PHYSICS TEACHER. THAT JOB MUST BE CURSED.*
HEY, RUBY!
*Find out what happened to the other physics teacher in Spectra #2. Available online at www.physicscentral.com
The quartet of friends make it to the physics class and meet the new teacher.
WHO'S THAT?
UNCLE LESLIE? WHAT ARE YOU DOING HERE?
HI THERE LITTLE RUBY! I WANTED TO SURPRISE YOU. NOW PLEASE. TAKE YOUR SEAT.
AND THE REST OF YOU...
SIT DOWN!!


I AM... GENERAL LESLIE J. RELATIVITY
HA! HAH! HA! HA! GIGGLE! HA! HA!
DO YOU THINK MY NAME IS FUNNY? BECAUSE, I'M NOT LAUGHING! I WAS NAMED AFTER MY DEAR OLD GRANDMOTHER.
YOU ALL WILL CALL ME GENERAL!
IF YOU DON'T, YOU WILL DROP AND GIVE ME 20 PUSH UPS.
FROM WHAT I'VE HEARD, YOU HAVE LEARNED ABOUT LASERS, WHICH ARE NEW AND FANCY, BUT IN MY CLASS WE'RE GOING BACK-TO-BASICS!
UM, AH, UM...
YOU THERE, BLONDE GIRL, DEFINE FORCE!
YOU! MR. FOOTBALL PLAYER! SINCE YOU'RE SUCH A HOTSHOT ON THE FIELD, YOU SHOULD KNOW ABOUT FORCE.

ACTIVITY 1: Doughy Physics

TEACHER'S GUIDE

INTRO

If someone holds up two objects, one heavy, one light, and asks which one will hit the ground first, if you are like most people you will instinctively pick the heavier object. And why wouldn't you, rocks fall faster than feathers after all! But there is a much more interesting relationship between weight and gravity and the time it takes an object to fall. This experiment will help students better understand those relationships. Students will use both their eyes and their ears to figure out how mass effects how something falls.

MATERIALS

- 2 cans of "Gravity Testing Material" (play dough)
- Two aluminum tart pans
- Chair or table (or both)
- Beam balance (optional)

KEY QUESTION:

How does mass effect how fast an object falls?

KEY TERMS

Mass: A measure of the amount of stuff (or matter). Not to be confused with weight or volume. This is a measure of how much actual stuff there is, not how big it is or how hard something is pulling on it.

Weight: Mass (amount of stuff) times how hard the planet is pulling on it.

Force: Mass times acceleration.

Velocity: A measure of how fast something is going in some direction. Not to be confused with speed, which is only how fast something is moving. "I was going 65 mph south on I-95" is a measure of velocity. "I was going 65 mph when Billy got car sick" is a measure of speed.

Acceleration: How fast the velocity is changing. When something accelerates it changes how fast it is going or the direction in which it is moving. If you go 65 mph south on I-95 and then turn around without slowing down you have accelerated.

Air resistance: The force air exerts on something moving through it. In this case, something falling through it. When a bigger surface falls through air, it feels more air resistance. Air resistance does not depend on the mass of the object.

BEFORE THE ACTIVITY STUDENTS SHOULD KNOW:

Gravity from the Earth makes things fall.

- When something falls through air it experiences air resistance.
- There's a difference between speed, velocity and acceleration.
- There's a difference between weight and mass.
- That a force is mass times acceleration.

AFTER THE ACTIVITY STUDENTS SHOULD KNOW:

- Explain how mass affects the speed at which objects fall.
- Explain why a hammer and a feather will fall at the same rate on the moon but not on the earth.

If someone showed you two different spheres, say 1g and 10kg and asked which would hit the ground first after being dropped from the Leaning Tower of Pisa, if you're like most people, you would say the 10kg sphere would hit first. Aristotle said this was the case and for 1,000 years everyone believed him. But doing the experiment would show you, besides a great view of Pisa, that in fact, both spheres hit the ground at the same time.

This is exactly what Galileo did, showing the world that objects of different masses fall at the same

ACTIVITY 1: Doughy Physics

TEACHER'S GUIDE

THE SCIENCE BEHIND FALLING OBJECTS

rate. This is also a good example of why it is important to do experiments and not just take someone's word for it. To start understanding why Galileo was right, we need to start by understanding several physics words that are often jumbled together and confused; mass, weight, speed, velocity, acceleration and force.

Let's start with mass and weight. Mass is the amount of stuff there is. Mass and weight are not the same thing. This is a really important point. If I had some amount of stuff, say a Kit-Kat candy bar, and took it from the earth to the moon, I would still have the same amount of stuff, one Kit-Kat bar (assuming I didn't get hungry on the trip). No matter where I put that one Kit-Kat bar, I will always have the same amount of Kit-Kat. This means that here or on the moon, my Kit-Kat has the same mass.

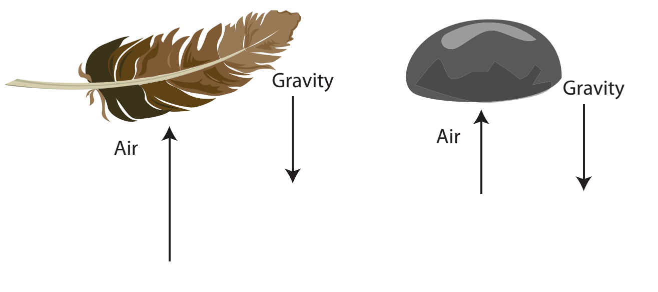
Mass has the unit of kilograms. But that Kit-Kat would be a lot easier to lift and put in my mouth on the moon than on earth, right? Weight is the amount of mass times how hard the planet is making it move towards the planet; how hard the planet is pulling on it. The earth pulls on the Kit-Kat harder than the moon would. Even though I have the same amount of stuff, the same mass, the weight of the Kit-Kat is greater on earth than it is on the moon. Weight has the unit of pounds. But wait, if mass and weight aren't the same thing how come it is easy to convert from pounds to kilograms (1 pound=0.454 kg)? This formula only works for converting pounds to kilograms on earth.

Those numbers just factor in how hard the earth is pulling. The fact that pounds and kilograms aren't really measuring the same thing doesn't matter for this conversion if you are on Earth. If I were on the moon and knew my Kit-Kat weighed .25 pounds on the moon, I couldn't use my favorite conversion equation to find its mass.

ACTIVITY 1: Doughy Physics

TEACHER'S GUIDE

Now on to velocity, speed, acceleration and force. Velocity and speed are two different things, but the difference is very small. Velocity gives more information than speed does. Speed is how fast something is going, but says nothing about the direction of that motion. Velocity is how fast something is going in a specific direction. Acceleration relates to velocity because it is how much the velocity is changing in a specific direction. If something has a constant velocity, say moving south at 65 mph, there is no acceleration.



Now how can you get something to accelerate? To accelerate, something needs to feel a force. If you run into a football player with some amount of force, he is going to change his velocity, so he's accelerating. Force is mass times acceleration. This means that force is the amount of stuff times how hard it is being pushed or pulled. Bigger football player, bigger force, bigger change in the other guy's acceleration. Weight is a force because it is how much stuff there is times how much the earth, or any planet, is pulling on it.

When something falls it falls because of the force of gravity. Because it feels a force, it accelerates and its velocity gets bigger and bigger as it falls. The acceleration is the pull of the earth. The amount the earth pulls on something in the form of gravity is a type of acceleration. And earth pulls on everything the exact same amount. Everything gets accelerated towards the earth exactly the same way. The force that objects feel may be different because they have different masses, but the acceleration they experience is exactly the same.

Because of this, because earth gives everything the exact same acceleration, objects with different masses will still hit the ground at the same time if they are dropped from the same height.

The first time you say that, no one will believe you because everyone has dropped a marble and a feather at the same time and they don't hit at the same time. That isn't because of any difference in how the earth is pulling, it is because of the way air is pushing against the object falling.

Gravity is not the only force acting on the falling objects, air resistance is also playing its part. The more surface area the falling object presents to the air as it is falling, the more air resistance it feels. The lighter the object is, the more the force of air resistance slows the object down. If two object were dropped on the moon, where there is no air, they would fall at the same rate no matter how much they differ in mass.

Astronaut Neil Armstrong did that by convincing everyone once that Galileo was right. In this play dough experiment, two objects of different masses that roughly experience the same air resistance will be dropped and hopefully convince your kids that mass has nothing to do with how things fall.

SAFETY NOTES:

- Play dough is a choking hazard, don't give it to children under 3 years old.

CORRESPONDING EXTENSION ACTIVITIES

- Spiraling CDs and DVDs
- Prisms
- Colors of compact florescent bulbs

SUGGESTED RESOURCES

http://nssdc.gsfc.nasa.gov/planetary/lunar/apollo_15_feather_drop.html
http://www.teachersdomain.org/resource/phy03.sci.phys.mfw.galileoexp/
http://galileosmuse.com/
http://news.nationalgeographic.com/news/2004/07/0714_040714_moonfacts.html

ACTIVITY 1: Doughy Physics

STUDENT'S GUIDE

INTRO

Which will hit the ground first, a hammer or a feather? What about two wads of play dough of different masses? Why? Are you sure? Are you really sure? Time to find out!

MATERIALS

- 2 cans of "gravity testing material" (play dough)
- Two aluminum tart pans
- Chair or table (or both)
- Beam balance (optional)

KEY QUESTION:

How does mass effect how fast an object falls?

GETTING STARTED

1. If you dropped a hammer and a feather at the same time from the same height, which would land first? Why?

____

2. Would the same thing happen if you were on the moon? Why?

____

3. What factors affect how an object falls?

____

____

4. If two bowling balls, one 15 lbs., the other 8 lbs. were dropped off the Leaning Tower of Pisa at the same time, which would hit first?

____

____

5. Which wad do you think would fall faster? The lighter one or the heavier one?

____

____

SETTING UP THE EXPERIMENT

1. Take the two pieces of paper and crumple one into a ball.

2. If you have a beam balance, find the mass of each piece of paper.

3. Take the two cans of "gravity testing material" (GTM) and make them into two equal sized balls.

4. Place the two tart pans on the floor, bottom up, about a foot apart.

5. If you have a beam balance, find the mass of the two wads of GTM.

ACTIVITY 1: Doughy Physics

STUDENT'S GUIDE

COLLECTING DATA

1. Drop the flat piece of paper and the crumpled piece of paper at the same time. Which hits the ground first? Are their masses different? (Figure 1)

___

2. Stand above the two tart pans holding one wad of GTM in each hand above the pans.

3. Drop the wads of GTM at the same time. When a wad hits, you should hear a loud "bang" from the tart pans. (Figure 2)

4. Record the number of "bangs" you heard. ____________

5. Now create two wads, but make one bigger than the other. If possible, record their masses. ____________

6. Repeat the experiment. Record the number of "bangs." ____________

7. Again change the mass of the wads so that the difference in mass between them is even greater and repeat. Do this 3 more times.

8. Now, if your teacher will let you, stand on a table or chair and repeat steps 1-6.

ANALYZING YOUR DATA

1. The masses of the two pieces of paper were the same, yet the crumpled piece hit the ground first. Why?

___

___

2. How many bangs did you hear each time you dropped the GTM?

___

___

3. Did it depend on how different the mass of the GTM wads?

___

___

4. If two bowling balls, one 15 lbs. one 8 lbs were dropped off the Leaning Tower of Pisa at the same time, which would hit first?

___

___

5. Which wad do you think would fall faster? The lighter one or the heavier one?

___

___

ACTIVITY 1: Doughy Physics

STUDENT'S GUIDE

Use your results to help the gang save Spectra with the "emergency shut off switch".

When two wads of different masses "gravity testing material" are dropped which hits the tart pans first? *(Circle you answer)*

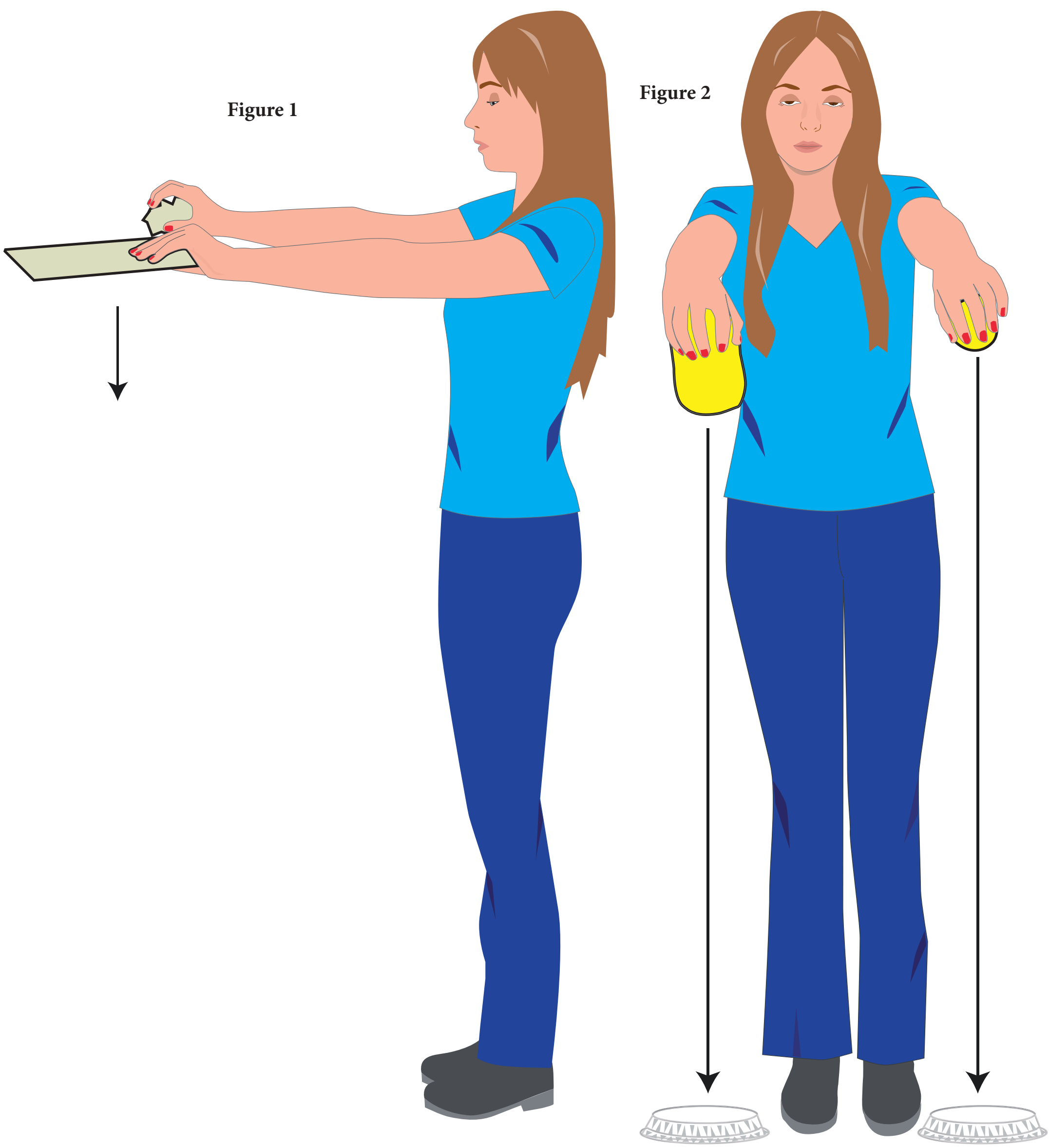
1. The larger one

2. The smaller one

3. It depends on the height from which they are dropped

4. They both hit at the same time

NOTE: This number is the FIRST number in the code needed to access the "emergency shut off switch". Write it in the FIRST space of the "emergency shut off switch" illustration.




