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SPECTRA
ENERGETIC ESCAPE!
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Welcome to PhysicsQuest: Spectra's

Your Mission

You are about to go on an adventure learning about different types of energy as Spectra and her gang try to complete the challenges thrown at them by Fetch magazine. Will their team win tickets to see the Free Radicals? Will they lose to Tiffany Maxwell and her Princess Patrol? Will they even survive?

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.

This year, APS is pleased to present this thirteenth kit, ***PhysicsQuest: Spectra's Energetic Escape***.

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 demise 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, Fetch magazine, with questionable Editor in Chief Nolan R. Gibbs, will do a profile of Tesla Junior High. Or at least that's what the students and Dr. Daniel originally thought. Instead, he puts them through a grueling competition to win tickets to see the newest boy band, The Free Radicals. As one might expect by this point, things go horribly wrong. Spectra and her gang must stop N.R.G. from accidentally killing off the students he's profiling! Students will learn about pendulums, friction, potential, and kinetic energy as they follow the team's adventures in this year's PhysicsQuest.

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 Physics-Quest groups or learn helpful tips and tricks.

The PhysicsQuest Materials

The PhysicsQuest kit includes this manual and most of the hardware your students need to complete the activities. There is also a 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. 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
4xPipe cleaners
Rubber bands
Fun dough
4xNuts
Rough and fine sandpaper
Yo Yo string
Bouncy Ball
Wire
Straw
Binder clips
Hand copter

Not included in this kit:

Scissors
Lots of tape
Paper
Permanent marker
Meter stick
Large piece of paper
Chairs
Books

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 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
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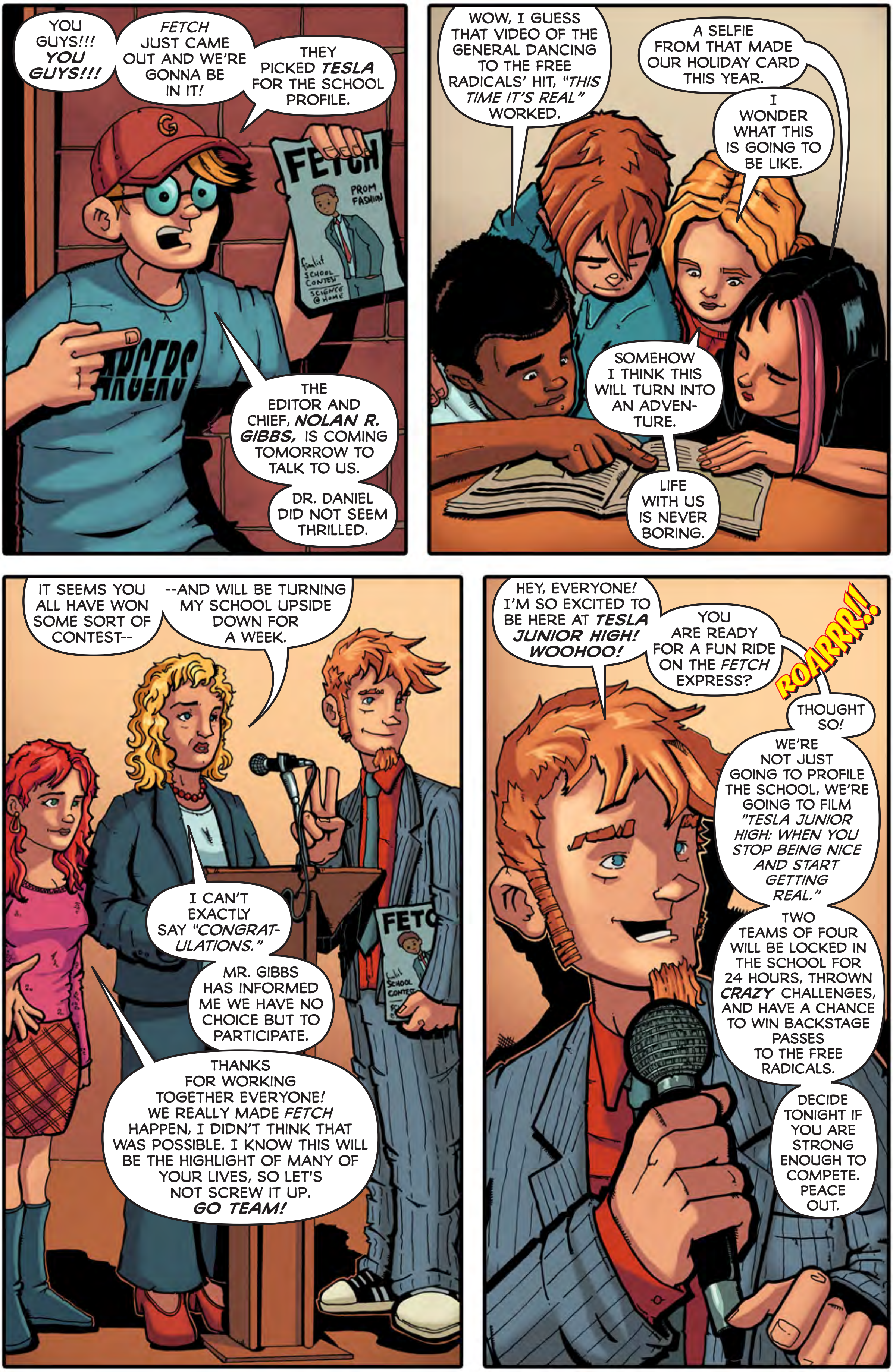
Teacher Manual graphics by James Roche
Comic Art by Roel Torres

American Physical Society (**www.aps.org**)


TESLA JUNIOR HIGH IS THE AVERAGE AMERICAN MIDDLE SCHOOL.
STUDENTS LIKE PIZZA AT PIZZA PI, SOCCER GAMES, AVOIDING HOMEWORK, AND MOST OF ALL READING FETCH MAGAZINE.
IN FACT, THEY LOVE IT SO MUCH THEY MADE A VIDEO ABOUT WHY THEIR SCHOOL SHOULD BE FEATURED IN A SPECIAL ISSUE THAT WILL PROFILE ONE LUCKY MIDDLE SCHOOL.
THEY ARE ABOUT TO FIND OUT THAT TODAY IS THEIR LUCKY DAY.
·HOME OF THE CHARGERS·
STATE SWIMMING CHAMPIONS
SWIM
SWIM TEAM
FETCH


YOU GUYS!!! YOU GUYS!!!
FETCH JUST CAME OUT AND WE'RE GONNA BE IN IT!
THEY PICKED TESLA FOR THE SCHOOL PROFILE.
FETCH
PROM FASHION
finalist SCHOOL CONTEST
SCIENCE @ HOME
THE EDITOR AND CHIEF, NOLAN R. GIBBS, IS COMING TOMORROW TO TALK TO US.
DR. DANIEL DID NOT SEEM THRILLED.
WOW, I GUESS THAT VIDEO OF THE GENERAL DANCING TO THE FREE RADICALS' HIT, "THIS TIME IT'S REAL" WORKED.
A SELFIE FROM THAT MADE OUR HOLIDAY CARD THIS YEAR.
I WONDER WHAT THIS IS GOING TO BE LIKE.
SOMEHOW I THINK THIS WILL TURN INTO AN ADVEN-TURE.
LIFE WITH US IS NEVER BORING.
IT SEEMS YOU ALL HAVE WON SOME SORT OF CONTEST--
--AND WILL BE TURNING MY SCHOOL UPSIDE DOWN FOR A WEEK.
I CAN'T EXACTLY SAY "CONGRAT-ULATIONS."
MR. GIBBS HAS INFORMED ME WE HAVE NO CHOICE BUT TO PARTICIPATE.
THANKS FOR WORKING TOGETHER EVERYONE! WE REALLY MADE FETCH HAPPEN, I DIDN'T THINK THAT WAS POSSIBLE. I KNOW THIS WILL BE THE HIGHLIGHT OF MANY OF YOUR LIVES, SO LET'S NOT SCREW IT UP. GO TEAM!
HEY, EVERYONE! I'M SO EXCITED TO BE HERE AT TESLA JUNIOR HIGH! WOOHOO!
YOU ARE READY FOR A FUN RIDE ON THE FETCH EXPRESS?
ROARRR!!
THOUGHT SO!
WE'RE NOT JUST GOING TO PROFILE THE SCHOOL, WE'RE GOING TO FILM "TESLA JUNIOR HIGH: WHEN YOU STOP BEING NICE AND START GETTING REAL."
TWO TEAMS OF FOUR WILL BE LOCKED IN THE SCHOOL FOR 24 HOURS, THROWN CRAZY CHALLENGES, AND HAVE A CHANCE TO WIN BACKSTAGE PASSES TO THE FREE RADICALS.
DECIDE TONIGHT IF YOU ARE STRONG ENOUGH TO COMPETE. PEACE OUT.

TEACHER'S GUIDE

ACTIVITY 1: GO NUTS!

Introduction

Pendulums are everywhere—from yo-yos to grandfather clocks, to pirate ships at amusement parks. They are a fundamental part of physics and understanding their motion is a key part of understanding potential and kinetic energy. Standard pendulum experiments look at how the period of a pendulum's swing changes depending on the amplitude, mass, and length of string. This experiment takes the next step and looks at what happens when several pendulums are all hanging from the same pivot point, in this case a rubber band. Now students aren't just looking at the energy in a pendulum's swing, but how that energy is transferred from one pendulum to another.

Key Question

How does the length of a pendulum affect its swing and transfer of energy?

Materials

4 pipe cleaners
4 nuts
4 small rubber bands (tan)

* 2 chairs
* ruler
* scissors

** not included in the PhysicsQuest kit*

Key Terms

Period: The time it takes for something to complete a full cycle. In the case of a pendulum, this is the time it takes for the pendulum to get back to where it started.

Frequency: The number of periods in a set amount of time. In this activity, this is the number of full swings per minute.

Potential Energy: Energy of position. The higher off the ground something is, the more potential energy it has.

Kinetic Energy: Energy of motion. The faster something is going, the more kinetic energy it has.

TEACHER'S GUIDE

Before the activity, students should know…

- The "period" of a pendulum's swing is from the starting point back to the same point.
- A pendulum's period is based on the length of the string and not the mass or amplitude.

After the activity, students should be able to…

- Discuss how energy can be transferred from one pendulum to another.
- State what needs to be the same about pendulums for energy transfer to occur.

The Science behind Coupled Pendulums

Welcome to PhysicsQuest! This kit will focus mainly on energy and how it changes from one form to other forms. Two of the most often discussed forms of energy are *potential* and *kinetic energy.* We'll also explore heat energy and friction. This activity will use pendulums to talk about potential energy, kinetic energy, and how it can be transformed and transferred.

Pendulums are everywhere—from swing sets to grandfather clocks (do kids still know what these are?). The rate at which a pendulum swings is very regular and depends on the length of the string on which it's swinging. This makes it ideal for clocks as well as teaching some physics. A single pendulum swinging is a great example of changing potential energy to kinetic energy and back again.

The two main types of energy involved in understanding a pendulum are *potential energy* and *kinetic energy.*

Potential energy is often a confusing way to saying that something has energy just because of where it is. When a pendulum bob (in this experiment, it's a nut) is pulled back, it has potential energy because it is some distance above its equilibrium point. The higher it is, the more potential energy it has. When it is let go, it starts swinging and gains kinetic energy—the energy of motion. The faster something moves, the more kinetic energy it has. A pendulum is moving at its fastest when it's at the bottom of its swing. The potential energy is decreased because the pendulum bob is no longer as high as it was when it started.

As I'm sure you have heard before, energy can neither be created nor destroyed. The trick is keeping track of it. The higher the bob starts, the faster the pendulum will eventually swing. However, I'm sure everyone has seen the videos of someone starting a bowling ball pendulum right at their nose and letting it swing right back up to their nose.

They don't end up in the hospital because some of the energy is lost as heat because of friction at the point the string connects to the ceiling. In this activity, we won't worry about heat energy lost and we'll explore friction later on.