I THINK, FORCE IS HOW HARD I HIT A PLAYER. SO HOW BIG I AM TIMES HOW MUCH I'M ACCELERATING? AM I RIGHT?
YES! AT LEAST ONE OF YOU CAN THINK. FORCE IS MASS TIMES ACCELERATION. NOW SHOW ME SOME FORCE, DROP AND GIVE ME 20!
WOW, LOOK AT THEM. I'M GLAD WE DON'T HAVE PHYSICS THIS YEAR, THAT GUY LOOKS SCARY!
HEY DUMMY, YOU SHOULD BE AFRAID. WE HAVE PHYSICS NEXT **PERIOD.**
1 2 3 4 5 6 7 8...
LATER THAT DAY, AT THE GANG'S FAVORITE HANGOUT
WOW, RUBY, I THOUGHT YOU SAID YOUR UNCLE WAS COOL! THAT GUY IS NUTS!
YEAH KAS, I'M MORE SORE FROM PHYSICS CLASS THAN WHEN I'M BEING A SUPERHERO.
HERE YOU GO, JIGGLES, PEPPERONI, YOUR FAVORITE.
PIZZA π


I'M REALLY SORRY GUYS, HE'S ALWAYS BEEN SO GREAT TO ME. THE LAST TIME HE WAS HERE, HE LET ME STAY UP LATE AND WE PLAYED WITH MY GLOW IN THE DARK PAINT AND LASERS.
NEXT TIME YOU SEE GLOW IN THE DARK PAINT, I'LL SHOW YOU HOW TO HAVE SOME FUN WITH IT.
THEN WE USED MY MODELING CLAY AND SOME PIE PANS TO "TEST GRAVITY." HE MADE SCIENCE SO MUCH FUN. I THINK YOU GUYS ARE BEING TOO HARSH! I HAD FUN TODAY.
KAS, GET OFF RUBY'S CASE! THE GENERAL TAUGHT ME A LOT ABOUT FOOTBALL AND PHYSICS.
YEAH, BECAUSE YOU'RE THE ONLY ONE WHO DOESN'T HAVE TO ICE WHEN YOU GET HOME!
I'VE HAD ENOUGH "UNCLE BASHING". C'MON LUCY, LET'S GO TO MY HOUSE AND SPEND SOME TIME WITH MY COOL UNCLE LESLIE!.
UNCLE LESLIE? I'M HOME AND I BROUGHT MY FRIEND LUCINDA.


???
HEY BOY! HOW YA DOING? LUCY, THIS IS MY UNCLE'S DOG, KARL.
AHHH, HE'S SO CUTE!
YIP!
ROWF!
HISSSS!!
GRRRR
AHHHH! RUBY! DON'T LET KARL HURT JIGGLES!!
KARL, SETTLE DOWN!
HI GIRLS, I DIDN'T EXPECT YOU TO BE HOME SO SOON. I SEE KARL HAS MET A NEW FRIEND.
ARE YOU STAYING WITH US TONIGHT LUCY?
YES SIR!
NO PROBLEM; GLAD TO HAVE YOU. YOU GIRLS HAVE FUN, THERE'S ICE CREAM IN THE FREEZER. I'LL BE IN MY ROOM.
DO NOT DISTURB
SLAM!

ACTIVITY 2: Swinging Yo-Yo

TEACHER'S GUIDE

INTRO

In this experiment students will learn what variables affect a pendulum's swing. When a pendulum swings there are lots of variables that could go into changing how it swings. The students will have to learn how to explore all of them effectively. And it uses yo-yo's which are just plain fun.

MATERIALS

- 2 yo-yos
- 2 cans "gravity testing material"
- Wrist watch with a second hand
- Sheets of graph paper

KEY TERMS

Mass: A measure of the amount of stuff (or matter). Not to be confused with weight or volume. This is a measure of how much actual stuff there is, not how big it is or how hard something is pulling on it.

Force: Mass times acceleration.

Period: The amount of time it takes for one whole swing.

Amplitude: How high a pendulum swings.

Independent Variable: This is a variable that can be changed by the person doing the experiment. Examples include length, mass and amplitude.

Dependant Variable: This is a variable that cannot be changed by the person doing the experiment but changes based on the independent variable. In this experiment the dependent variable is the pendulum's period.

KEY QUESTION:

What variables affect the period of a pendulum?

BEFORE THE ACTIVITY STUDENTS SHOULD KNOW

- The definitions of both amplitude and period.
- Gravity from the Earth makes things fall.
- The force of gravity is always pulling straight down towards the floor.
- Force is mass times acceleration.

AFTER THE ACTIVITY STUDENTS SHOULD KNOW

- Understand what variables affect the period of a pendulum and what variables have no effect.
- See a system with many variables and design an experiment that gives results that help explain one aspect of the system.

THE SCIENCE BEHIND A PENDULUM'S SWING

If you look around, there are pendulums everywhere. If you're like a lot of people, the first ones you think of are the ones used to tell time, like in a grandfather clock or a metronome. Pendulums can be completely mesmerizing, just think of a hypnotist with a swinging watch. What makes them both so useful and so hypnotic is the extreme regularity of their swing. But what causes that? What does it depend on? How can the swing be changed?

The simplest pendulum has a string with a mass at the end. In this experiment students will use yo-yos. To start a pendulum swinging, the first thing to do is pull the mass back a little bit. When

ACTIVITY 2: Swinging Yo-Yo

TEACHER'S GUIDE

its pulled back and held, gravity is pulling directly toward the ground and the string is pulling back toward the the pivot point. No matter what happens to the mass of the pendulum throughout the swing, gravity will always be pulling straight toward the ground and the string will keep pulling toward the pivot.

When you let the mass go, gravity pulls it down and the pendulum starts to swing. As it swings it speeds up as gravity makes it accelerate. Because the string is holding it up, it swings in an arc. When it is at the bottom of its swing it is going as fast as it can and gravity is pulling straight down and the string is pulling straight up. As it swings through this point it starts to swing up the other way and gravity is now working to slow it down. When it gets to the top of its swing it has been slowed down to a stop and the whole process repeats in the other direction.

So what affects how fast a pendulum swings? Gravity is one variable. A pendulum on the moon would swing differently than one on earth because the force of gravity would be different.. But, considering you are not taking your class to the moon any time soon, lets concentrate on some other variables. What would happen if you changed the mass at the end of the string? In activity one, we learned that different masses always fall at the same rate. Because of this factor, changing of the pendulum's mass will not change how fast it swings.

What happens if you start it out with a greater amplitude? It will still take the same time to get through one swing, it will just be going faster at the bottom of the swing. It had more time to speed up as it was swinging, so it is going faster, but because it is going faster, it covers the lager distance in the same amount of time. The last easy thing to change is the length of the string.

This is the only variable (that we can easily change) that affects the period of a pendulum. The longer the string, the more time it takes to go through one swing. So if you want to set your grandfather clock, the only thing you need to change is the length from the pivot point to the mass. If you've ever played the piano, you will remember that this is how a metronome is set, by sliding the mass.

Pendulum motion is a neat thing to have your students explore in a more free form way. There are only really three variables they can change, mass, length and starting amplitude, and one variable they can measure, the period.

In addition to teaching students about pendulums, this activity has them design their own experiment and learn that it's only useful to change one variable at a time, that they should do repeated trials and that there are many different ways to represent results, some more useful than others. Make sure to give your students the guidance they need and make sure that different groups are changing different variables. With limited class time, all students will be able to see what happens when each variable is changed.

SAFETY

Play dough is a choking hazard, do not give it to children under 3 years old. Students should be supervised when using yo-yos, they can cause injury if used incorrectly.

CORRESPONDING EXTENSION ACTIVITIES

- Newton's Cradle
- Face Smash (or not)
- Coupled Pendulums

SUGGESTED RESOURCES

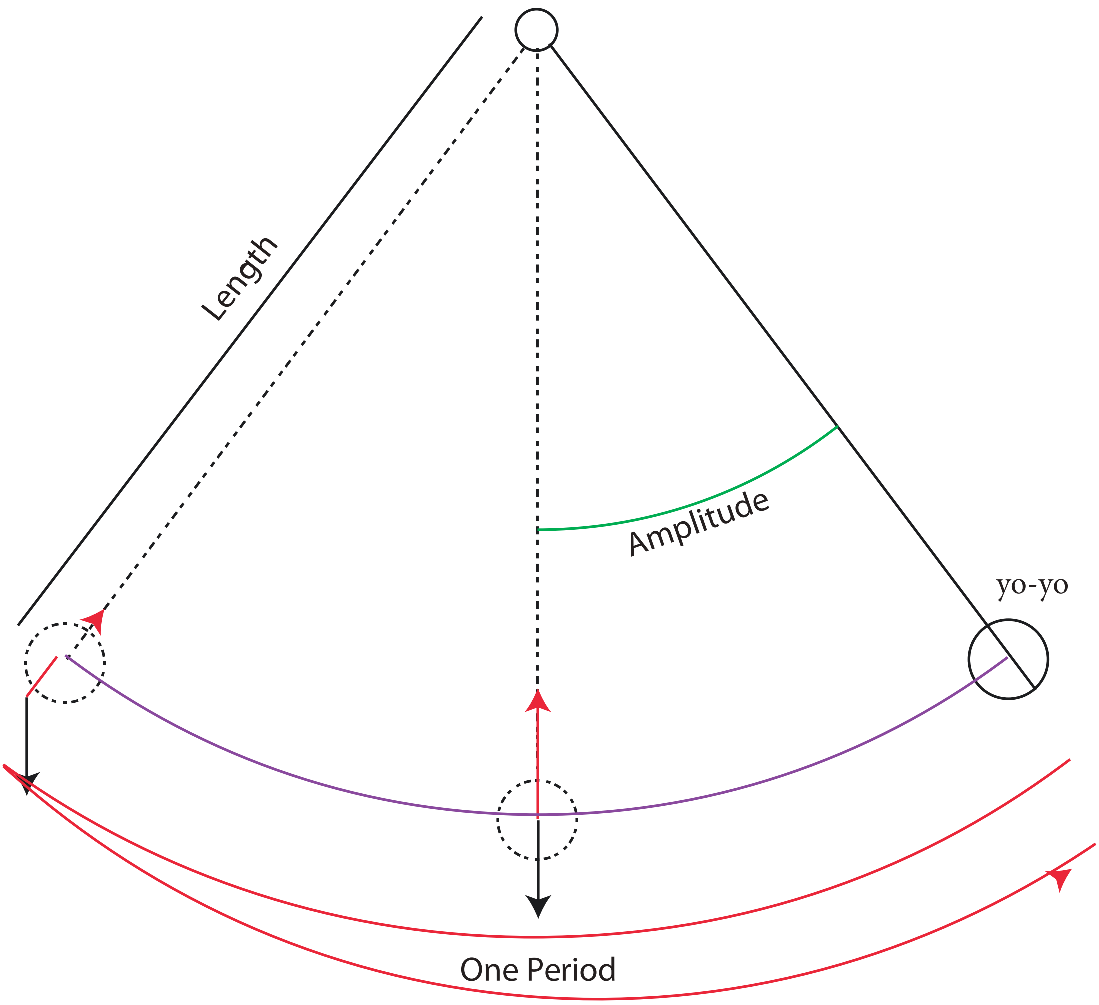
http://phet.colorado.edu/sims/pendulum-lab/pendulum-lab_en.html

http://www.worsleyschool.net/science/files/pendulum/experiment.html

http://pbskids.org/zoom/games/pendulum/what_makes_swing.html

ACTIVITY 2: Swinging Yo-Yo

TEACHER'S GUIDE



ACTIVITY 2: Swinging Yo-Yo

STUDENT'S GUIDE

INTRO

Pendulums are everywhere. Because the swing of a pendulum is so regular they are often used to time things like in a clock or a metronome. But what changes how a pendulum swings? Why is it so regular? This experiment will help you find out.

MATERIALS

- 2 yo-yos
- 2 cans "gravity testing material"
- Wrist watch with a second hand
- Sheets of graph paper

KEY QUESTION:

What variables affect the period of a pendulum?

KEY TERMS

Mass: A measure of the amount of stuff (or matter). Not to be confused with weight or volume. This is a measure of how much actual stuff there is, not how big it is or how hard something is pulling on it.

Force: Mass times acceleration.

Period: The amount of time it takes for one whole swing.

Amplitude: How high a pendulum swings.

Independent variable: This is a variable that can be changed by the person doing the experiment. Examples include length, mass and amplitude.

Dependant variable: This is a variable that cannot be changed by the person doing the experiment but changes based on the independent variable. In this experiment the dependent variable is the pendulum's period.

GETTING STARTED

1. Where do you see pendulums? What different types can you think of?

____

2. What is meant by the "period" of a pendulum? What might you use to measure the period?

____

3. What are all the types of variables are involved in a pendulum's swing?

____

4. Of the variables above, which ones are the independent variables (variables you change) and which are dependent variables (variables you measure after changing an independent variable)?

____

SETTING UP THE EXPERIMENT

This is an experiment you will be designing yourself. The question you will have to answer is "What variables affect the swing of a pendulum and how?" It is your job to design a method to do that.

1. To start off, look at the materials you have in front of you and play with them a bit. What kind of things can you do with the stuff you have?

2. Use the yo-yo (or yo-yos) as a pendulum and start exploring how it swings.

3. In the section above you were asked to list some independent variables. List ways you might be able to change them with the materials you have in front of you.

____

4. Using the information you wrote down above, design an experiment to test how one variable affects a pendulum's swing. What will you change? How? By how much? What will you measure? How many trials will you do (might I suggest more than one)? Once you have this data, what will you do with it? What will it teach you? How will you analyze it?

ACTIVITY 2: Swinging Yo-Yo

STUDENT'S GUIDE

COLLECTING DATA

It's up to you! You wrote down what you were going to do, now have at it.

ANALYZING YOUR RESULTS

In step 4 of "setting up the experiment" you should have written down a plan for analyzing the data you collected. If you are still not sure what to do, here are some suggestions.

1. Make a table where you have the values for your independent variable in one column and the corresponding values for the dependent variable in the other. Do you notice any patterns?

2. Try graphing your data. Remember, the independent variable always goes on the "x" axis and the dependent variable goes on the "y" axis. Do you see any patterns now? ________________________________

3. Can you draw any conclusions about what affects the period of the pendulum?

____

____

Use your results to help the gang save Spectra with the "emergency shut off switch".

What variables affect the period of a pendulum?

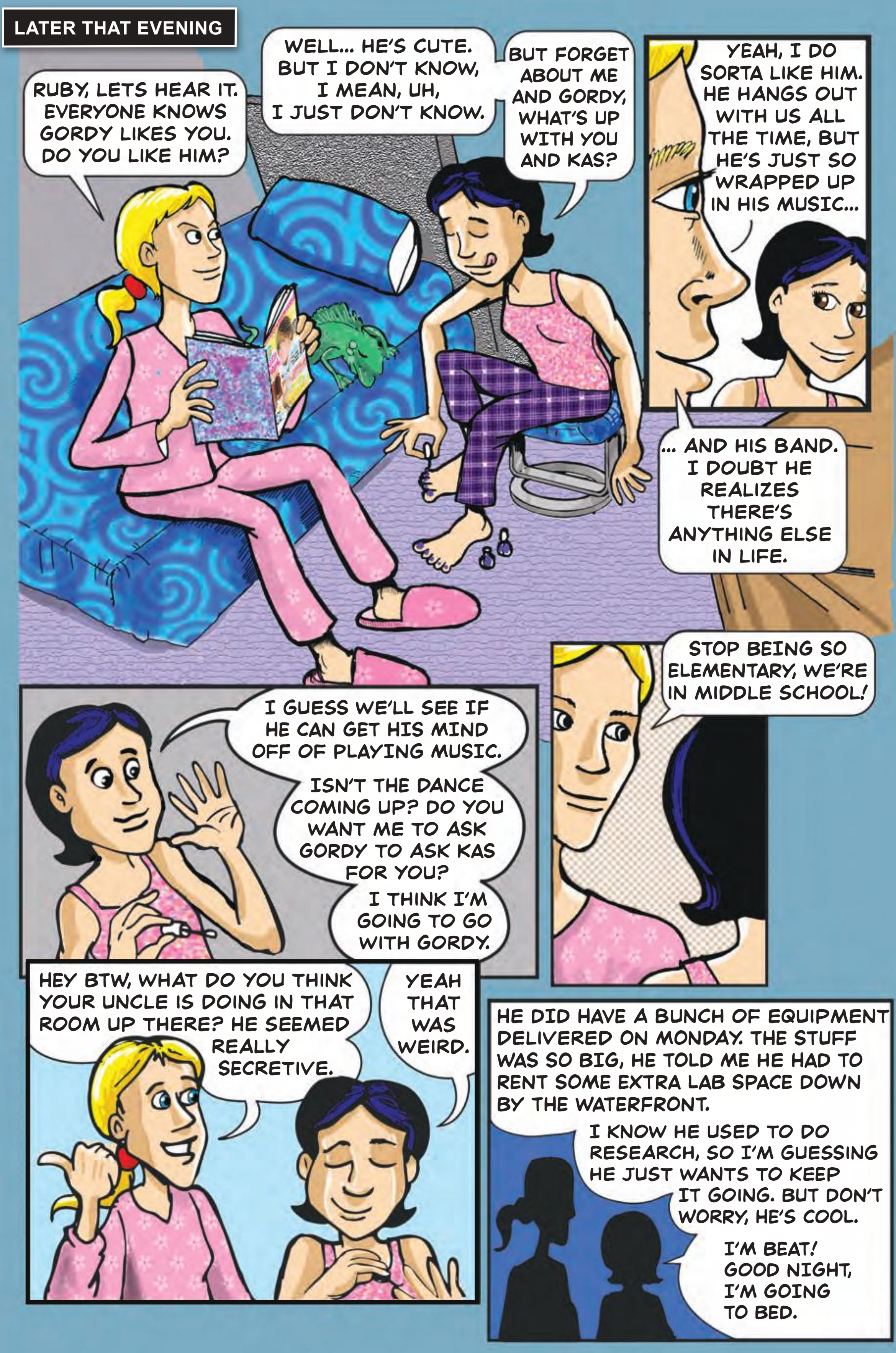
1. Mass of what's swinging

2. Mass and length of string

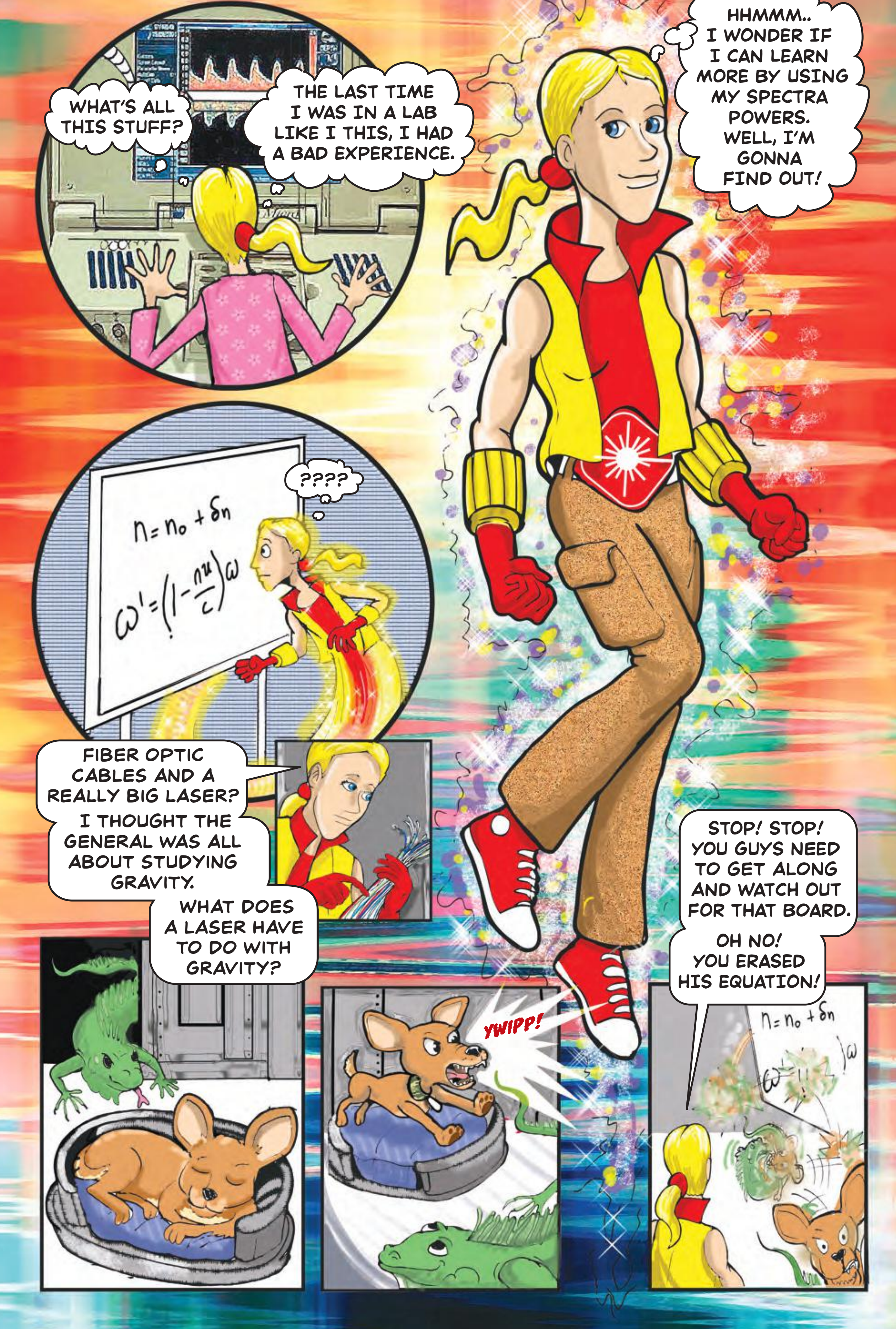
3. Starting amplitude

4. Length of string

This number is the SECOND number in the code needed to access the "emergency shut off switch". Write it in the SECOND space of the "emergency shut off switch" illustration.


LATER THAT EVENING
RUBY, LETS HEAR IT. EVERYONE KNOWS GORDY LIKES YOU. DO YOU LIKE HIM?
WELL... HE'S CUTE. BUT I DON'T KNOW, I MEAN, UH, I JUST DON'T KNOW.
BUT FORGET ABOUT ME AND GORDY, WHAT'S UP WITH YOU AND KAS?
YEAH, I DO SORTA LIKE HIM. HE HANGS OUT WITH US ALL THE TIME, BUT HE'S JUST SO WRAPPED UP IN HIS MUSIC...
... AND HIS BAND. I DOUBT HE REALIZES THERE'S ANYTHING ELSE IN LIFE.
I GUESS WE'LL SEE IF HE CAN GET HIS MIND OFF OF PLAYING MUSIC.
ISN'T THE DANCE COMING UP? DO YOU WANT ME TO ASK GORDY TO ASK KAS FOR YOU?
I THINK I'M GOING TO GO WITH GORDY.
STOP BEING SO ELEMENTARY, WE'RE IN MIDDLE SCHOOL!
HEY BTW, WHAT DO YOU THINK YOUR UNCLE IS DOING IN THAT ROOM UP THERE? HE SEEMED REALLY SECRETIVE.
YEAH THAT WAS WEIRD.
HE DID HAVE A BUNCH OF EQUIPMENT DELIVERED ON MONDAY. THE STUFF WAS SO BIG, HE TOLD ME HE HAD TO RENT SOME EXTRA LAB SPACE DOWN BY THE WATERFRONT.
I KNOW HE USED TO DO RESEARCH, SO I'M GUESSING HE JUST WANTS TO KEEP IT GOING. BUT DON'T WORRY, HE'S COOL.
I'M BEAT! GOOD NIGHT, I'M GOING TO BED.


8
IT'S 3 A.M. AND JIGGLES GETS RESTLESS AND DECIDES TO EXPLORE.
THOSE DARN ALIENS!
WHAT'S THAT NOISE??
HEY!! JIGGLES WHAT ARE YOU DOING? COME BACK TO BED!
PLLOPP!!
JIGGLES, GET OUTTA THERE. THAT'S THE GENERAL'S ROOM!
HUH??


WHAT'S ALL THIS STUFF?
THE LAST TIME I WAS IN A LAB LIKE I THIS, I HAD A BAD EXPERIENCE.
HHMMM.. I WONDER IF I CAN LEARN MORE BY USING MY SPECTRA POWERS. WELL, I'M GONNA FIND OUT!
????
n = n₀ + δn
ω' = (1 - nu/c) ω
FIBER OPTIC CABLES AND A REALLY BIG LASER?
I THOUGHT THE GENERAL WAS ALL ABOUT STUDYING GRAVITY.
WHAT DOES A LASER HAVE TO DO WITH GRAVITY?
YWIPP!
STOP! STOP! YOU GUYS NEED TO GET ALONG AND WATCH OUT FOR THAT BOARD.
OH NO! YOU ERASED HIS EQUATION!

ACTIVITY 3: Twist & Shout

TEACHER'S GUIDE

INTRO

We're used to seeing things spin, from yo-yos to ballet dancers. However, we usually see them spin in one direction. What happens when something spins in more than one direction at once? In this activity we will use nothing more than a cardboard tube marked with an "x" and "o" to show what happens when something spins in two directions at once. Though on its surface this experiment seems simple, the results are unexpected and exciting.

KEY QUESTION:

When a tube spins in two directions at once, what does it look like?

MATERIALS

- White cardboard tube
- Marker

KEY TERMS

Axis of rotation: When something is spinning, the axis of rotation is the imaginary line around which it spins

Torque: The spinning force. For something like a wheel to start spinning, a force must be applied to one edge. This force is called torque.

Force: For something to change how its moving, a force must act on it. With no force, it will continue to do what it is doing. Force is equal to the mass of the object times the acceleration it feels.

BEFORE THE ACTIVITY STUDENTS SHOULD KNOW

- An "axis of rotation" is the direction around which something spins.
- When things spin, twist or even just pushed or pulled, you add up all the directions in which it is moving to find its resultant motion.

AFTER THE ACTIVITY STUDENTS SHOULD KNOW

- Explain why different parts of a spinning tube appear to stop and speed up
- Explain why it is possible to see either the "x" or "o" when the tube is spinning but not both.
- Predict what will happen to the number of times you can see the "x" or "o" if the diameter or length of the tube were changed.

THE SCIENCE BEHIND ROTATION IN TWO DIRECTIONS

Have you ever watched a tea cup ride like the one in Disney World? The tea cups are rotating around two or even three axes at once. But think about what the people look like as they are whizzing by you. At some points you can clearly see their faces, its as if they were standing still, while at other times there faces are all a blur. Now think about what it feels like when you are on the ride (if you have not ridden this ride before, stop reading and go to your nearest amusement park. It counts as work, its for science!). At points you feel like you are spinning very fast, but at points you feel like you are sitting still even though you are still being spun in several directions at once.