A pendulum's *period* is the time it takes to get from one point back to that same point. If you start a pendulum from a certain height, the period is how long it takes to get back to where you started it. (Fig. 1)

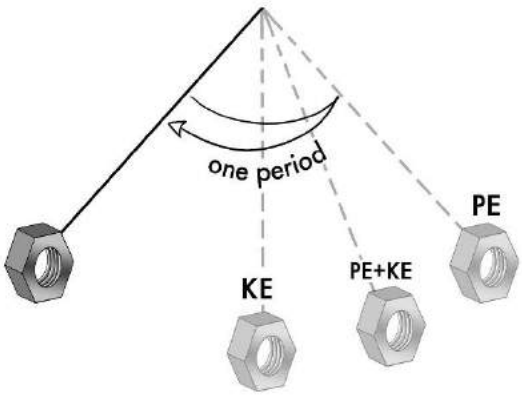


Figure 1

The *frequency* is the number of times a pendulum makes a full swing back to the point it started in a set amount of time. In this activity we'll look at the number of swings per minute.

A pendulum's period depends on the length of the string but not on the bob's weight. It also depends on the strength of gravity, but since this activity won't be done on the moon, we don't have to think too much about that.

If you want to make a pendulum swing higher (or keep going since it will be slowed down with friction), you have to push it. But this only works if you push it at exactly the right time. Think of trying to push someone on a swing. You have to push them at the right time to get them to move faster. You push the person once a swing, or once a period.

Pendulums with different lengths need to be pushed at different times since they have different natural periods. We intuitively know when to push someone on a swing. We also know that if we push at the wrong time, the swing will stop. You might also know that you get into a rhythm so that no matter how high the person on the swing goes, he or she will need to be pushed at the same time.

In this activity, instead of a human doing the pushing, it will be another pendulum. In a coupled pendulum system, two pendulums will be attached to the same pivot string, in this case a yo-yo string. First, two pendulums with the same length will be attached to the string. One will be pulled back, giving it potential energy. The second pendulum doesn't have any energy at all since it stays in the equilibrium position.

TEACHER'S GUIDE

As the first pendulum swings, its potential energy will be turned to kinetic, but just like the bowling ball some of it will be lost in pulling on the string. As it swings, friction—the same force that is slowing it down—tugs on the string in the direction the pendulum is moving.

This string movement tugs on the other pendulum. If the tugs come at the right time, the second pendulum will start moving, just like someone pushing a person on a swing. The "right time" depends on the length of the pendulum. If the two pendulums are the same length, the tugs will come at just the right time and cause the second pendulum to swing. When it starts swinging, it gains energy. Since energy is neither created nor destroyed, the first pendulum loses energy as the second gains it. Eventually, the second pendulum gets most of the energy and starts swinging a bunch. But then, the same process repeats itself and the first pendulum starts swinging again. This keeps going until all the energy is lost to friction.

When two pendulums of different lengths are attached to the yo-yo string, the first pendulum doesn't tug at the second pendulum at the right time. This is like you pushing someone on a swing incorrectly. Because of that, the second pendulum will never start swinging. The time it takes for the energy to transfer back and forth between the two pendulums depends on the pendulum's length. A good way to think of this is that if the period is longer, it is tugging on the string less frequently, and the energy won't be transferred as fast. The faster the swing, the more quickly the energy is transferred.

This is a fairly quick and fun experiment. It's easy to do only qualitatively and get the general physics across. There are also plenty of ways to make it more quantitative if that's what will work best in your classroom. I have always liked this experiment because even though the physics makes sense, it's still surprising to see it in action.

Suggested Resources

Exploratorium Science Snacks:
www.exploratorium.edu/snacks/coupled-resonant-pendulums

Phet Simulation:
https://phet.colorado.edu/en/simulation/pendulum-lab

Excellent video of an undergrad physics student explaining a coupled pendulum:
www.youtube.com/watch?v=PLBzFriHu4E

STUDENT GUIDE

ACTIVITY 1: GO NUTS!

Materials

4 pipe cleaners
4 nuts
4 small rubber bands (tan)

- * 2 chairs
- * ruler
- * scissors

* *not included in the PhysicsQuest kit*

Introduction

From clocks to dog's ears, pendulums are everywhere. By now you may know some of the rules of pendulums. If you've done past PhysicsQuest activities, you probably know that how long it takes for one swing is based on how long the string is, not how much the swinging mass weighs. But what happens when you put two, three, or even four of these things together? How will they swing? What will happen to the energy? How will one affect the others? This activity will answer all these questions.

Key Question

How does the length of a pendulum affect its swing and transfer of energy?

Getting Started

1. Name several types of pendulums.

2. What is meant by a pendulum's "period?"

3. What might the period depend on?

4. What do you think would happen if two pendulums shared a pivot, much like two swings on the same swing set?

5. What is meant by "kinetic energy?"

6. What is meant by "potential energy?"

7. What are some ways you might transfer energy from one pendulum to another?

Setting Up the Experiment

Your pendulum lengths should be 6" from the yo-yo string to the top of the nut (for the long pendulums), and 2.25" to the top of the nut (for the short ones).

1. Tie each end of the yo-yo string to the arms of the two chairs.
2. Place the chairs as far apart as you can without breaking the yo-yo string.
3. Take the four nuts and wrap one end of the pipe cleaner through and around the nut to make a pendulum.
4. Attach two of the nut pendulums to the yo-yo string about 4"-6" apart so that the nuts hang about 6" below the yo-yo string. (Fig. 1)

Collecting Data

Qualitative:

1. Swing one of the two pendulums. What happens to both pendulums?
2. Watch for a bit longer. Now what is happening?
3. Remove one of the longer pendulums and replace it with a shorter one. Swing the longer pendulum. What happens to the shorter one?
4. Swing the shorter one. What happens to the longer one?

Figure 1

STUDENT GUIDE

Quantitative:

1. Start again with only the long pendulum tied to the yo-yo string. Pull it back a bit and let it swing.

2. Measure how many swings this pendulum takes in one minute. This is the *frequency*.

3. The *period* is the time it takes for one swing. To find the period, divide 60 seconds by the number of swings in a minute. This is the time for one swing. Record both in the chart below.

4. Repeat steps 1-3 with the shorter pendulum after removing the longer pendulum.

5. Attach two longer pendulums and repeat 1-3, swinging just one of the two. What happens to the second pendulum?

6. Set a stopwatch for two minutes. Record how many times one pendulum goes from still to swinging at its maximum during those two minutes. Record this in the last column of the chart.

7. Repeat steps 5 and 6 with the two shorter pendulums.

8. Attach one long and one short pendulum. Swing the long pendulum. What happens to the short one? Swing the short one. What happens to the long one?

9. Attach all four pendulums as shown on the previous page. Swing one of the smaller pendulums. What happens to all four?

10. Swing one of the larger pendulums. What happens to all four?

	Frequency (swings per 60 seconds)	**Period (seconds per swing)**	**Period of Energy Transfer**
Long Pendulum			XXXXX
Long Coupled Pendulum			
Short Pendulums			XXXXX
Short Coupled Pendulum			

STUDENT GUIDE

Analyzing Your Results

1. How did the period of the long pendulum compare to the period of the short pendulum?

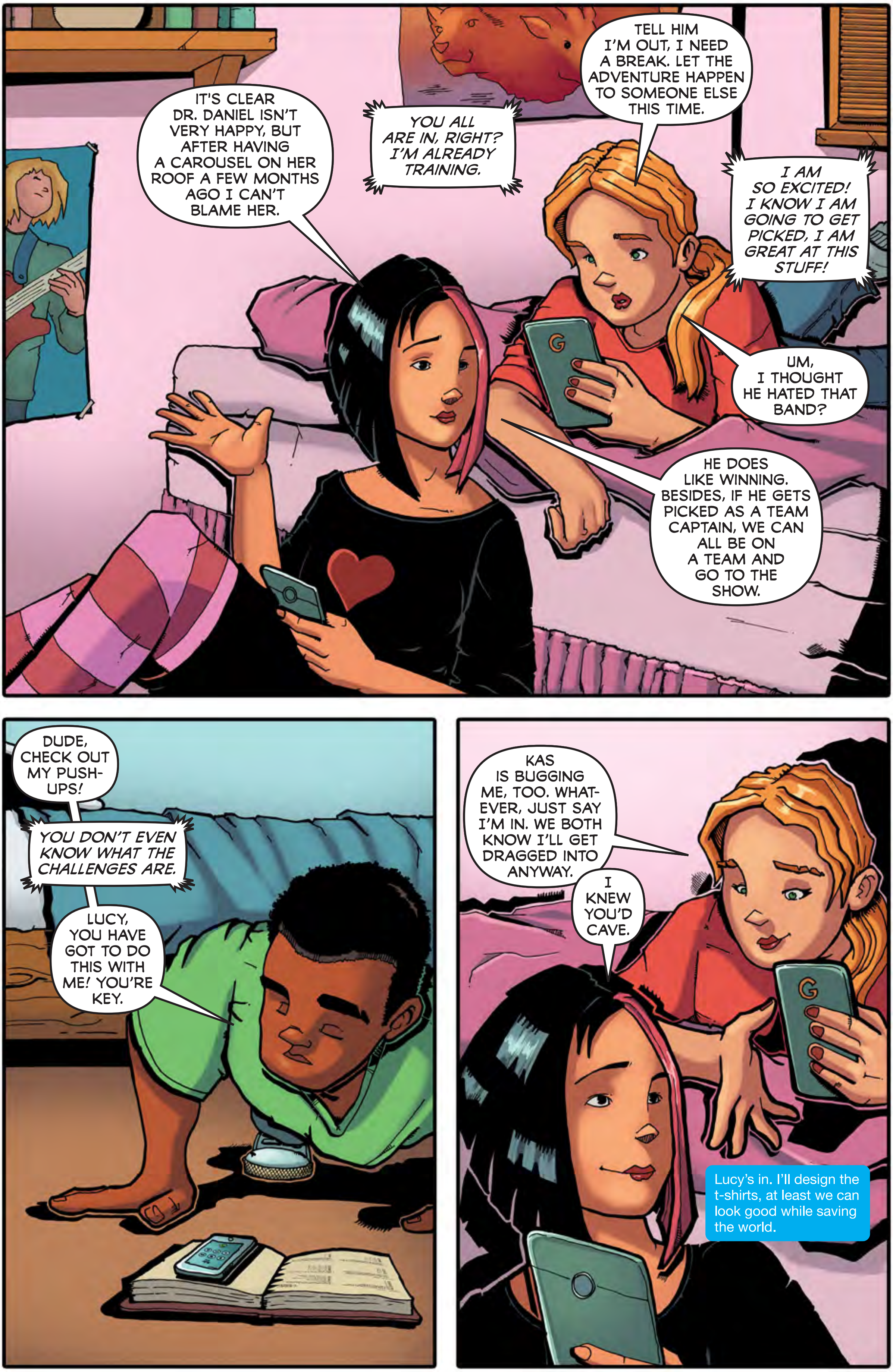
2. How was the period of energy transfer different for the shorter pendulum than the longer one?