This spinning tube is like an ant sized tea cup ride. It's spinning in two directions at once. One axis of rotation is down the middle of the

ACTIVITY 3: Twist & Shout

TEACHER'S GUIDE

tube and the second axis of rotation is perpendicular to the table sticking out of the very center of the tube. (Figure 1)

Once the tube is spinning in two directions because of the dual direction push from your finger, do you know how it all came together to make what you see happen? (Figure 2)

When things are moving in two ways at once, what you see is how the movement in the two directions adds up. Think of a block with two strings tied to adjacent edges. Let say you pull on both strings at the same time. There's force in two directions but you only see the box move in one direction, diagonally. This is because the forces add up and the movement is in the direction of the sum of these forces. (Figure 3)

The same effect happens when something spins. When the tube spins the resultant speed of the spin is found by adding the spin about both axes. Sometimes this adds up to a really fast spin and sometimes it adds up to spinning really slowly. When it adds up to a slow spin, your eye can see what is written on the tube.

When you start the tube spinning by pushing on the "x," the spinning always adds up to be slow when the "x" is on top so you can see it, but when the "o" is on top, the opposite is happening and the tube is spinning very fast so you can't see the "o." (Fig. 4) When the tube spins fast, you can actually see not one but 4 "x"s or "o"s. This is because it takes our eye and brain a bit of time to forget what it just saw, so the image of one "x" is still hanging out in your head when the next image appears. This keeps happening so you end up seeing all 4 "x"s at the same time. You can try this experiment with different tubes of different lengths or diameters. It's pretty easy to find white cardboard tubes around the house. PVC pipe works well too.

Figure 1

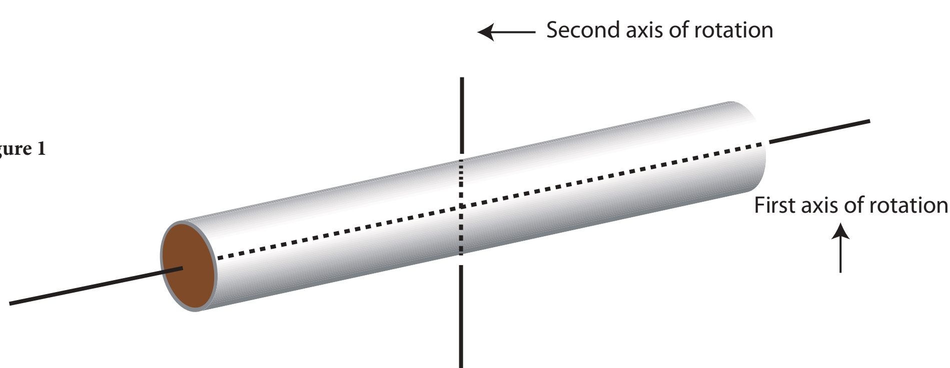
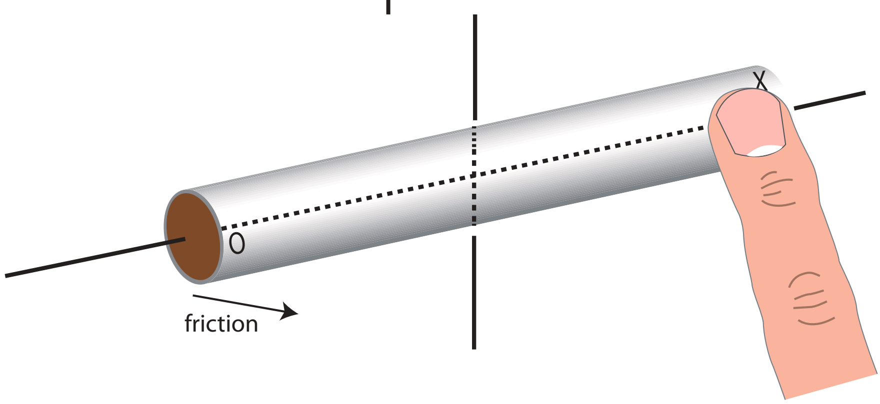


Figure 2



ACTIVITY 3: Twist & Shout

TEACHER'S GUIDE

Figure 3

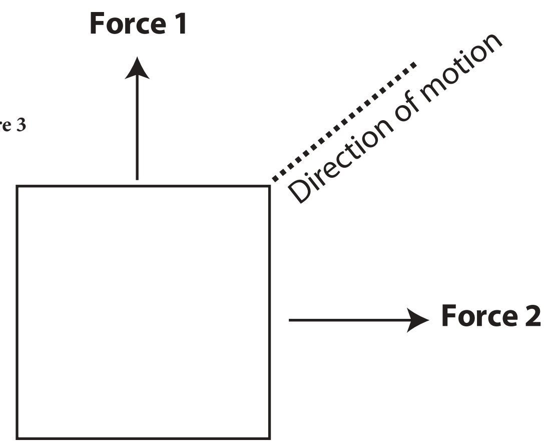
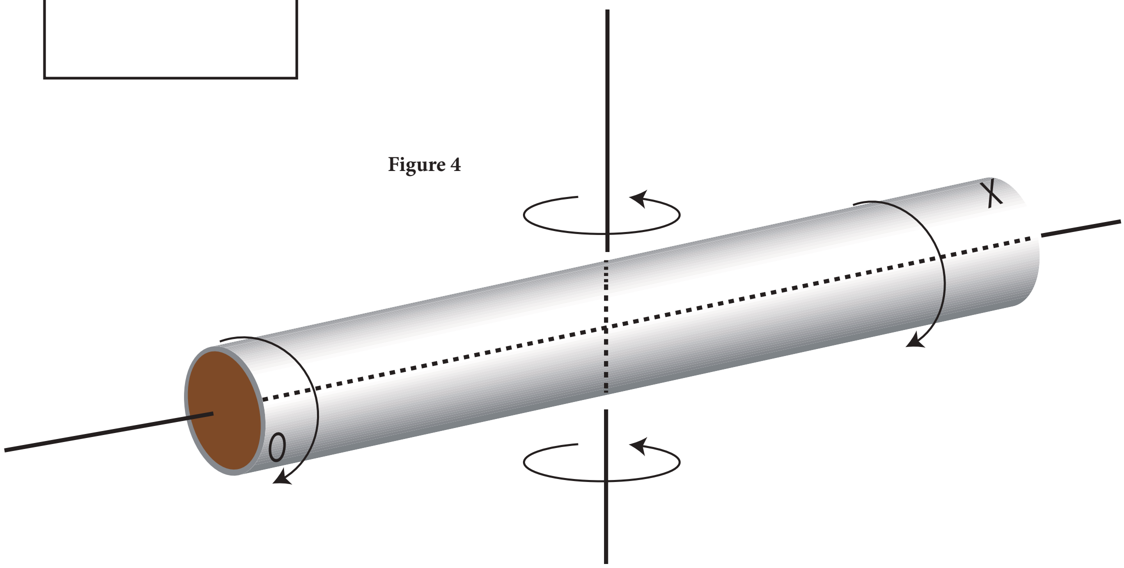


Figure 4



SAFETY NOTES:

- There are no obvious safety concerns for this activity.

CORRESPONDING EXTENSION ACTIVITIES :

- Twirling Cardboard Tube
- Spinning in the Office
- Cycloid Ramp

SUGGESTED RESOURCES

http://ajp.aapt.org/resource/1/ajpias/v78/i5/p467_s1?isAuthorized=no

http://www.youtube.com/watch?v=F8-PrVJ5Q-Y

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

ACTIVITY 3: Twist & Shout

STUDENT'S GUIDE

INTRO

What happens when things spin in a circle in two directions at once?

KEY QUESTION:

When a tube spins in two directions at once, what does does it look like?

MATERIALS

- White cardboard tube
- Marker

GETTING STARTED

1. Why are you able to see and something like a letter, number or symbol on something, that's moving like a wheel?

____

____

2. Draw a rolling log, what forces are acting on it that make it roll? Now draw these forces and an arrow indicating which direction the log is turning.

3. What things can you think of that spin in two directions at once? Draw them and indicate which directions they are spinning.

4. What happens when something is spinning in two directions? Does it spin the same speed at every point in its spin or do the two directions of spinning add up to the spinning you see?

____

____

ACTIVITY 3: Twist & Shout

STUDENT'S GUIDE

SETTING UP THE EXPERIMENT

This experiment is extremely easy to set up, but don't let that fool you. Exciting things happen! Some very awesome physics can be done with very simple equipment.

1. Cut the tube into two sections, one 1.5" long and one 2.5" long. (Figure 1)

2. For each piece put an "x" on one end and an "o" on the opposite side at the opposite end. (Figure 2)

COLLECTING DATA *(Qualitative - get a feel for what you will be working with):*

1. Hold the tube by the middle and spin it back and forth. Around which axis is it turning?

2. Now pick another axis and turn the tube around that.

3. How many axes can you think of around which you can turn the tube?

ACTIVITY 3: Twist & Shout

STUDENT'S GUIDE

QUANTITATIVE (TAKE SOME DATA):

1. Set the longer tube on the table with the "x" up and on the right side.

2. Push on the "x" so that the tube both rotates and spins. (Figure 3)

3. Start with the tube in the same position, but this time spin it by pushing on the side without the "x".

4. Set the tube on the table with the "o" up and on the right side and push on the "o" to spin and rotate the tube.

5. Start with the tube in the same position as in step 4, but this time spin the tube by pushing on the side without the "o"

6. Now repeat steps 1-5 with the shorter piece of tube.

ANALYZING YOUR RESULTS

1. When you pushed on the tube to get it started, what forces were acting on it? Think about the force of your finger, the table etc.?

2. When the tube was spun by pushing on the "x," what did you see? What about what happened when you pushed on the "o" to start it spinning and rotating? Draw it:

3. Did the same thing happen when you pushed on the blank end? Draw it:

4. Why do you think you could sometimes see more than one "x" or more than one "o" at the same time even though there was really only one "x" or one "o" on the tube?

5. What do you think would happen if you had the "x" and "o" on opposite ends but on the same side of the tube?

6. What differences did you see between the short tube and the long tube?

ACTIVITY 3: Twist & Shout

STUDENT'S GUIDE

Use your results to help the gang save Spectra with the "emergency shut-off switch".

When the long tube is spun starting with the "o" up, what do you see? *(Circle you answer)*

1. "x" 4 times
2. "o" 2 times
3. "o" 4 times
4. "x" 2 times

NOTE: This number is the THIRD number in the code needed to access the "emergency shut of switch". Write it in the THIRD space of the "Emergency shut off switch"

Figure 1

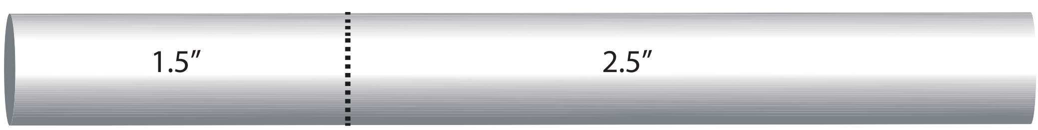


Figure 2

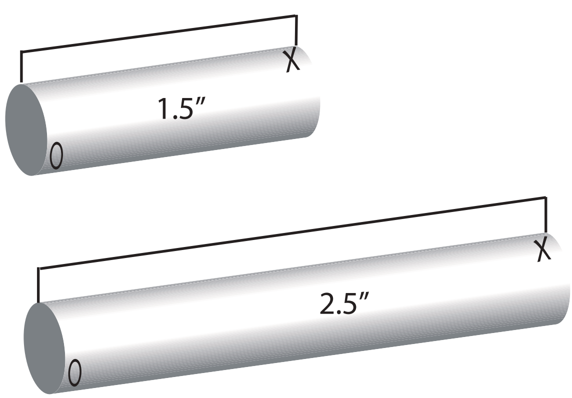
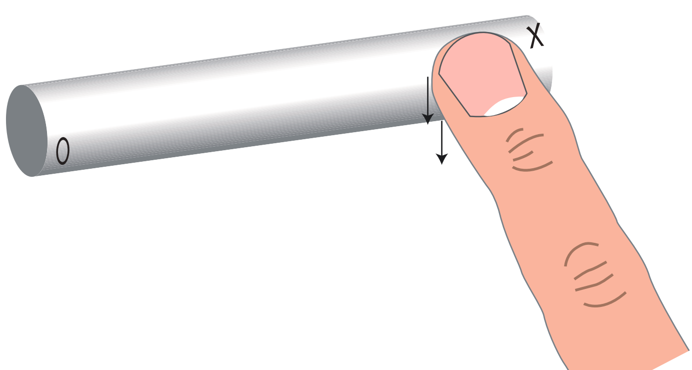
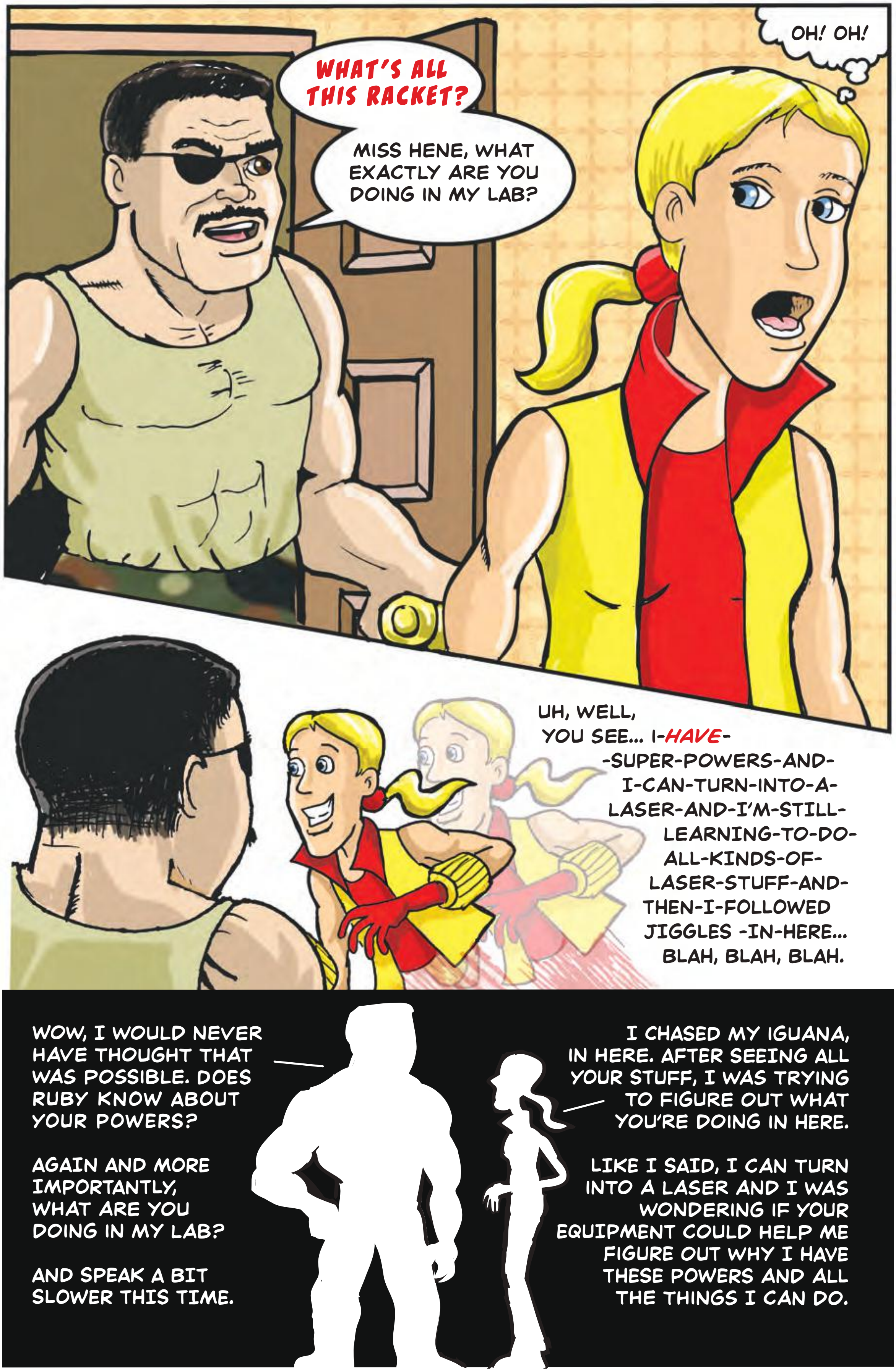
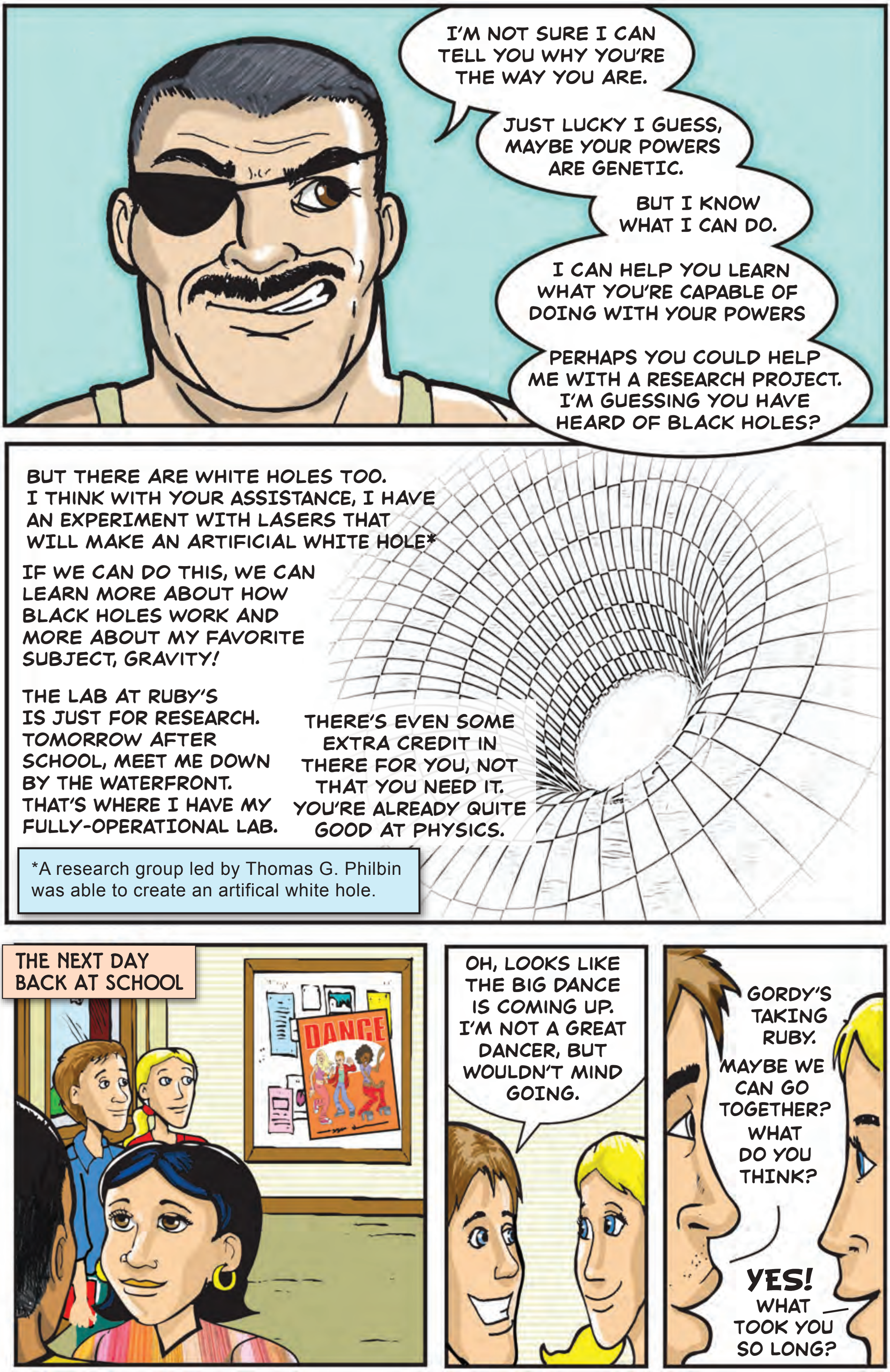
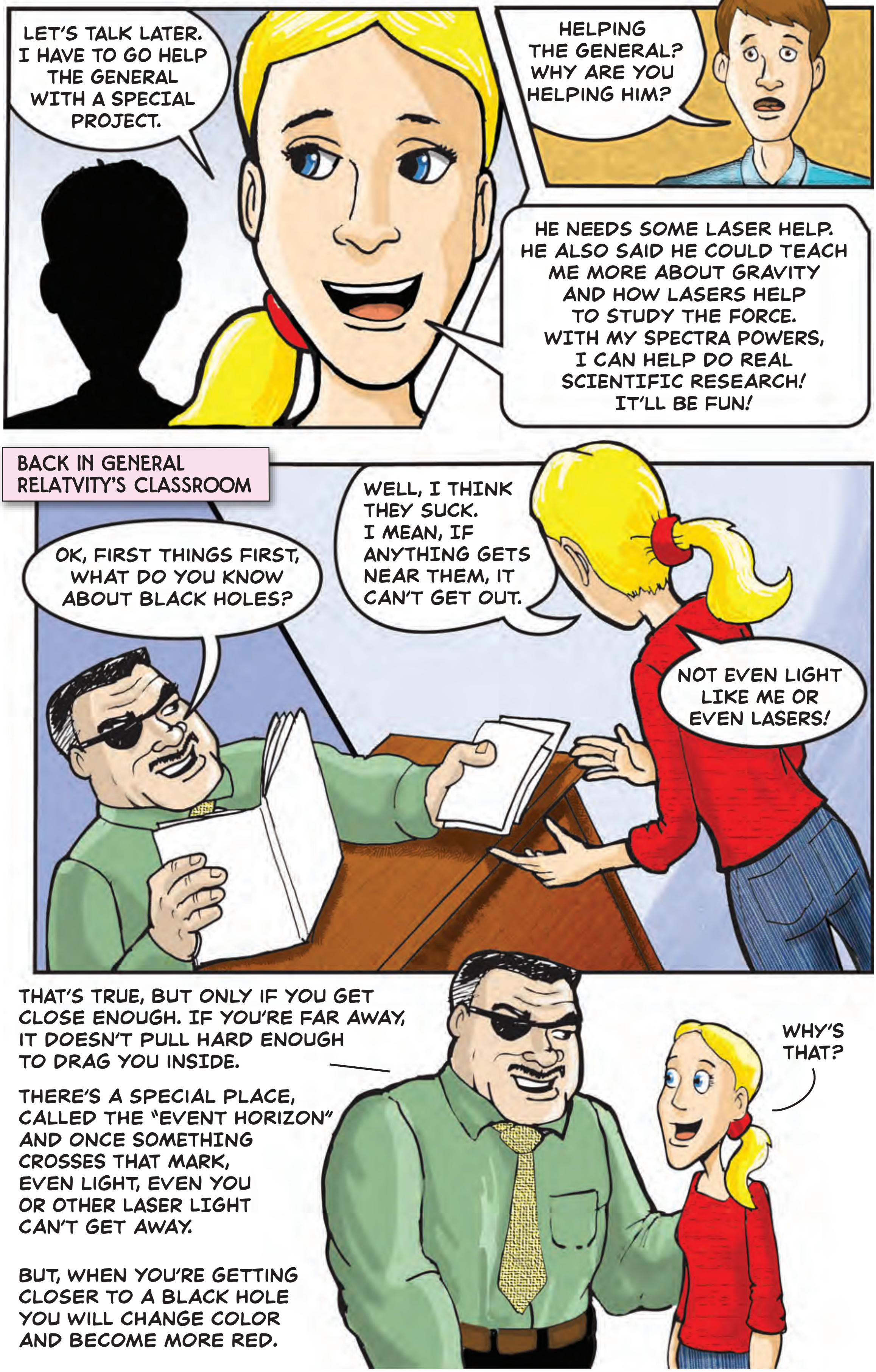