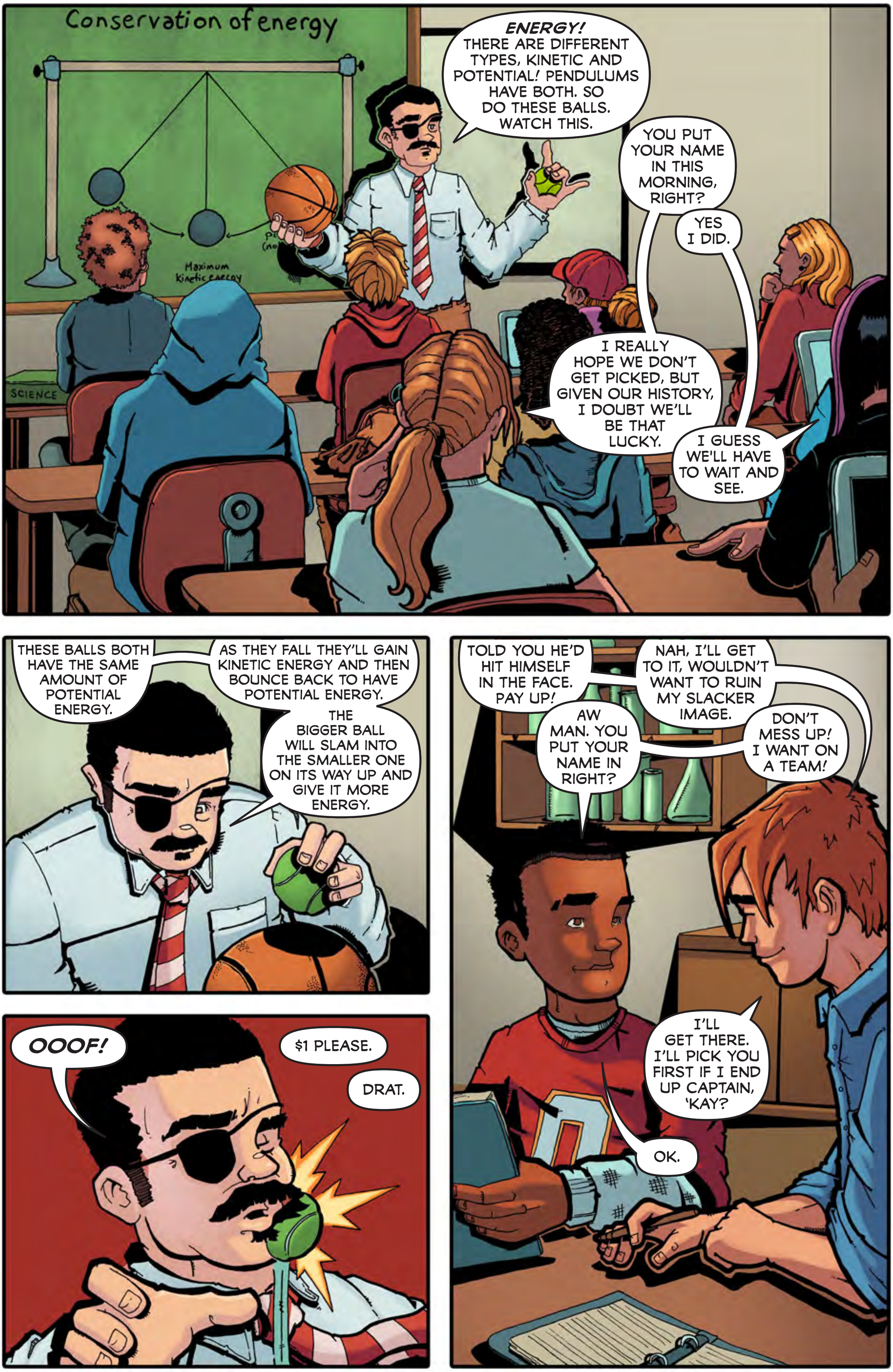
3. How did the period of energy transfer compare to the period of the swing?

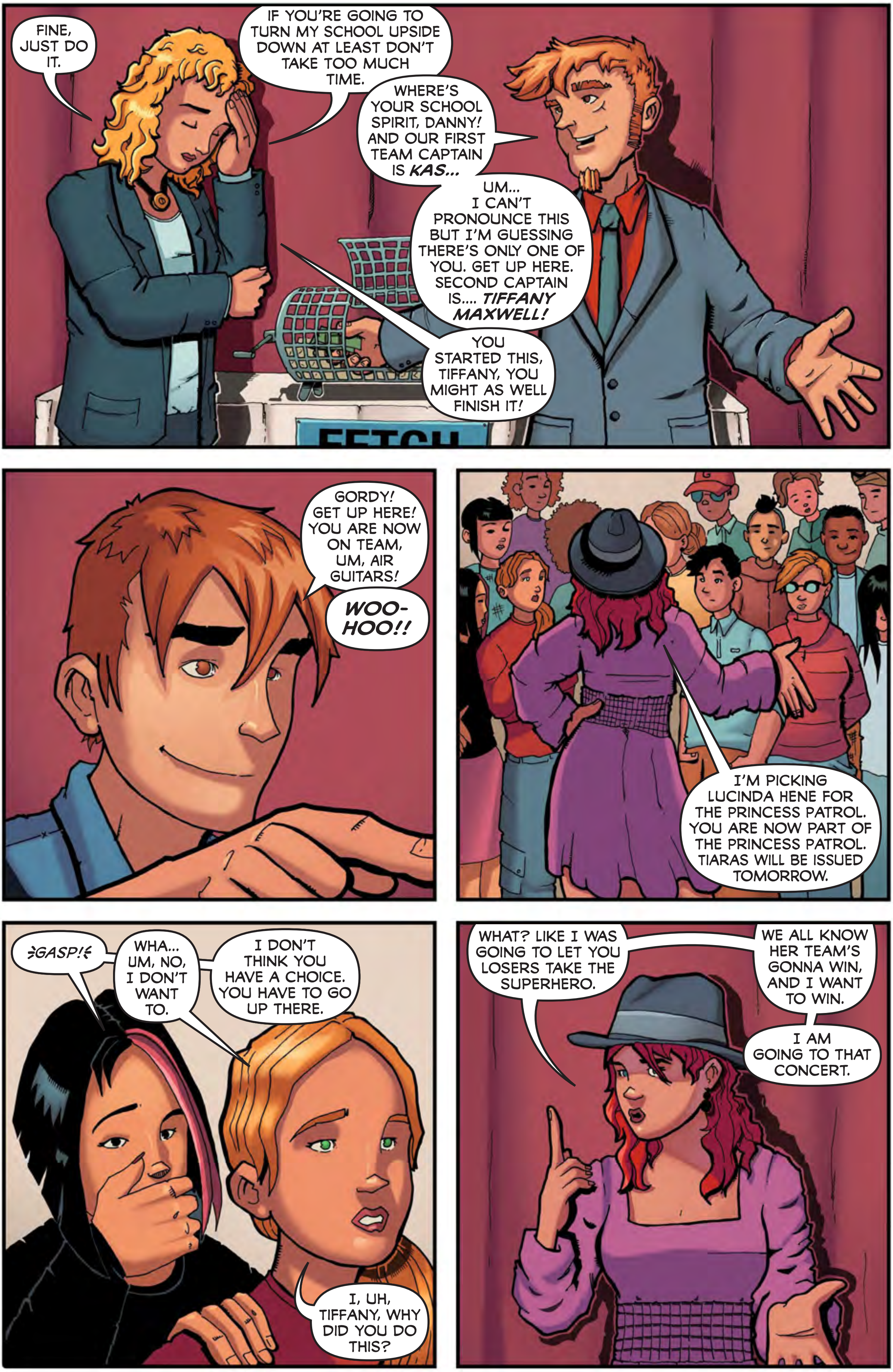
4. When you swung the long pendulum with the shorter pendulum attached to the yo-yo string, what happened to the shorter pendulum? What happened to the long one when the short one was swung?

5. Think back to what the period depends on. Hopefully you theorized that a pendulum's length determines the period. What can you say about coupled pendulums of different lengths?

6. Can two pendulums of different lengths transfer energy?


IT'S CLEAR DR. DANIEL ISN'T VERY HAPPY, BUT AFTER HAVING A CAROUSEL ON HER ROOF A FEW MONTHS AGO I CAN'T BLAME HER.
YOU ALL ARE IN, RIGHT? I'M ALREADY TRAINING.
TELL HIM I'M OUT, I NEED A BREAK. LET THE ADVENTURE HAPPEN TO SOMEONE ELSE THIS TIME.
I AM SO EXCITED! I KNOW I AM GOING TO GET PICKED, I AM GREAT AT THIS STUFF!
UM, I THOUGHT HE HATED THAT BAND?
HE DOES LIKE WINNING. BESIDES, IF HE GETS PICKED AS A TEAM CAPTAIN, WE CAN ALL BE ON A TEAM AND GO TO THE SHOW.
DUDE, CHECK OUT MY PUSH-UPS!
YOU DON'T EVEN KNOW WHAT THE CHALLENGES ARE.
LUCY, YOU HAVE GOT TO DO THIS WITH ME! YOU'RE KEY.
KAS IS BUGGING ME, TOO. WHATEVER, JUST SAY I'M IN. WE BOTH KNOW I'LL GET DRAGGED INTO ANYWAY.
I KNEW YOU'D CAVE.
Lucy's in. I'll design the t-shirts, at least we can look good while saving the world.


Conservation of energy
Maximum Kinetic energy
SCIENCE
ENERGY! THERE ARE DIFFERENT TYPES, KINETIC AND POTENTIAL! PENDULUMS HAVE BOTH. SO DO THESE BALLS. WATCH THIS.
YOU PUT YOUR NAME IN THIS MORNING, RIGHT?
YES I DID.
I REALLY HOPE WE DON'T GET PICKED, BUT GIVEN OUR HISTORY, I DOUBT WE'LL BE THAT LUCKY.
I GUESS WE'LL HAVE TO WAIT AND SEE.
THESE BALLS BOTH HAVE THE SAME AMOUNT OF POTENTIAL ENERGY.
AS THEY FALL THEY'LL GAIN KINETIC ENERGY AND THEN BOUNCE BACK TO HAVE POTENTIAL ENERGY.
THE BIGGER BALL WILL SLAM INTO THE SMALLER ONE ON ITS WAY UP AND GIVE IT MORE ENERGY.
OOOF!
$1 PLEASE.
DRAT.
TOLD YOU HE'D HIT HIMSELF IN THE FACE. PAY UP!
NAH, I'LL GET TO IT, WOULDN'T WANT TO RUIN MY SLACKER IMAGE.
AW MAN. YOU PUT YOUR NAME IN RIGHT?
DON'T MESS UP! I WANT ON A TEAM!
I'LL GET THERE. I'LL PICK YOU FIRST IF I END UP CAPTAIN, 'KAY?
OK.


FINE, JUST DO IT.
IF YOU'RE GOING TO TURN MY SCHOOL UPSIDE DOWN AT LEAST DON'T TAKE TOO MUCH TIME.
WHERE'S YOUR SCHOOL SPIRIT, DANNY! AND OUR FIRST TEAM CAPTAIN IS *KAS...*
UM... I CAN'T PRONOUNCE THIS BUT I'M GUESSING THERE'S ONLY ONE OF YOU. GET UP HERE. SECOND CAPTAIN IS.... *TIFFANY MAXWELL!*
YOU STARTED THIS, TIFFANY, YOU MIGHT AS WELL FINISH IT!
GORDY! GET UP HERE! YOU ARE NOW ON TEAM, UM, AIR GUITARS!
WOO-HOO!!
I'M PICKING LUCINDA HENE FOR THE PRINCESS PATROL. YOU ARE NOW PART OF THE PRINCESS PATROL. TIARAS WILL BE ISSUED TOMORROW.
GASP!
WHA... UM, NO, I DON'T WANT TO.
I DON'T THINK YOU HAVE A CHOICE. YOU HAVE TO GO UP THERE.
I, UH, TIFFANY, WHY DID YOU DO THIS?
WHAT? LIKE I WAS GOING TO LET YOU LOSERS TAKE THE SUPERHERO.
WE ALL KNOW HER TEAM'S GONNA WIN, AND I WANT TO WIN.
I AM GOING TO THAT CONCERT.

TEACHER'S GUIDE

ACTIVITY 2: FRICTION FUN

Introduction

Friction is that unseen force that mostly seems to make life more difficult. It always slows things down or makes them stop. Friction makes things overheat, causes wear and tear, and always needs to be accounted for when talking about energy. We overcome friction with heat sinks, WD-40, ball bearings, and wax. It's often a way to explain why something doesn't work as you think it should. However, friction is a lot more than that and is rarely directly measured.