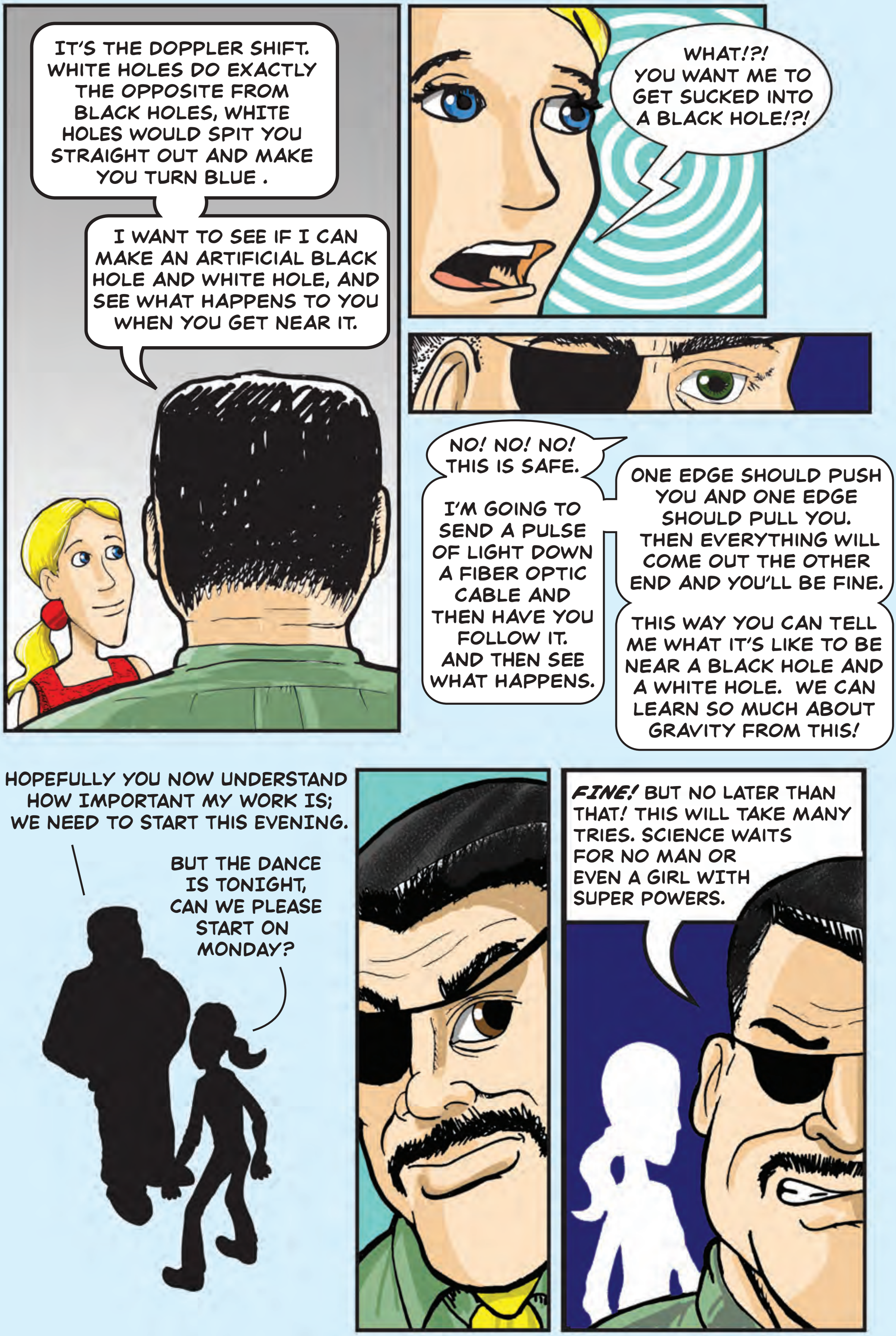
Figure 3

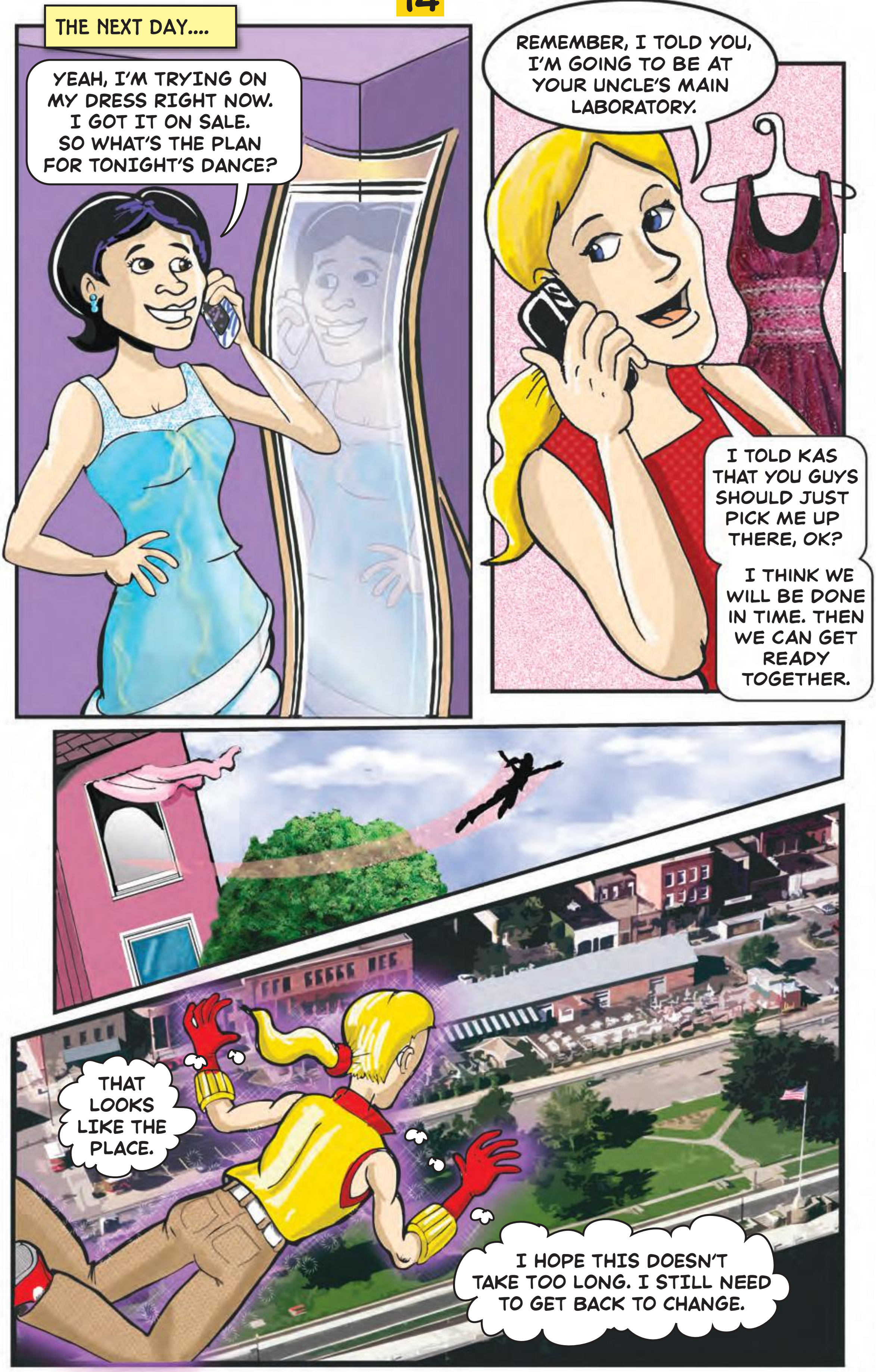



OH! OH!
WHAT'S ALL THIS RACKET?
MISS HENE, WHAT EXACTLY ARE YOU DOING IN MY LAB?
UH, WELL, YOU SEE... I-HAVE--SUPER-POWERS-AND-I-CAN-TURN-INTO-A-LASER-AND-I'M-STILL-LEARNING-TO-DO-ALL-KINDS-OF-LASER-STUFF-AND-THEN-I-FOLLOWED JIGGLES -IN-HERE... BLAH, BLAH, BLAH.
WOW, I WOULD NEVER HAVE THOUGHT THAT WAS POSSIBLE. DOES RUBY KNOW ABOUT YOUR POWERS?
AGAIN AND MORE IMPORTANTLY, WHAT ARE YOU DOING IN MY LAB?
AND SPEAK A BIT SLOWER THIS TIME.
I CHASED MY IGUANA, IN HERE. AFTER SEEING ALL YOUR STUFF, I WAS TRYING TO FIGURE OUT WHAT YOU'RE DOING IN HERE.
LIKE I SAID, I CAN TURN INTO A LASER AND I WAS WONDERING IF YOUR EQUIPMENT COULD HELP ME FIGURE OUT WHY I HAVE THESE POWERS AND ALL THE THINGS I CAN DO.


I'M NOT SURE I CAN TELL YOU WHY YOU'RE THE WAY YOU ARE.
JUST LUCKY I GUESS, MAYBE YOUR POWERS ARE GENETIC.
BUT I KNOW WHAT I CAN DO.
I CAN HELP YOU LEARN WHAT YOU'RE CAPABLE OF DOING WITH YOUR POWERS
PERHAPS YOU COULD HELP ME WITH A RESEARCH PROJECT. I'M GUESSING YOU HAVE HEARD OF BLACK HOLES?
BUT THERE ARE WHITE HOLES TOO. I THINK WITH YOUR ASSISTANCE, I HAVE AN EXPERIMENT WITH LASERS THAT WILL MAKE AN ARTIFICIAL WHITE HOLE*
IF WE CAN DO THIS, WE CAN LEARN MORE ABOUT HOW BLACK HOLES WORK AND MORE ABOUT MY FAVORITE SUBJECT, GRAVITY!
THE LAB AT RUBY'S IS JUST FOR RESEARCH. TOMORROW AFTER SCHOOL, MEET ME DOWN BY THE WATERFRONT. THAT'S WHERE I HAVE MY FULLY-OPERATIONAL LAB.
THERE'S EVEN SOME EXTRA CREDIT IN THERE FOR YOU, NOT THAT YOU NEED IT. YOU'RE ALREADY QUITE GOOD AT PHYSICS.
*A research group led by Thomas G. Philbin was able to create an artifical white hole.
THE NEXT DAY BACK AT SCHOOL
DANCE
OH, LOOKS LIKE THE BIG DANCE IS COMING UP. I'M NOT A GREAT DANCER, BUT WOULDN'T MIND GOING.
GORDY'S TAKING RUBY.
MAYBE WE CAN GO TOGETHER? WHAT DO YOU THINK?
YES! WHAT TOOK YOU SO LONG?


LET'S TALK LATER. I HAVE TO GO HELP THE GENERAL WITH A SPECIAL PROJECT.
HELPING THE GENERAL? WHY ARE YOU HELPING HIM?
HE NEEDS SOME LASER HELP. HE ALSO SAID HE COULD TEACH ME MORE ABOUT GRAVITY AND HOW LASERS HELP TO STUDY THE FORCE. WITH MY SPECTRA POWERS, I CAN HELP DO REAL SCIENTIFIC RESEARCH! IT'LL BE FUN!
BACK IN GENERAL RELATVITY'S CLASSROOM
OK, FIRST THINGS FIRST, WHAT DO YOU KNOW ABOUT BLACK HOLES?
WELL, I THINK THEY SUCK. I MEAN, IF ANYTHING GETS NEAR THEM, IT CAN'T GET OUT.
NOT EVEN LIGHT LIKE ME OR EVEN LASERS!
THAT'S TRUE, BUT ONLY IF YOU GET CLOSE ENOUGH. IF YOU'RE FAR AWAY, IT DOESN'T PULL HARD ENOUGH TO DRAG YOU INSIDE.
THERE'S A SPECIAL PLACE, CALLED THE "EVENT HORIZON" AND ONCE SOMETHING CROSSES THAT MARK, EVEN LIGHT, EVEN YOU OR OTHER LASER LIGHT CAN'T GET AWAY.
BUT, WHEN YOU'RE GETTING CLOSER TO A BLACK HOLE YOU WILL CHANGE COLOR AND BECOME MORE RED.
WHY'S THAT?


IT'S THE DOPPLER SHIFT. WHITE HOLES DO EXACTLY THE OPPOSITE FROM BLACK HOLES, WHITE HOLES WOULD SPIT YOU STRAIGHT OUT AND MAKE YOU TURN BLUE .
I WANT TO SEE IF I CAN MAKE AN ARTIFICIAL BLACK HOLE AND WHITE HOLE, AND SEE WHAT HAPPENS TO YOU WHEN YOU GET NEAR IT.
WHAT!?! YOU WANT ME TO GET SUCKED INTO A BLACK HOLE!?!
NO! NO! NO! THIS IS SAFE.
I'M GOING TO SEND A PULSE OF LIGHT DOWN A FIBER OPTIC CABLE AND THEN HAVE YOU FOLLOW IT. AND THEN SEE WHAT HAPPENS.
ONE EDGE SHOULD PUSH YOU AND ONE EDGE SHOULD PULL YOU. THEN EVERYTHING WILL COME OUT THE OTHER END AND YOU'LL BE FINE.
THIS WAY YOU CAN TELL ME WHAT IT'S LIKE TO BE NEAR A BLACK HOLE AND A WHITE HOLE. WE CAN LEARN SO MUCH ABOUT GRAVITY FROM THIS!
HOPEFULLY YOU NOW UNDERSTAND HOW IMPORTANT MY WORK IS; WE NEED TO START THIS EVENING.
BUT THE DANCE IS TONIGHT, CAN WE PLEASE START ON MONDAY?
FINE! BUT NO LATER THAN THAT! THIS WILL TAKE MANY TRIES. SCIENCE WAITS FOR NO MAN OR EVEN A GIRL WITH SUPER POWERS.


THE NEXT DAY....
YEAH, I'M TRYING ON MY DRESS RIGHT NOW. I GOT IT ON SALE. SO WHAT'S THE PLAN FOR TONIGHT'S DANCE?
REMEMBER, I TOLD YOU, I'M GOING TO BE AT YOUR UNCLE'S MAIN LABORATORY.
I TOLD KAS THAT YOU GUYS SHOULD JUST PICK ME UP THERE, OK?
I THINK WE WILL BE DONE IN TIME. THEN WE CAN GET READY TOGETHER.
THAT LOOKS LIKE THE PLACE.
I HOPE THIS DOESN'T TAKE TOO LONG. I STILL NEED TO GET BACK TO CHANGE.

ACTIVITY 4: Watch it Fly

TEACHER'S GUIDE

INTRO

In activities one and two we looked at what happens with things fall, both straight down and as part of a pendulum. Now we're going to look at what happens with something that moves in two directions, down-and-out!

KEY QUESTION:

How does the mass of a projectile and its initial velocity affect how far it flies and how fast it drops?

MATERIALS

- 4 rubber bands
- 2 sets of chop sticks
- 4 different sized wooden balls
- Lots of masking tape

KEY TERMS

Mass: A measure of the amount of stuff (or matter). Not to be confused with weight or volume. This is a measure of how much actual stuff there is, not how big it is or how hard something is pulling on it.

Force: Mass times acceleration.

Velocity: A measure of how fast something is going in some direction.

Projectile: An object projected through space because of a force. A thrown baseball or a cannon ball are good examples.

BEFORE THE ACTIVITY STUDENTS SHOULD KNOW

- A projectile is something that moves in two directions at once.
- Gravity from the Earth makes objects fall.
- The force of gravity is always pulling straight down towards the floor.
- Once something is moving, it will stay moving until a force acts on it.

AFTER THE ACTIVITY STUDENTS SHOULD KNOW

- Describe how motion in one direction affects motion in another.
- State that an object does not change its velocity unless a force acts on it.
- Describe the affect of mass on how fast something falls.

THE SCIENCE BEHIND A PROJECTILE MOTION

In activity one, we learned that things fall at the same rate (if there's no air resistance) and that wads of play dough of different masses will hit the ground at the same time. But in that experiment, they were only moving in one direction, down toward the floor. But what happens if they're moving out at the same time they're moving down? Will they still hit at the same time? Turns out, yes!

When something is moving, it is going to continue moving in the same way unless acted on by a force. This is Newton's first

ACTIVITY 4: Watch it Fly

TEACHER'S GUIDE

law. If a hockey puck is moving on the ice, it is going to continue going in the same direction unless it is hit by something like a hockey stick. In experiment one, there were two forces acting on the play doh, gravity and air resistance. The force of gravity made the play doh fall, while air resistance pushed back and slowed it down a little. But what if there are been no forces? If nothing was pushing or pulling the play doh, it would have happily stayed where it was.

This is true for things that are moving at a constant velocity as well, like the hockey puck. As the puck scoots across the ice, the force of gravity is pulling it down, the ice is pushing back up, there is no force acting in the direction it is moving. So it will happily stay moving until a force does come along, maybe a hockey player trying to shoot a goal. Just because something is moving, doesn't mean there is currently a force acting on it and just because something is motionless doesn't mean there are no forces acting.

All of this is true in projectile motion as well. When something is launched off the edge of a counter or table, it has been given some initial velocity off the table (in this experiment, by a slingshot) and then begins to fall down toward the ground. But as soon as it leaves the table, the only forces that are acting on it are the force of gravity and the force of air resistance. There are no forces acting to change its forward motion, just its motion toward the ground. Because of this, as the ball flies through the air and eventually hits the ground, it will always be moving forward with the same velocity.

But will this forward velocity change how it falls toward Earth? No, not at all. Motion in one direction does not affect motion in another. So how fast it falls depends only on how hard the Earth is pulling, not on how fast the ball is moving forward. In this experiment students will get to see that no matter how the initial velocity changes or how the mass changes, the balls will always take the same time to fall.

SAFETY

Make sure that students are out of the way before launching the wooden balls off of the table.

CORRESPONDING EXTENSION ACTIVITIES

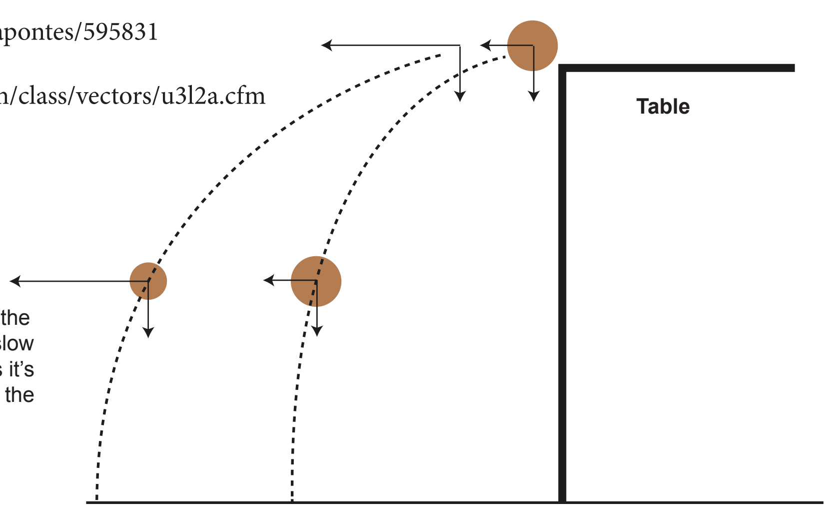
- Up and out
- Food Fight

SUGGESTED RESOURCES

http://galileoandeinstein.physics.virginia.edu/more_stuff/Applets/ProjectileMotion/jarapplet.html

http://scratch.mit.edu/projects/dapontes/595831

http://www.physicsclassroom.com/class/vectors/u3l2a.cfm



The balls keep going to the left at the same speed. There's no force to slow them down. A longer arrow means it's moving faster. The balls still fall at the same rate.

ACTIVITY 4: Watch it Fly

STUDENT'S GUIDE

INTRO

In activities one and two we looked at what happens with things fall, both straight down and as part of a pendulum. Now we are going to look at what happens with something moves in two directions, down and out!

MATERIALS

- 4 rubber bands
- 2 sets of chop sticks
- 4 different sized wooden balls
- Lots of masking tape

KEY QUESTION:

How does the mass of a projectile and its initial velocity affect how far it flies and how fast it drops?

KEY TERMS

Mass: A measure of the amount of stuff (or matter). Not to be confused with weight or volume. This is a measure of how much actual stuff there is, not how big it is or how hard something is pulling on it.

Force: Mass times acceleration.

Velocity: A measure of how fast something is going in some direction.

Projectile: An object projected through space because of a force. A thrown baseball or a cannon ball are good examples.

GETTING STARTED

1. What is a projectile? ______________________

____

2. When you throw a ball or launch something from a sling shot, what path does it take? Draw it.

3. When something is flying like a projectile, in how many directions is it moving?

____

4. Do you think a projectile moving forward very fast will hit the ground sooner or later than a projectile moving forward slowly?

____

SETTING UP THE EXPERIMENT

You'll be making two sling shots out of rubber bands and chopsticks.

1. Tape two chopsticks to the edge of a table 3 inches apart with about 3 inches of actual chop stick about the table. Do the same with the second set of chop sticks on the same table edge about 6" away from the first set.

ACTIVITY 4: Watch it Fly

STUDENT'S GUIDE

2. Take two rubber bands and tie them together. Do this again with another two rubber bands.

3. On each set of rubber bands, put a piece of masking tape over the knot so that you have a little handle.

4. Put the sets of rubber bands on the chop sticks to create slingshot!

5. Put strips of tape 4", 6.5" and 9" back from the edge of the table.

WARNING

Make sure you have plenty of space in front of your slingshots, your projectiles can fly very far.

COLLECTING DATA

You are going to explore what happens when an object, in this case a wooden ball, moves in two directions at once. When an object falls it is moving in one direction and this motion is caused by the force of gravity. To get our projectiles moving in two directions, we need to give them a "kick" off the table so that they will be moving forward as well as down. For this activity the "kick" will come from a rubber band and chopstick sling shot. The farther the rubber band is pulled back, the harder the ball will be hit and the faster it will going forward when it leaves the table.

1. Label the balls 1 through 4 from largest to smallest.

2. Place ball 1 at the edge of the table in one of the chop stick sling shots and ball 2 in the other. (Figure 1)

3. Pull the rubber bands back to the closest strip of tape and let go, launching the balls. Put a piece of tape where each of the balls hit and label it with the ball number and the distance the rubber band was pulled back. Do this three times, marking with tape each time. It's always important to do repeated trials. Find the average distance traveled. Note which ball hit the ground first.

4. Now do the same thing, only pulling the rubber band back to the second strip of tape. Again do this 3 times and find the average. Each time, note which ball hit the ground first.

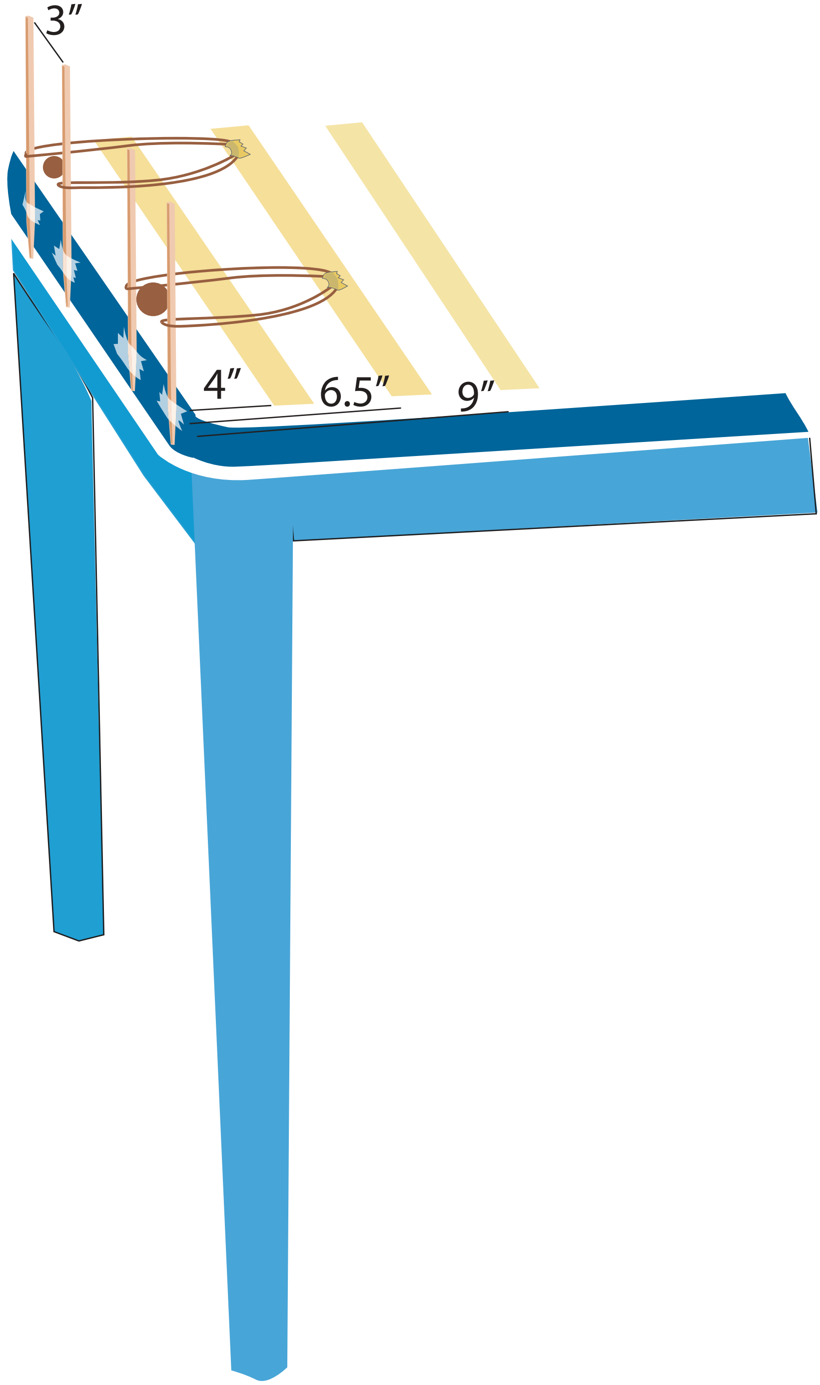
5. Repeat with ball 1 & 3, 1 & 4, 2 & 3, 2 & 4, and 3 & 4. Each time note which ball hits the ground first.

	DISTANCE	ORDER IT HIT
BALL ◯		
BALL ◯		
BALL ◯		
BALL ◯		

ACTIVITY 4: Watch it Fly

STUDENT'S GUIDE

Figure 1



ACTIVITY 4: Watch it Fly

STUDENT'S GUIDE

ANALYZING YOUR DATA

1. Draw the path a ball took as it flew off the table. Was it what you predicted?

2. Looking at what you recorded in your chart, did the distance the ball traveled forward affect how long it took to fall to the ground?

3. Did the balls with more mass take a longer or shorter time to hit the ground?

4. What can you say about how horizontal motion affects vertical motion?

Use your results to help the gang save Spectra with the "emergency shut off switch".

Which ball flew the furthest and which landed first?

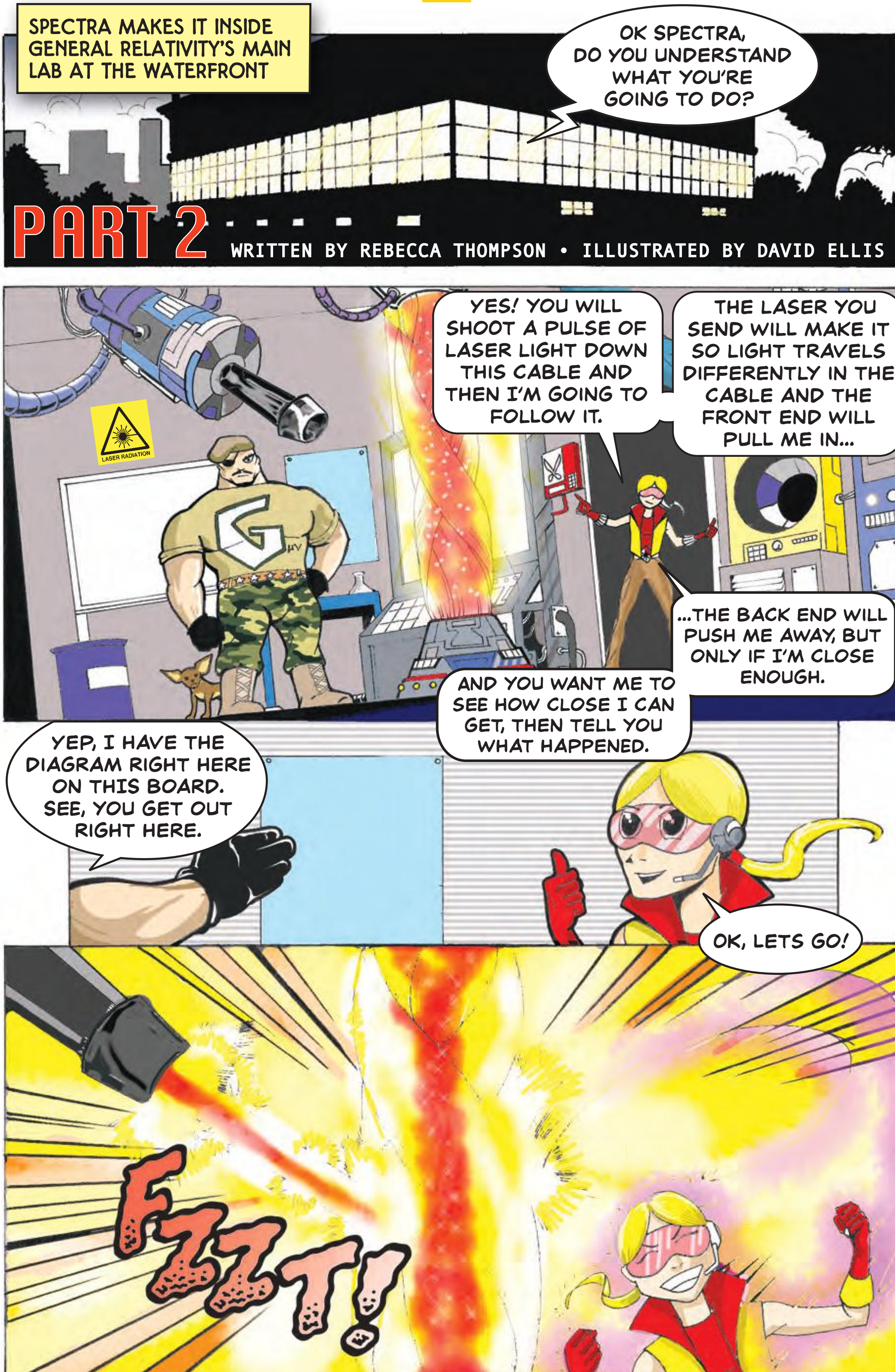
1. Ball 4 always flew the farthest and ball 1 always landed first.

2. Ball 1 always flew the farthest and ball 4 always landed first**.**

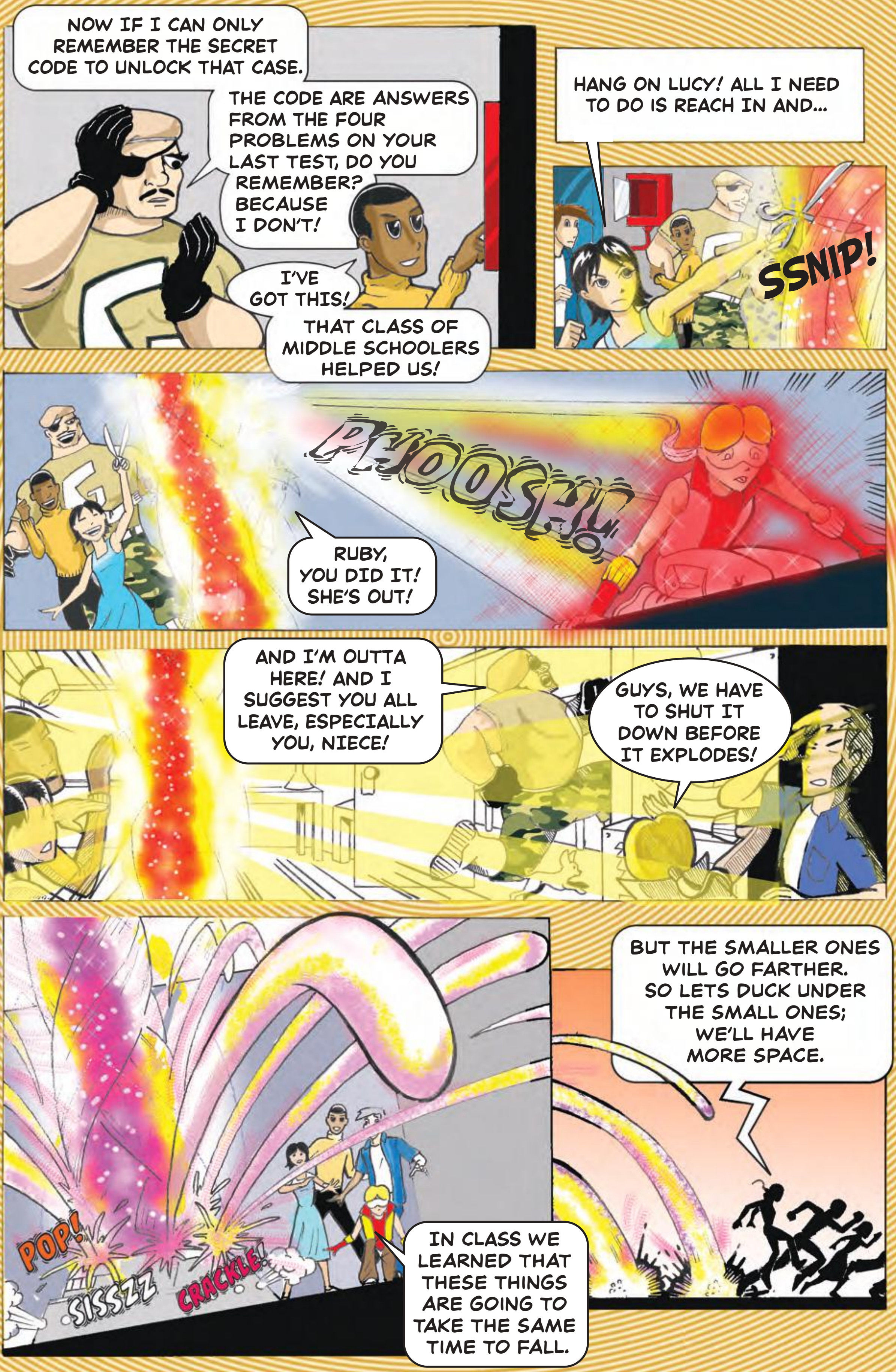
3. Ball 1 always flew the farthest and the balls all landed at the same time.