In this activity we are going to quantify this annoying force. I'm sure you have an intuitive sense that something that weighs more experiences more friction when sliding and that rougher surfaces cause more friction. The experiment will try to quantify how these two factors—weight and surface material—affect friction.

Key Question

How does weight and surface roughness affect the force of friction felt by an object?

Materials

Rough grain sandpaper
Fine grain sandpaper
4 nuts
Fun dough
Rubber bands

* ruler
* tape

** not included in the PhysicsQuest kit*

Key Terms

Friction: The resistance to motion of one object moving against another. Rougher surfaces moving against each other have more friction.

Force: Something that changes the motion of an object. Pushing or pulling is a force; so is friction.

Coefficient of Friction: A number that tells how strong frictional force will be for a particular weight. Different surfaces have different coefficients of friction. Ice has a lower coefficient of friction than sandpaper.

TEACHER'S GUIDE

Before the activity, students should know...

- How forces act on an object.
- If something is moving at a constant rate, there are equal forces.

After the activity, students should be able to...

- Discuss the difference between static friction and friction of movement.
- Discuss how friction depends on both weight and the surface over which something is moving.

The Science behind Friction

Friction is my least favorite force. Sure, it has its uses, but in general it just works against whatever I'm trying to do. The best use of it I can think of is those amusement park rides that spin really fast and then have the floor drop out. It's friction that holds you against the side and stops you from falling down with the floor. Even though I'm not a fan of friction, it's a force we all encounter every day and it is important to understand.

As two surfaces move against each other, they lose some energy to friction. Friction is a force that resists movement. The classic example is rubbing your hands together and feeling them get hot. Friction is turning some of the energy from rubbing your hands into the heat energy you feel. Any time two surfaces are moving when smooshed against each other, there will be some friction.

For any combination of surface and object there is a maximum amount of force that friction can apply. To get an object to move on that surface, the force you are applying has to be greater than the maximum amount of force friction can exert. The maximum amount of frictional force depends on how heavy the mass is and how rough the surface is.

Think about a 100-pound box sliding on carpet versus a 10-pound box on ice. You have to push harder on the heavy box on carpet because the maximum frictional force in that system is high. It wouldn't take near as much to overcome the maximum friction of a box on ice. (Fig. 1)

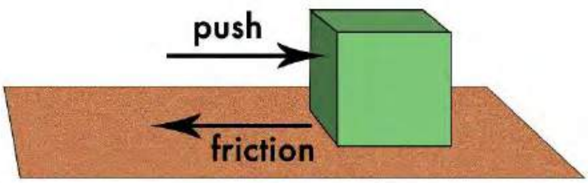


Figure 1

It's possible to measure this maximum frictional force for a specific mass and surface by figuring out how much force is required to just barely start the object moving. That's the point at which the maximum frictional force is overcome and the object starts sliding at a constant rate. If you can find a way to figure out how much force is applied at that point, then you also know how much force friction can exert. By comparing how that max force changes with surfaces and weights, you get a good idea of how those two things change frictional force.

For any surface there is a number, call the *coefficient of friction*, that says how much frictional force is exerted for any given weight. If you know this number and you know the weight of something, you can find the maximum force of friction. The rougher the surface, the higher this number will be.

In this activity, students will measure how much force it takes to move different weights—in this case, nuts—on two different surfaces. It's hard to find something that will fit in a PhysicsQuest kit that can directly measure force. Instead, the students will be using rubber bands and looking at how far they stretch before the mass of nuts moves.

I don't want to go too far on a tangent about how rubber bands work and the potential energy involved, so I'll sum up how they are used to measure relative forces. When a rubber band is stretched, it has potential energy. That stretch also exerts a force on whatever it is attached to. The more the rubber band is stretched, the more energy it has and the more force it is exerting on anything it is attached to. If the object isn't moving, it means it is exerting the same force as the rubber band—only in the opposite direction.

In the case of rubber bands and nuts, if the rubber band is being stretch and the nuts aren't moving, it means that friction is exerting the same amount of force as the rubber band in the opposite direction. When the rubber band is stretched to the point that the nuts begin to move, it is applying exactly the same amount of force as the maximum amount of frictional force. By measuring the length of the rubber band right at the moment of movement for different systems, you can see how the maximum amount of frictional force changes from one system to the other. This certainly isn't the most precise way to do it, but it is a great way to introduce students to the different things that affect friction.

Suggested Resources

Explanation of friction:
www.livescience.com/37161-what-is-friction.html

Another explanation of friction:
www.bbc.co.uk/guides/zxqrdxs

For a different activity that shows the same concepts:
www.perkinselearning.org/accessible-science/activities/friction-different-surfaces-lab

STUDENT GUIDE

ACTIVITY 2: FRICTION FUN

Introduction

If you rub your hands together really fast, they hurt and get hot. You've most likely been told a million times that this is because of friction. Some of the energy your muscles are generating to rub your hands together is being changed into heat energy by friction. If you push your hands together harder, they get hotter. What do you think would happen if you could make your hands rougher? Is there a way to measure the force of friction? This activity will use some fun dough, nuts, rubber bands, and sandpaper to find out.

Materials

Rough grain sandpaper
Fine grain sandpaper
4 nuts
Fun dough
Rubber bands

* ruler
* tape

** not included in the PhysicsQuest kit*

Key Question

What affects the force of friction?

Getting Started

1. What happens when two things rub up against each other?

____
____
____
____
____

2. What is friction?

____
____
____
____
____

3. What do you think causes friction?

____
____
____
____
____

4. What things might affect friction?

____
____
____
____
____

5. What would be harder: pushing a box across a shiny wood floor or pushing a box across carpet? Why?

____
____
____
____
____

STUDENT GUIDE

6. What would be harder: pushing a light box or a heavy box? Why?

Setting Up the Experiment

1. Take the rubber bands and hook loop one through the other to attach them together.
2. Take one end of the rubber bands and loop it through one nut to attach the rubber bands to the nut.
3. Surround the nut with fun dough, making sure the rubber band is sticking out. (Fig. 1)
4. Tape the two strips of sandpaper next to each other on a table or desk.
5. Set down a ruler along the sand-paper strips.

Collecting Data

Qualitative:

1. Place the dough/nut combo on one end of the fine grain sandpaper strip.

2. Gently and steadily pull the rubber band until the dough/nut combo begins to move. Did the rubber band stretch before the dough and nut started to move?

3. Now do the same thing with the coarse grain sandpaper. Did the rubber band stretch more or less than with the fine grain sandpaper?

4. Unwrap the nut from the fun dough and attach the rubber band around all four nuts. Rewrap the four nuts in fun dough.

5. Repeat steps 1-3 with four nuts. What changed?

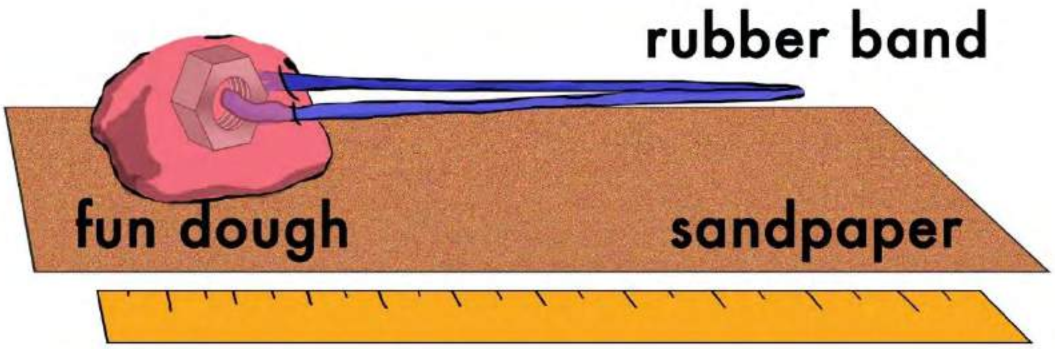


Figure 1

Quantitative:

You are now going to do something very similar to the qualitative experiments on the previous page, only this time you will measure how much the rubber band stretches before the dough blob moves.

1. Start with one nut and the fine grain strip of sandpaper.
2. Very slowly stretch the rubber band until the blob starts moving. Record the distance the rubber band stretched before the blob moved. Repeat this four more times and take the average. Record that number in the table below.
3. Repeat step 2 for two nuts, three nuts, and four nuts, with five tries each. For each try, keep track of the distance the rubber band stretched before the blob moved. Record the average in the table.
4. Repeat steps 2 and 3 with the coarse grain sandpaper, recording the numbers in the table. Make sure to use units!

	Fine grain	**Coarse grain**
One nut		
Two nuts		
Three nuts		
Four nuts		

Analyzing Your Results

1. Which combination of sandpaper and nuts needed the most rubber band stretch to make the blob move? Which required the least?

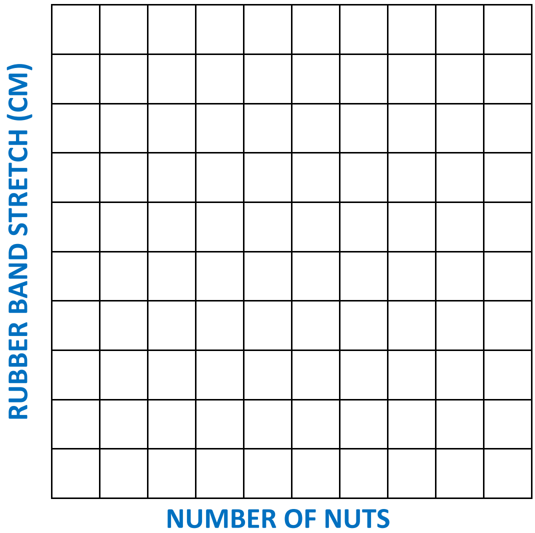
2. When the rubber band was pulled, it exerted a force on the blob. What force was pulling back on the blob?

3. How does the force of friction compare for each combination?

4. What different things does friction depend on? If you wanted to decrease the force of friction, what two things might you change?

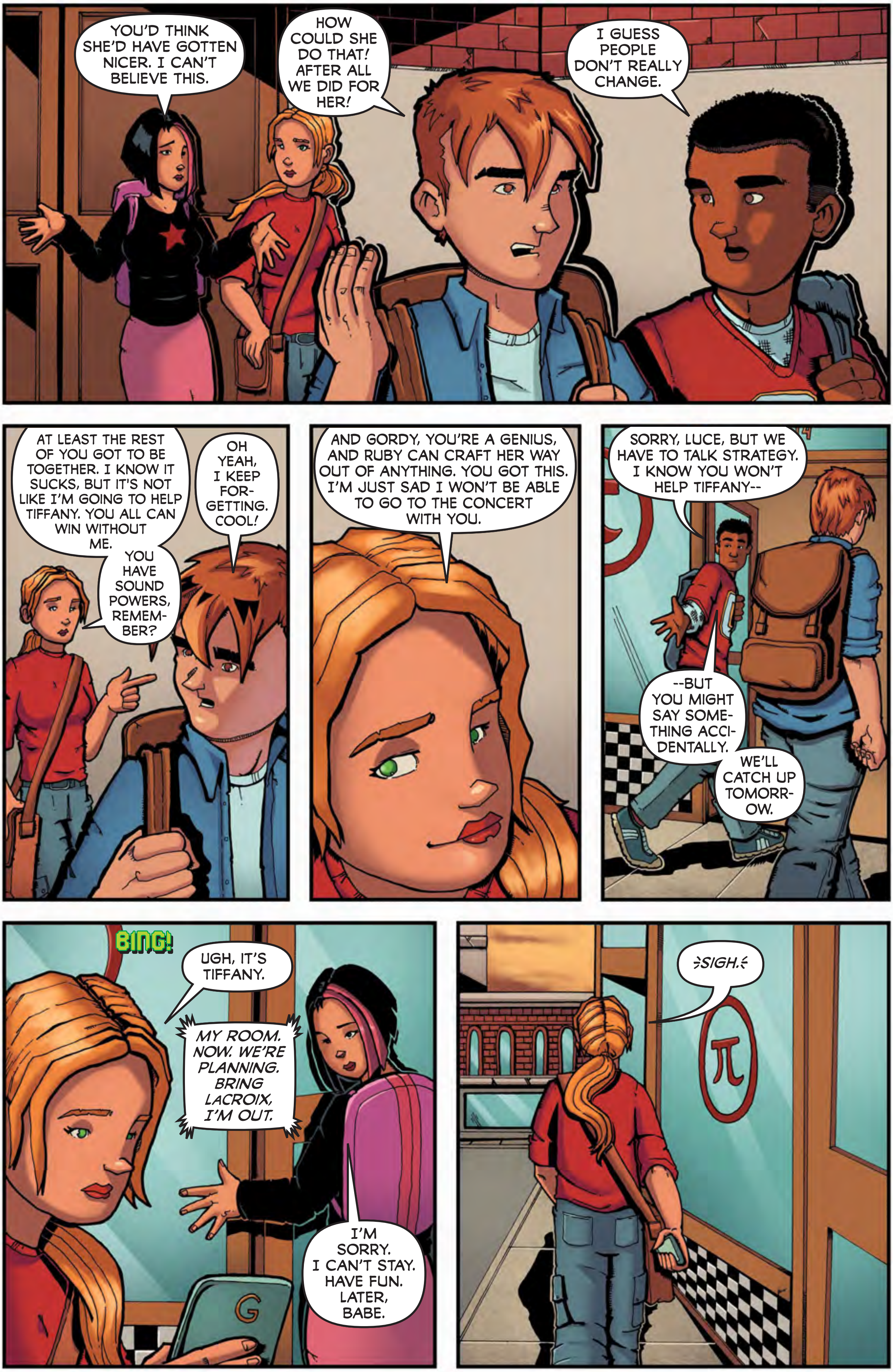
5. Graph the rubber band stretch versus the number of nuts (stretch on the Y axis, number of nuts on the X axis) for both the fine grain and coarse grain sandpaper. Hint: use different colored pencils for each type of sandpaper. What does the graph look like?

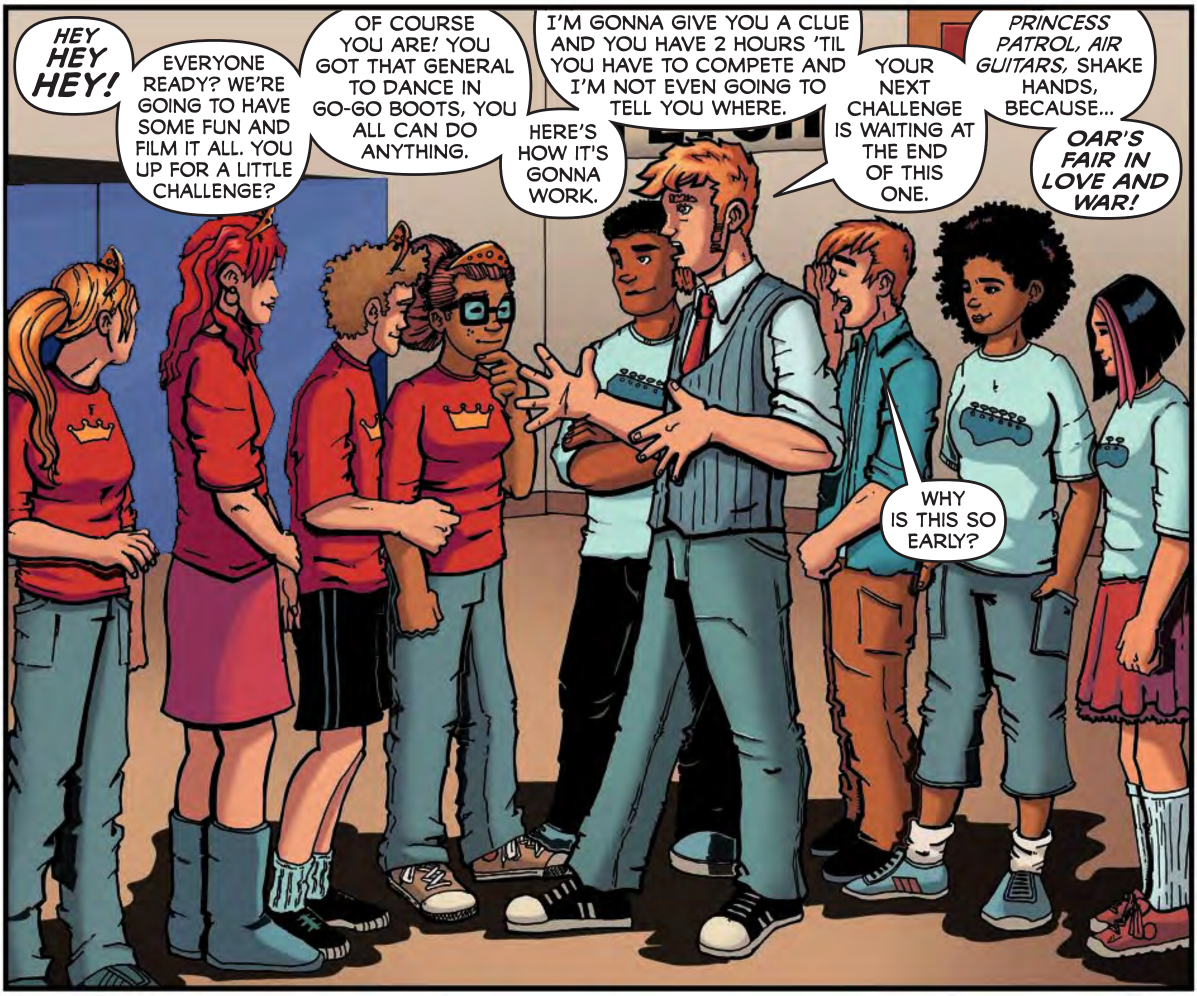
RUBBER BAND STRETCH (CM) VS NUMBER OF NUTS



6. Surfaces have something called a "coefficient of friction" which tells you how strong friction is. This coefficient is the force you measured by the amount of rubber band stretch divided by the weight—in this case the number of nuts. Can you find the coefficient of friction for both the fine grain and coarse grain sandpaper? Which one is bigger?

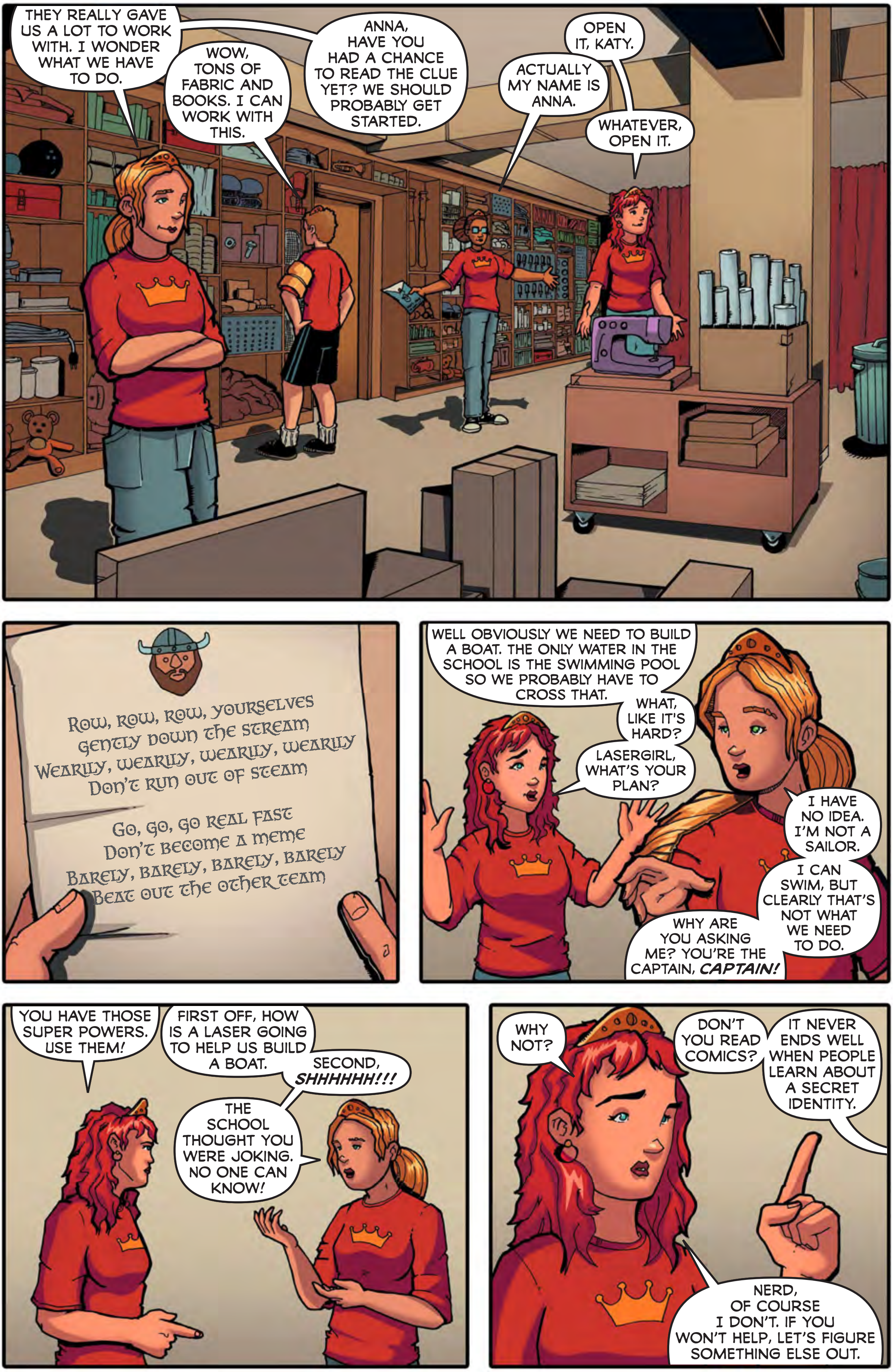
7. Do you think ice has a high or low coefficient of friction? What about grip tape? Another name for grip tape is friction tape. Can you think of why it might be called that?


YOU'D THINK SHE'D HAVE GOTTEN NICER. I CAN'T BELIEVE THIS.
HOW COULD SHE DO THAT! AFTER ALL WE DID FOR HER!
I GUESS PEOPLE DON'T REALLY CHANGE.
AT LEAST THE REST OF YOU GOT TO BE TOGETHER. I KNOW IT SUCKS, BUT IT'S NOT LIKE I'M GOING TO HELP TIFFANY. YOU ALL CAN WIN WITHOUT ME.
YOU HAVE SOUND POWERS, REMEM-BER?
OH YEAH, I KEEP FOR-GETTING. COOL!
AND GORDY, YOU'RE A GENIUS, AND RUBY CAN CRAFT HER WAY OUT OF ANYTHING. YOU GOT THIS. I'M JUST SAD I WON'T BE ABLE TO GO TO THE CONCERT WITH YOU.
SORRY, LUCE, BUT WE HAVE TO TALK STRATEGY. I KNOW YOU WON'T HELP TIFFANY--
--BUT YOU MIGHT SAY SOME-THING ACCI-DENTALLY.
WE'LL CATCH UP TOMORR-OW.
BING!
UGH, IT'S TIFFANY.
MY ROOM. NOW. WE'RE PLANNING. BRING LACROIX, I'M OUT.
I'M SORRY. I CAN'T STAY. HAVE FUN. LATER, BABE.
SIGH.