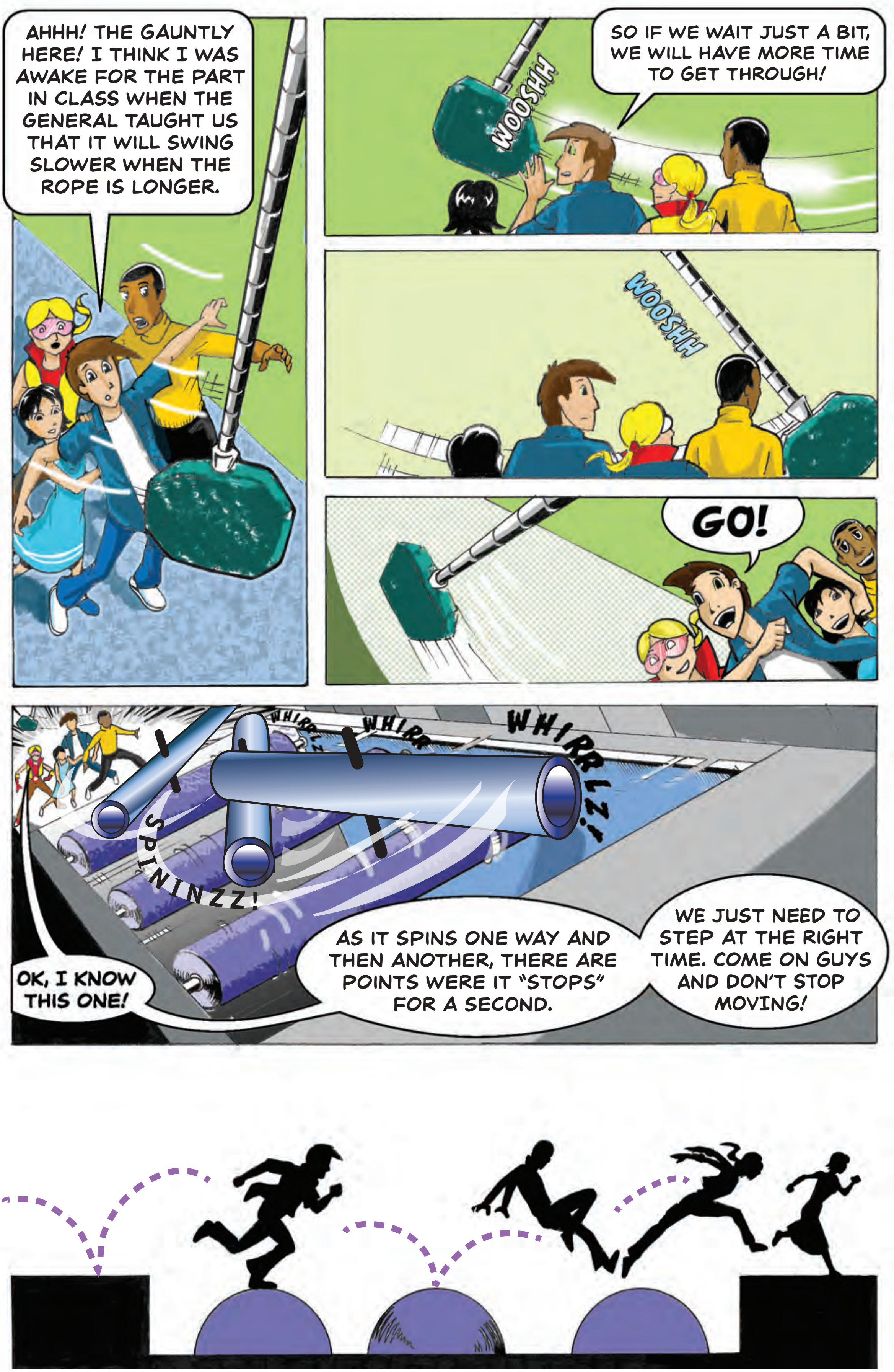
4. Ball 4 always flew the farthest and the balls all landed at the same time.

This number is the FOURTH number in the code needed to access the "emergency shut off switch". Write it in the SECOND space of the "emergency shut off switch" illustration.


SPECTRA MAKES IT INSIDE GENERAL RELATIVITY'S MAIN LAB AT THE WATERFRONT
OK SPECTRA, DO YOU UNDERSTAND WHAT YOU'RE GOING TO DO?
PART 2
WRITTEN BY REBECCA THOMPSON • ILLUSTRATED BY DAVID ELLIS
YES! YOU WILL SHOOT A PULSE OF LASER LIGHT DOWN THIS CABLE AND THEN I'M GOING TO FOLLOW IT.
THE LASER YOU SEND WILL MAKE IT SO LIGHT TRAVELS DIFFERENTLY IN THE CABLE AND THE FRONT END WILL PULL ME IN...
...THE BACK END WILL PUSH ME AWAY, BUT ONLY IF I'M CLOSE ENOUGH.
AND YOU WANT ME TO SEE HOW CLOSE I CAN GET, THEN TELL YOU WHAT HAPPENED.
LASER RADIATION
YEP, I HAVE THE DIAGRAM RIGHT HERE ON THIS BOARD. SEE, YOU GET OUT RIGHT HERE.
OK, LETS GO!
FZZZT!


I THINK I AM CLOSE ENOUGH, I'M STARTING TO SHIFT, RED AND BLUE. YOU DID IT GENERAL! THIS MUST BE LIKE A BLACK HOLE!
SUCCESS!!!
OUCH! YOU SAID I COULD GET OUT!?
WHERE'S THE END!!!!
I'M BEING STRETCHED TOO MUCH, I CAN'T HANDLE THIS, IT HURTS!
UNCLE LESLIE, WHAT'S GOING ON? WHERE'S LUCY?
BUT HERE ON MY DIAGRAM. OH NO! SOMETHING MUST HAVE GONE WRONG! THIS ISN'T RIGHT. I DON'T KNOW HOW TO GET YOU OUT!
RUBY, SHE'S IN DANGER! QUICK, GRAB THAT EMERGENCY SHUT-OFF DEVICE, I HAVE TO CUT THE CABLE!


NOW IF I CAN ONLY REMEMBER THE SECRET CODE TO UNLOCK THAT CASE.
THE CODE ARE ANSWERS FROM THE FOUR PROBLEMS ON YOUR LAST TEST, DO YOU REMEMBER? BECAUSE I DON'T!
I'VE GOT THIS!
THAT CLASS OF MIDDLE SCHOOLERS HELPED US!
HANG ON LUCY! ALL I NEED TO DO IS REACH IN AND...
SSNIP!
PHOOSH!
RUBY, YOU DID IT! SHE'S OUT!
AND I'M OUTTA HERE! AND I SUGGEST YOU ALL LEAVE, ESPECIALLY YOU, NIECE!
GUYS, WE HAVE TO SHUT IT DOWN BEFORE IT EXPLODES!
POP!
SISSZZ
CRACKLE!
IN CLASS WE LEARNED THAT THESE THINGS ARE GOING TO TAKE THE SAME TIME TO FALL.
BUT THE SMALLER ONES WILL GO FARTHER. SO LETS DUCK UNDER THE SMALL ONES; WE'LL HAVE MORE SPACE.


AHHH! THE GAUNTLY HERE! I THINK I WAS AWAKE FOR THE PART IN CLASS WHEN THE GENERAL TAUGHT US THAT IT WILL SWING SLOWER WHEN THE ROPE IS LONGER.
WOOSHH
SO IF WE WAIT JUST A BIT, WE WILL HAVE MORE TIME TO GET THROUGH!
WOOSHH
GO!
WHIRR
WHIRRLZZ!
SPININZZ!
OK, I KNOW THIS ONE!
AS IT SPINS ONE WAY AND THEN ANOTHER, THERE ARE POINTS WERE IT "STOPS" FOR A SECOND.
WE JUST NEED TO STEP AT THE RIGHT TIME. COME ON GUYS AND DON'T STOP MOVING!


WOW, THAT WAS CLOSE. I'M SUPER GLAD UNCLE LESLIE TAUGHT US ABOUT FORCE AND MOTION THIS YEAR!
AND THAT THOSE KIDS KNEW THE CODE TO SHUT OFF THE EXPERIMENT!
DO YOU THINK WE WILL EVER HAVE A PHYSICS TEACHER THAT DOESN'T TRY TO USE SPECTRA?
I SURE HOPE NOT. I'M GLAD THAT WE'RE ALL SAFE...
... LOOK AT THE TIME!
WE CAN STILL GET TO THE DANCE! LET ME GO QUICKLY CHANGE. BACK IN A FLASH SO TO SPEAK!
SHORTLY AFTERWARDS
DANCE


KAS, I WONDER WHY NO ONE IS A DANCING? THIS IS ONE OF MY FAVORITE SONGS.
HUH, I NEVER UNDERSTOOD WHY PEOPLE LIKE THIS FLUFFY MUSIC.
BUT FOR YOU, I'LL LISTEN TO ANYTHING. UHH, WOULD YOU LIKE TO DANCE?
I WOULD LOVE TO DANCE.
BTW, YOU LOOK WONDERFUL TONIGHT. I MEAN, I GUESS, UHHH, YOU ALWAYS LOOK NICE.
AND AFTER ALMOST BEING PULLED APART BY A BLACKHOLE, I'M IMPRESSED YOU CAME OUT LOOKING SO PRETTY.
THANK YOU AND YOU CLEAN UP WELL, TOO!
THE END

NOTES

www.aps.org

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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.

THE SPECTRA ISSUE #3 TEAM

REBECCA THOMPSON is the Head of Public Outreach at APS and the co-creator of Spectra. She often travels all over the world to research and write comics. With her PhD in physics and Ironman finisher's medal, she has the smarts and endurance to reach out to the world proselytizing physics while tanning.

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DAVID ELLIS works in the APS Editorial Offices in Ridge, NY developing electronic and graphic design projects. A comic book fan his entire life, David considers drawing Spectra the perfect combination of his day job and his dream job.

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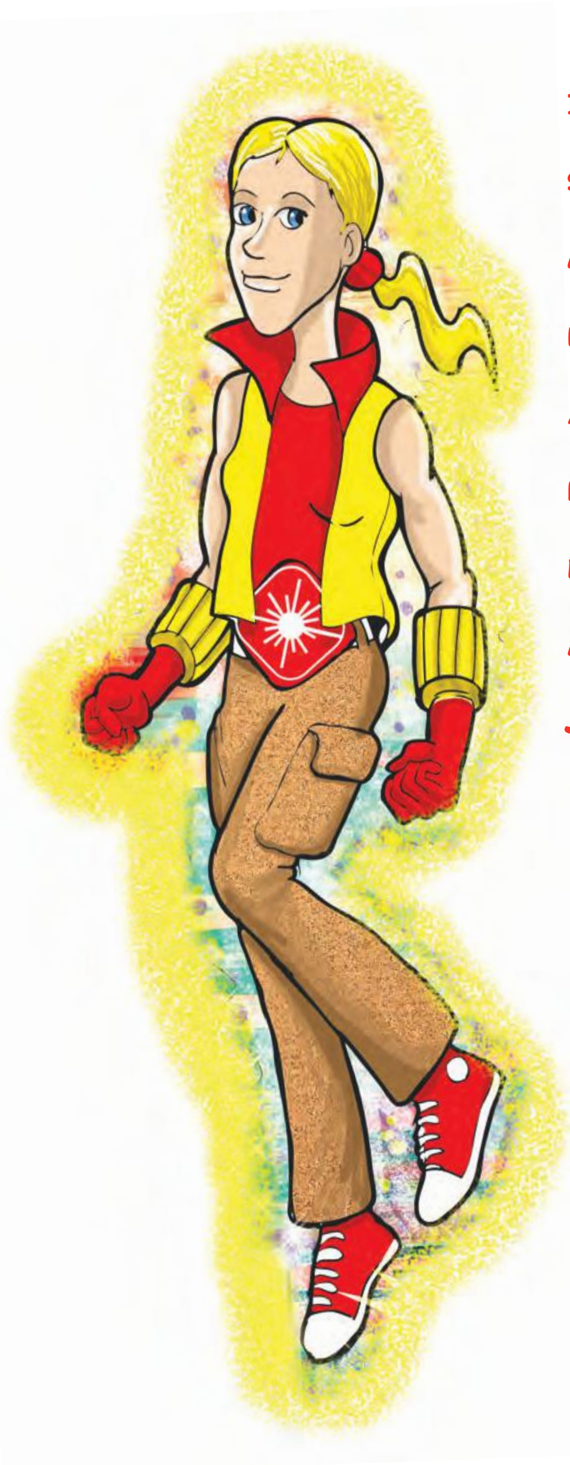

IN THIS THIRD INSTALLMENT OF THE SPECTRA SERIES, OUR LASER-POWERED MIDDLE SCHOOL HERO TRIES TO PREVENT HER BEST FRIEND'S UNCLE FROM ACCIDENTALLY DESTROYING THE WORLD! HELP SPECTRA AND HER CREW BY LEARNING ABOUT GRAVITY, FORCE AND MOTION IN PHYSICSQUEST 2010 *SPECTRA'S FORCE.*

COLLECT THEM ALL!

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ISSUE #2

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