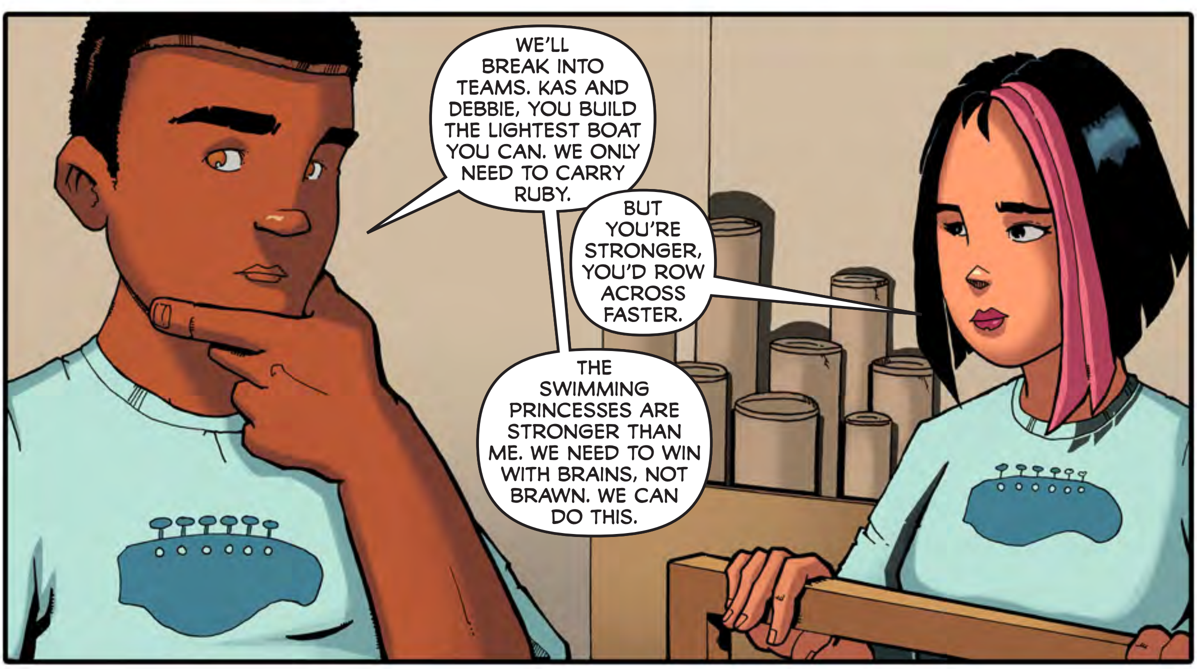

HEY HEY HEY!
EVERYONE READY? WE'RE GOING TO HAVE SOME FUN AND FILM IT ALL. YOU UP FOR A LITTLE CHALLENGE?
OF COURSE YOU ARE! YOU GOT THAT GENERAL TO DANCE IN GO-GO BOOTS, YOU ALL CAN DO ANYTHING.
HERE'S HOW IT'S GONNA WORK.
I'M GONNA GIVE YOU A CLUE AND YOU HAVE 2 HOURS 'TIL YOU HAVE TO COMPETE AND I'M NOT EVEN GOING TO TELL YOU WHERE.
YOUR NEXT CHALLENGE IS WAITING AT THE END OF THIS ONE.
PRINCESS PATROL, AIR GUITARS, SHAKE HANDS, BECAUSE...
OAR'S FAIR IN LOVE AND WAR!
WHY IS THIS SO EARLY?

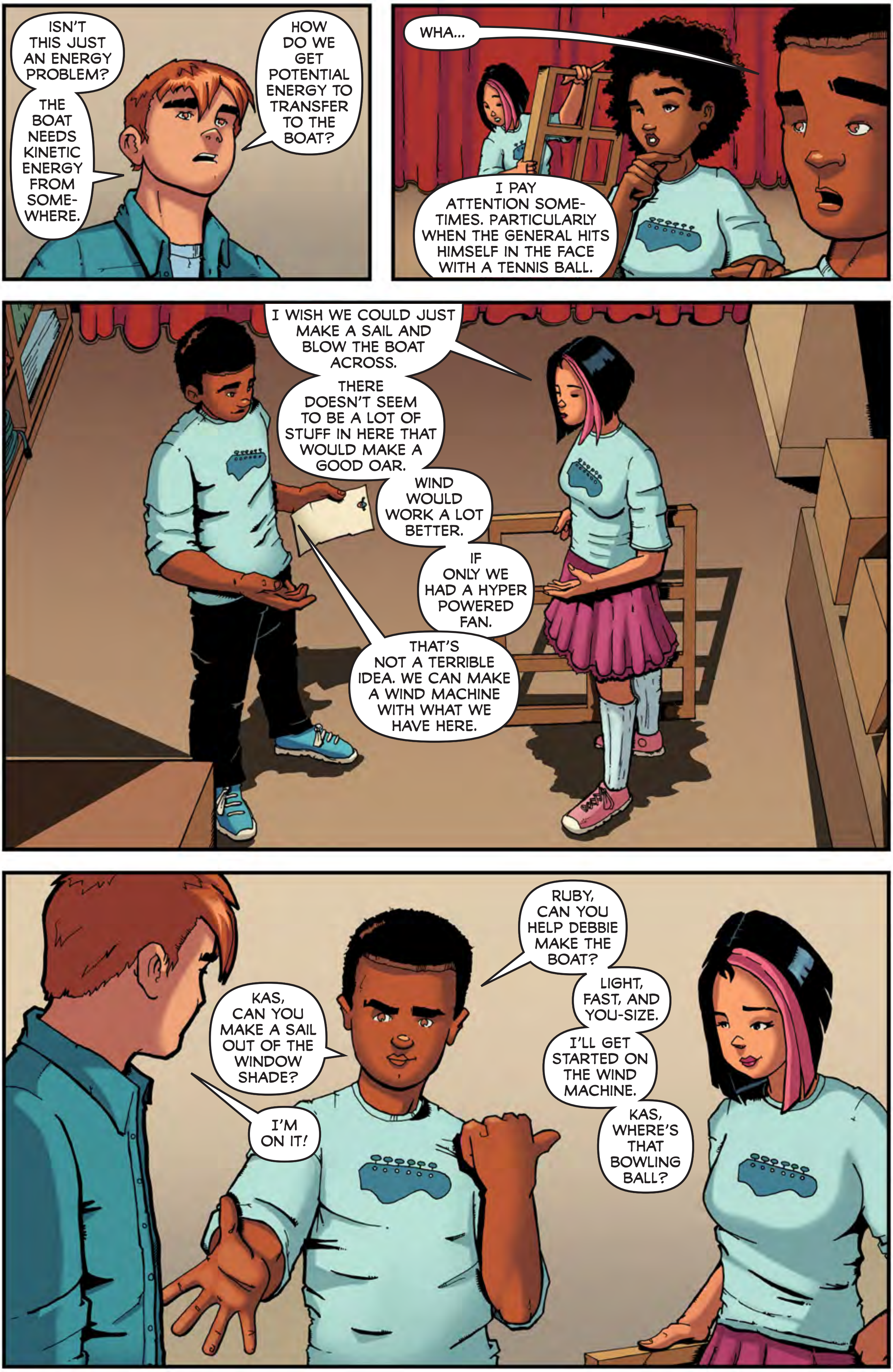

TWO HOURS TO BE A *VIKING!*
OAR'S FAIR IN LOVE & WAR.

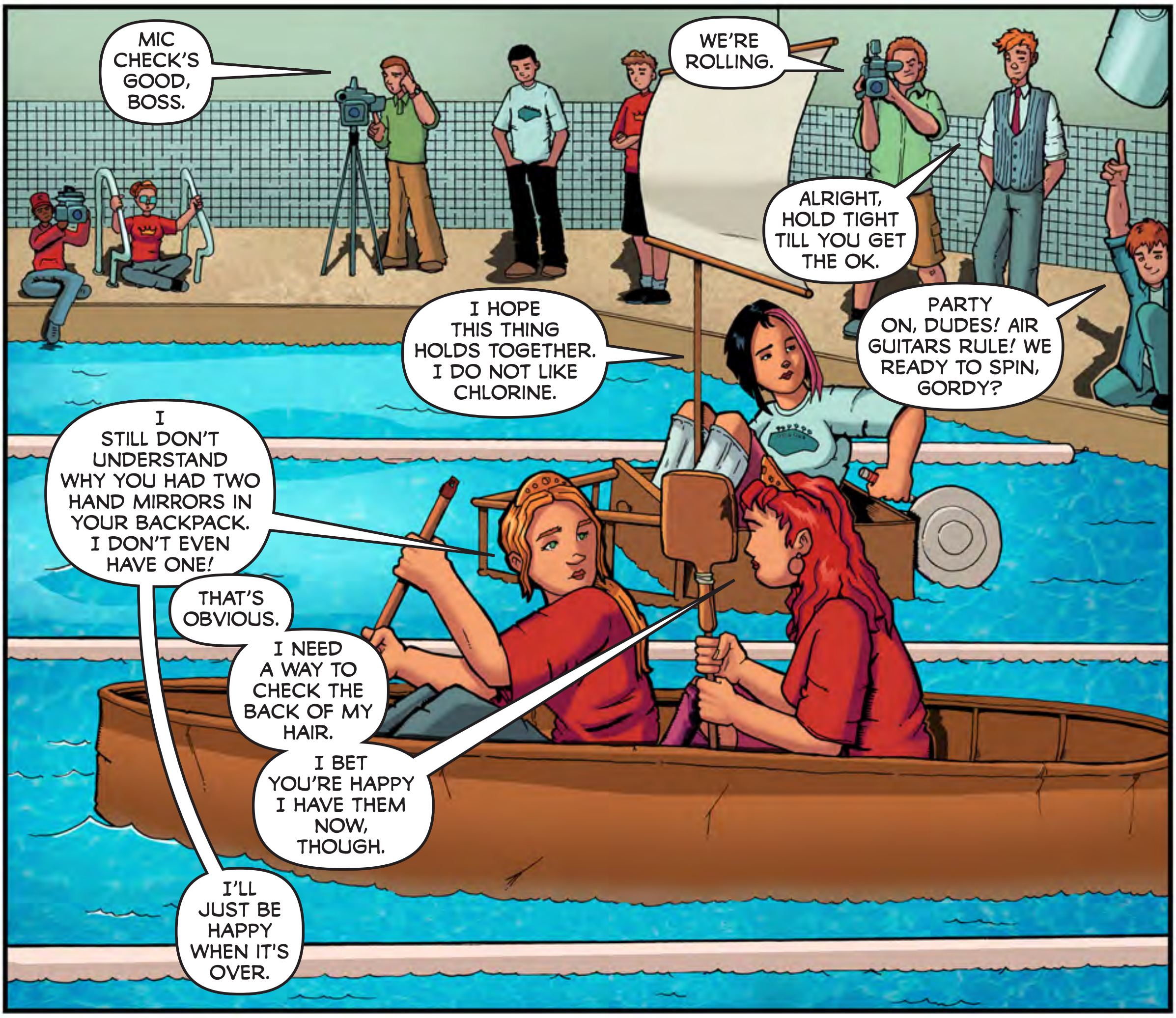

YOU FIRST CHALLENGE IS TO FIND YOUR "SUPPLY" ROOM.
IF YOU KNOW THE SCHOOL AS WELL AS YOU SAY YOU DO, WON'T BE A PROBLEM.
AND YOUR TIME STARTS.... ***NOW!***

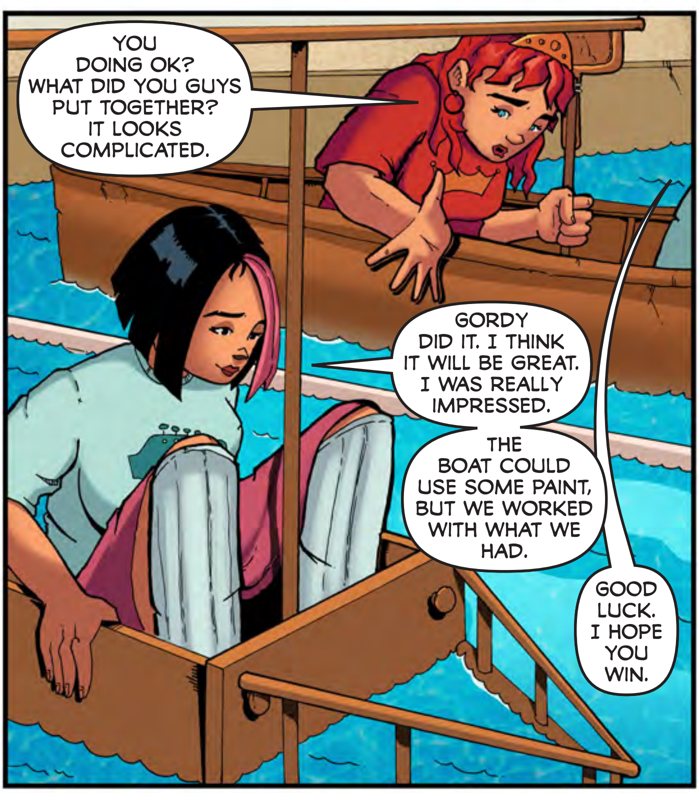

THEY REALLY GAVE US A LOT TO WORK WITH. I WONDER WHAT WE HAVE TO DO.
WOW, TONS OF FABRIC AND BOOKS. I CAN WORK WITH THIS.
ANNA, HAVE YOU HAD A CHANCE TO READ THE CLUE YET? WE SHOULD PROBABLY GET STARTED.
ACTUALLY MY NAME IS ANNA.
OPEN IT, KATY.
WHATEVER, OPEN IT.
Row, row, row, yourselves
Gently down the stream
Wearily, wearily, wearily, wearily
Don't run out of steam
Go, go, go real fast
Don't become a meme
Barely, barely, barely, barely
Beat out the other team
WELL OBVIOUSLY WE NEED TO BUILD A BOAT. THE ONLY WATER IN THE SCHOOL IS THE SWIMMING POOL SO WE PROBABLY HAVE TO CROSS THAT.
WHAT, LIKE IT'S HARD?
LASERGIRL, WHAT'S YOUR PLAN?
I HAVE NO IDEA. I'M NOT A SAILOR.
I CAN SWIM, BUT CLEARLY THAT'S NOT WHAT WE NEED TO DO.
WHY ARE YOU ASKING ME? YOU'RE THE CAPTAIN, ***CAPTAIN!***
YOU HAVE THOSE SUPER POWERS. USE THEM!
FIRST OFF, HOW IS A LASER GOING TO HELP US BUILD A BOAT.
SECOND, ***SHHHHHH!!!***
THE SCHOOL THOUGHT YOU WERE JOKING. NO ONE CAN KNOW!
WHY NOT?
DON'T YOU READ COMICS?
IT NEVER ENDS WELL WHEN PEOPLE LEARN ABOUT A SECRET IDENTITY.
NERD, OF COURSE I DON'T. IF YOU WON'T HELP, LET'S FIGURE SOMETHING ELSE OUT.


IT LOOKS LIKE WE HAVE TO BUILD A BOAT AND RACE THE OTHER TEAM IN THE POOL.
PUZZLES ARE EASIEST WHEN WE BREAK THEM DOWN.
WE NEED A BOAT, A SAILOR, AND SOME WAY TO POWER THE BOAT.
WOW, THERE'S A LOT OF STUFF HERE. WE COULD MAKE AN AMAZING BOAT.
I THOUGHT *I* WAS CAPTAIN!
YOU ARE, BUT I FIGURED YOU WERE JUST GOING TO ASK ME WHAT TO DO ANYWAY.
YOU KNOW ME WELL. CARRY ON.


WE'LL BREAK INTO TEAMS. KAS AND DEBBIE, YOU BUILD THE LIGHTEST BOAT YOU CAN. WE ONLY NEED TO CARRY RUBY.
BUT YOU'RE STRONGER, YOU'D ROW ACROSS FASTER.
THE SWIMMING PRINCESSES ARE STRONGER THAN ME. WE NEED TO WIN WITH BRAINS, NOT BRAWN. WE CAN DO THIS.


ISN'T THIS JUST AN ENERGY PROBLEM?
THE BOAT NEEDS KINETIC ENERGY FROM SOME-WHERE.
HOW DO WE GET POTENTIAL ENERGY TO TRANSFER TO THE BOAT?
WHA...
I PAY ATTENTION SOME-TIMES. PARTICULARLY WHEN THE GENERAL HITS HIMSELF IN THE FACE WITH A TENNIS BALL.
I WISH WE COULD JUST MAKE A SAIL AND BLOW THE BOAT ACROSS.
THERE DOESN'T SEEM TO BE A LOT OF STUFF IN HERE THAT WOULD MAKE A GOOD OAR.
WIND WOULD WORK A LOT BETTER.
IF ONLY WE HAD A HYPER POWERED FAN.
THAT'S NOT A TERRIBLE IDEA. WE CAN MAKE A WIND MACHINE WITH WHAT WE HAVE HERE.
KAS, CAN YOU MAKE A SAIL OUT OF THE WINDOW SHADE?
I'M ON IT!
RUBY, CAN YOU HELP DEBBIE MAKE THE BOAT?
LIGHT, FAST, AND YOU-SIZE.
I'LL GET STARTED ON THE WIND MACHINE.
KAS, WHERE'S THAT BOWLING BALL?


MIC CHECK'S GOOD, BOSS.
WE'RE ROLLING.
ALRIGHT, HOLD TIGHT TILL YOU GET THE OK.
I HOPE THIS THING HOLDS TOGETHER. I DO NOT LIKE CHLORINE.
PARTY ON, DUDES! AIR GUITARS RULE! WE READY TO SPIN, GORDY?
I STILL DON'T UNDERSTAND WHY YOU HAD TWO HAND MIRRORS IN YOUR BACKPACK. I DON'T EVEN HAVE ONE!
THAT'S OBVIOUS.
I NEED A WAY TO CHECK THE BACK OF MY HAIR.
I BET YOU'RE HAPPY I HAVE THEM NOW, THOUGH.
I'LL JUST BE HAPPY WHEN IT'S OVER.


YOU DOING OK? WHAT DID YOU GUYS PUT TOGETHER? IT LOOKS COMPLICATED.
GORDY DID IT. I THINK IT WILL BE GREAT. I WAS REALLY IMPRESSED.
THE BOAT COULD USE SOME PAINT, BUT WE WORKED WITH WHAT WE HAD.
GOOD LUCK. I HOPE YOU WIN.


WELL DONE, TEAMS!
YOU FIGURED IT OUT AND ARE READY TO ROCK.
FIRST ONE TO THE OTHER SIDE WINS, BUT YOUR CLUE IS OVER THERE.
NO MATTER WHAT, YOU AND YOUR BOAT HAVE TO GET ACROSS.
AIR GUITARS, I HAVE NO IDEA WHAT YOU DID, BUT I HOPE, FOR YOUR SAKE, IT WORKS.
ON MY COUNT.
3... 2... 1... *ROW!*

TEACHER'S GUIDE

ACTIVITY 3: STRAW ROCKETS

Introduction

In the first activity we looked at potential energy changing into kinetic energy and back again through a pendulum. The real goal of that activity, though, was to talk about how energy was transferred from one pendulum to the other. This activity explores the idea of potential and kinetic energy in more depth. It's based on a fun demo (that can go horribly wrong if you're General Relativity) but adds in some straws to make sure kids can take some actual data. Have fun "blasting off" with these bouncy ball straw rockets!

Key Question

How does the bounce height of a ball change with the height from which it is dropped?

Materials

Bouncy Ball
Straw
Wire

* meter stick
* scissors
* large sheet of paper
* pen or pencil
* tape

* *not included in the PhysicsQuest kit*

Key Terms

Kinetic Energy: Kinetic energy is energy of motion. It depends on an object's mass and velocity.

Potential Energy: Potential energy is energy of position. It depends on the height above ground, the pull of gravity, and the mass.

Energy Conservation: In a closed system—meaning one where nothing is being added or subtracted—energy is conserved. This means all the energy that the system started with, it will end with.

TEACHER'S GUIDE

Before the activity, students should know…

- Energy comes in different forms.
- Energy is never created nor destroyed.

After the activity, students should be able to…

- Describe what's happening to the energy in a bouncy ball and straw system.
- Determine how initial potential energy affects kinetic energy and the potential energy of a system.

The Science behind Bouncy Rockets

As I explained earlier, this activity looks at the interplay between kinetic and potential energy. However, it puts in a bit of a twist by looking at a system with two parts: a bouncy ball and a straw that will pop off when dropped. Both have potential energy at the start. That potential is transferred to kinetic energy as they drop and then back to potential energy on the rebound. The fact that the system has two parts leads to some interesting dynamics.

When the ball and straw system is held above the ground, it has potential energy. Potential energy depends on the height above the ground, the pull of gravity, and the mass of the object. Though both the straw and the ball are at the same height above the ground and feel the same pull of gravity, their potential energy is different. As they start falling, that potential energy is transferred into kinetic energy.

Both the straw and the ball fall at the same rate because they are both being pulled by gravity in the same way. The ball shields the straw from the air resistance that would otherwise slow it down. Kinetic energy depends on the mass and the square of the velocity. Since the mass stays the same and energy doesn't go away, as the ball and straw fall, they speed up and gain exactly as much kinetic energy as they lost in potential energy. When they hit the ground they are going at their maximum possible speed. The higher the height from which they dropped, the faster they will be going at the end of their fall.

There are some interesting physics going on when the ball hits. It's not important to the activity but interesting nonetheless, so I'll talk about it briefly. When the bouncy ball hits the ground, it squishes a little bit. The rubber acts like a bunch of tiny little springs. When it's compressed, the rubber stores the energy as potential energy in a spring. Just like when you compress a spring and then let it go, that potential energy is turned back into kinetic.

TEACHER'S GUIDE

When they hit the ground, the straw and ball are going at the same speed but they aren't in contact. The ball hits the ground and bounces. As it bounces, it hits the straw which is still sort of on its way down. At this point, some of the kinetic energy from the bouncy ball is transferred to the straw during the collision.

The straw has significantly less mass than the bouncy ball. Since kinetic energy depends on mass and velocity, and since the straw's mass is lower, the straw gains a whole lot of velocity and shoots into the air. As it goes, its kinetic energy is slowly changed back into potential energy. Since it has the potential energy it started with when it was first dropped and the kinetic energy that was added to it from the ball, it has even more energy than when it started. This means it will end up going higher than the initial position from which it was dropped. (Fig. 1)

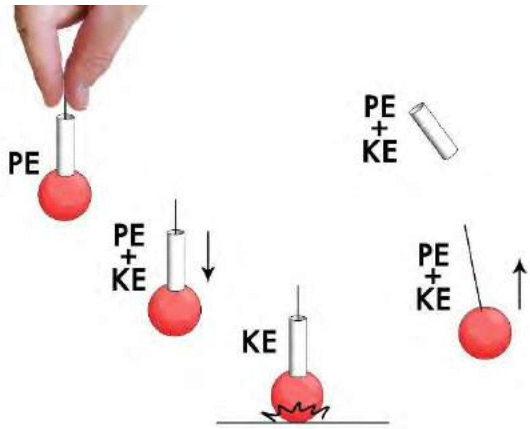


Figure 1

In the first activity, I talked a bit about how some energy is lost to friction in the form of heat. In this activity, students will be asked to discuss what types of energy are involved in this system. They will probably say that when the ball hits the ground, some energy is lost to heat. There are few other places that energy is lost in the system. There is a large amount of air resistance, so some energy is lost to that. Without air resistance the straw would fly much higher.

Energy is also lost to sound when the ball bounces. That bouncing noise you hear takes energy to create. Students will be asked to talk about all the energy in the system and where it goes so it is important not to forget these "hidden" losses of energy.

Suggested Resources

A different explanation of what's happening as well as another look at straw rockets:
www.TeacherSource.com/downloads/lesson_pdf/RKT-625.pdf

Great article on the double ball bounce and what it can be used for:
https://io9.gizmodo.com/using-balls-to-simulate-a-supernova-456130240

Another explanation of how this same principle is used to help spaceships:
http://sciphile.org/lessons/stacked-ball-drop-lessons-conservation-energy-and-momentum

STUDENT GUIDE

ACTIVITY 3: STRAW ROCKETS

Introduction

Bouncy balls are awesome. If you drop them, they come most of the way back. If you throw them down really hard, they can bounce all the way up to the ceiling. They can do this because of the fact that energy is conserved. That means the amount on energy in a system will stay the same—it just might come in different forms. This activity is going to involve bouncy balls and shooting straws to demonstrate different types of energy.

Materials

Bouncy Ball
Straw
Wire

* meter stick
* scissors
* large sheet of paper
* pen or pencil
* tape

* *not included in the PhysicsQuest kit*

Key Question

How does the bounce height of a ball change with the height from which it is dropped?

Getting Started

1. How many different types of energy can you name?

2. What are some examples of when you see these types of energy?

3. Can you talk about when you've seen one type of energy change into other?

4. What is "potential energy?"

5. What is "kinetic energy?"

6. When you hold a bouncy ball up before dropping it, what kind of energy does it have? What about if you throw it down really hard? Is there a difference?

7. Why might a bouncy ball not go as high after you drop it if energy is supposed to be conserved?

Setting Up the Experiment

1. Jam the wire in the bouncy ball so that it's sticking straight up. This seems like it should be really hard to do but I promise, it is not.
2. Place the straw over the wire (like a sleeve) and cut the straw so it is a bit shorter than the wire sticking out of the ball.
3. There should be enough of the wire above the straw that you can hold onto the wire without touching the straw.
4. Tape a giant piece of paper to the bottom of the wall. (Fig. 1).

Collecting Data

Qualitative:

1. Place the straw over the wire. Then hold the bouncy ball by the tip of the wire, without touching the straw, a few feet above the ground.
2. Drop the ball, making sure that it hits the ground with the straw at the top and as perpendicular to the floor as possible. Don't slam the ball down—just let it drop out of your hand. *Make sure the floor is hard (wood, tile, stone, etc.), not carpeted.*
3. What happened?
4. Now drop the ball in the same way, only from a lower height.
5. What happened?
6. Drop the ball from a higher height than you did initially.
7. How do the height of the drop and the height of the rebounding rocket compare?

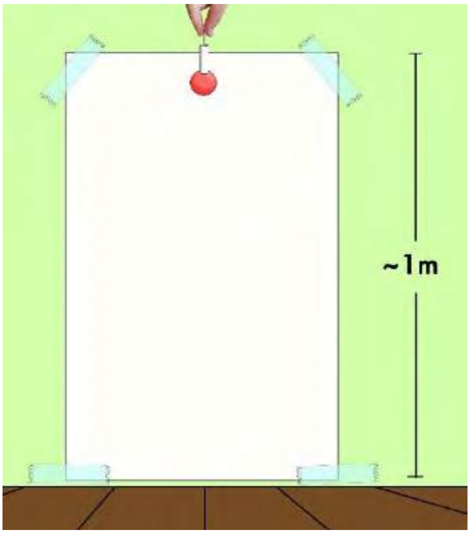


Figure 1

STUDENT GUIDE

Quantitative:

1. Hold a meter stick next to the piece of paper taped on the wall. *Make sure the floor is hard (wood, tile, stone, etc.), not carpeted.*

2. Hold the ball/straw combo just as you did in the qualitative experiment. Start with the combo 15 cm above the floor.

3. Drop the ball and have another team member make a mark at the highest point of the straw's trajectory as it flies upward.

4. Repeat five more times and average the five trials. Be aware that some of your tests might not work, but that's okay.

5. Increase the height to 20 cm and repeat steps 1-4.

6. Continue in 5 cm increments until you can no longer reach the top of the straw's trajectory to measure it.

Analyzing Your Results

1. Qualitatively, how did the height of the straw's flight compare to the height at which it started?

2. What type of energy do the ball and straw have right before they drop? What about when they hit the ground? When they rebound? At the top of the straw's trajectory?

3. On the next page, graph the height the straw reached (in cm) versus the height from which it was dropped (in cm).

4. What does the graph look like? How high do you think the straw might go if the ball was dropped from 5 m?

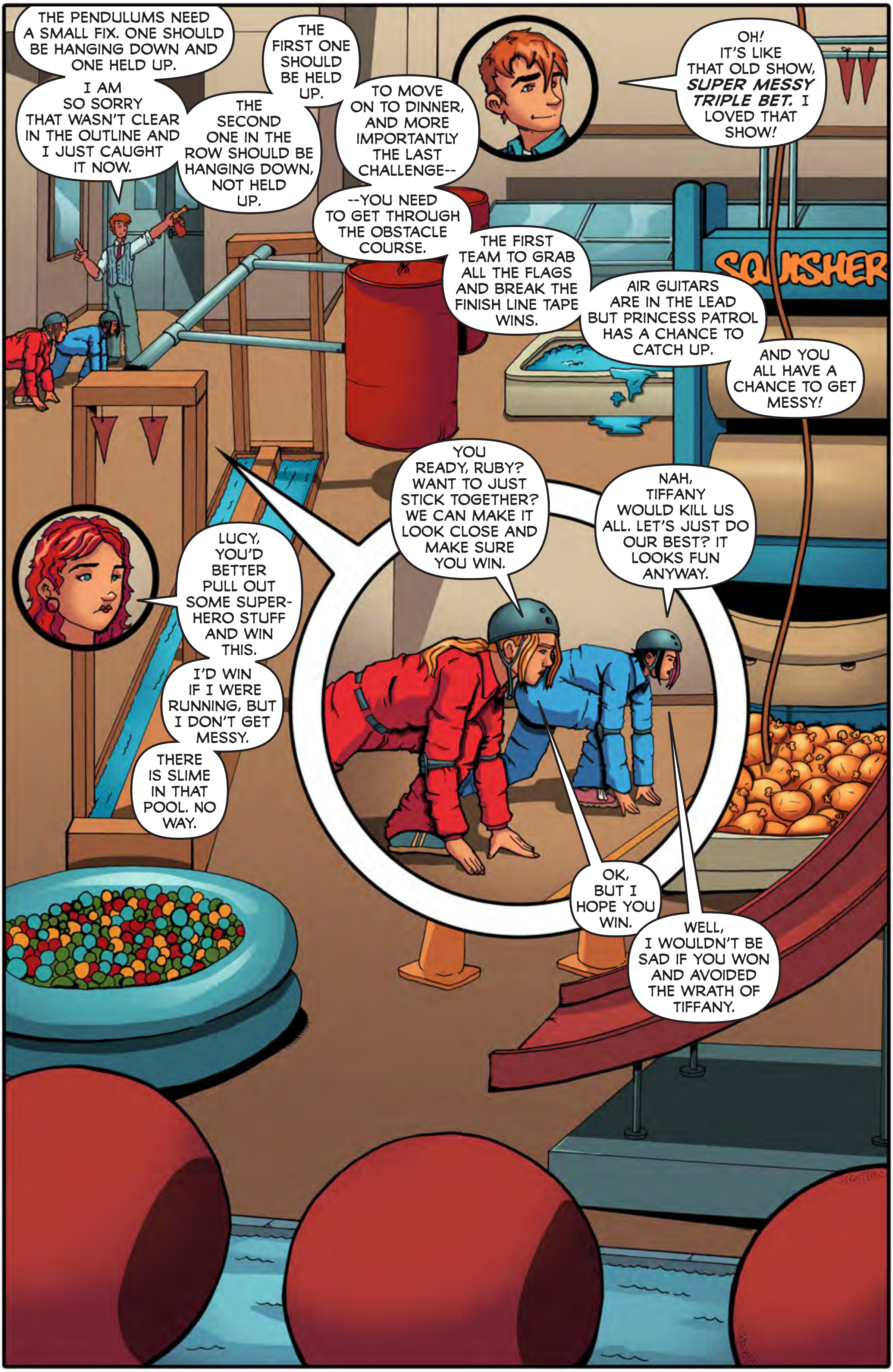
5. Why do you think the straw could go as high as it did? Why do you think it could go higher than it started?

6. What happened to the ball? Did it go higher than its starting point?

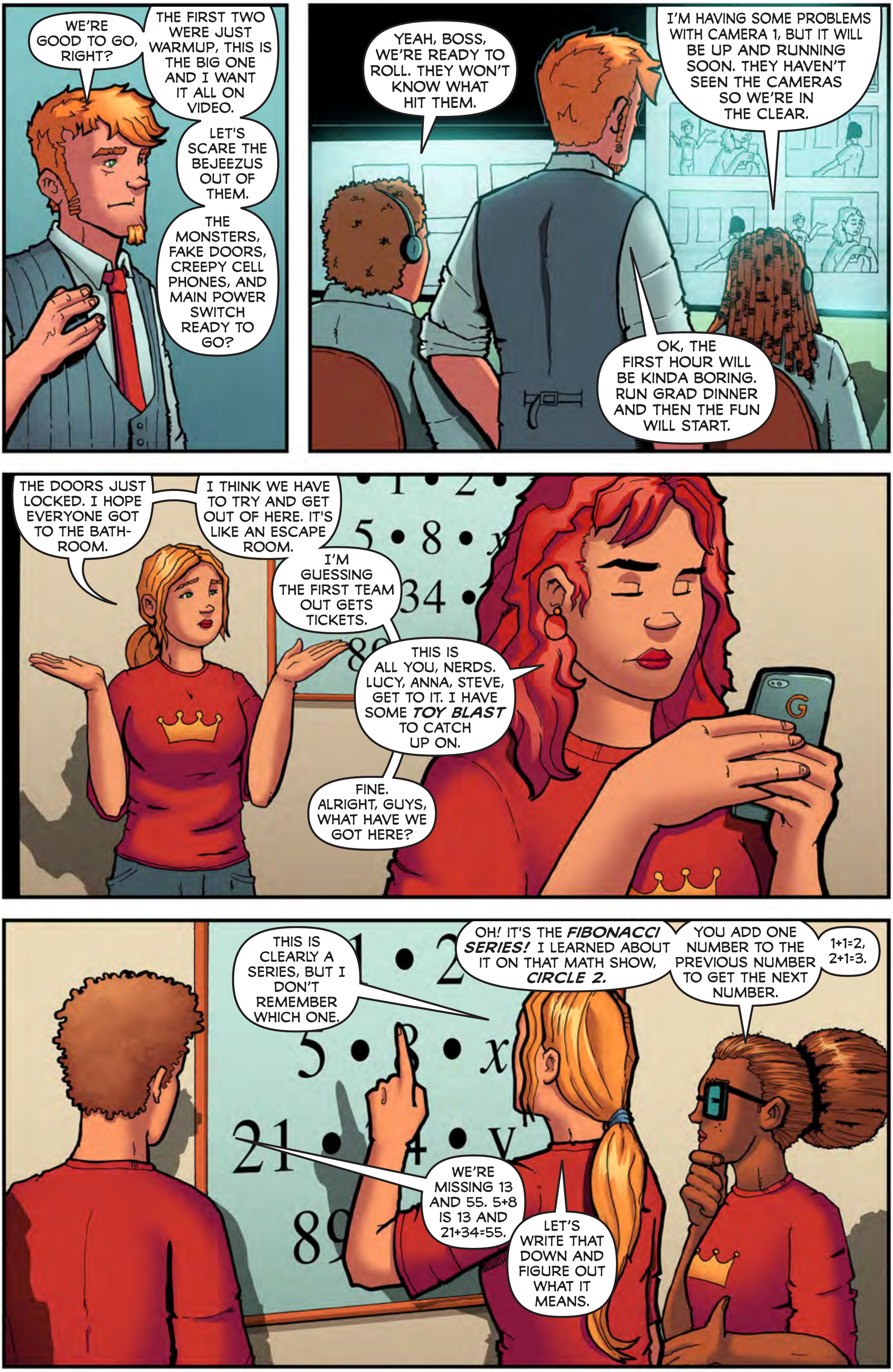
7. What do you think might make the straw go higher?

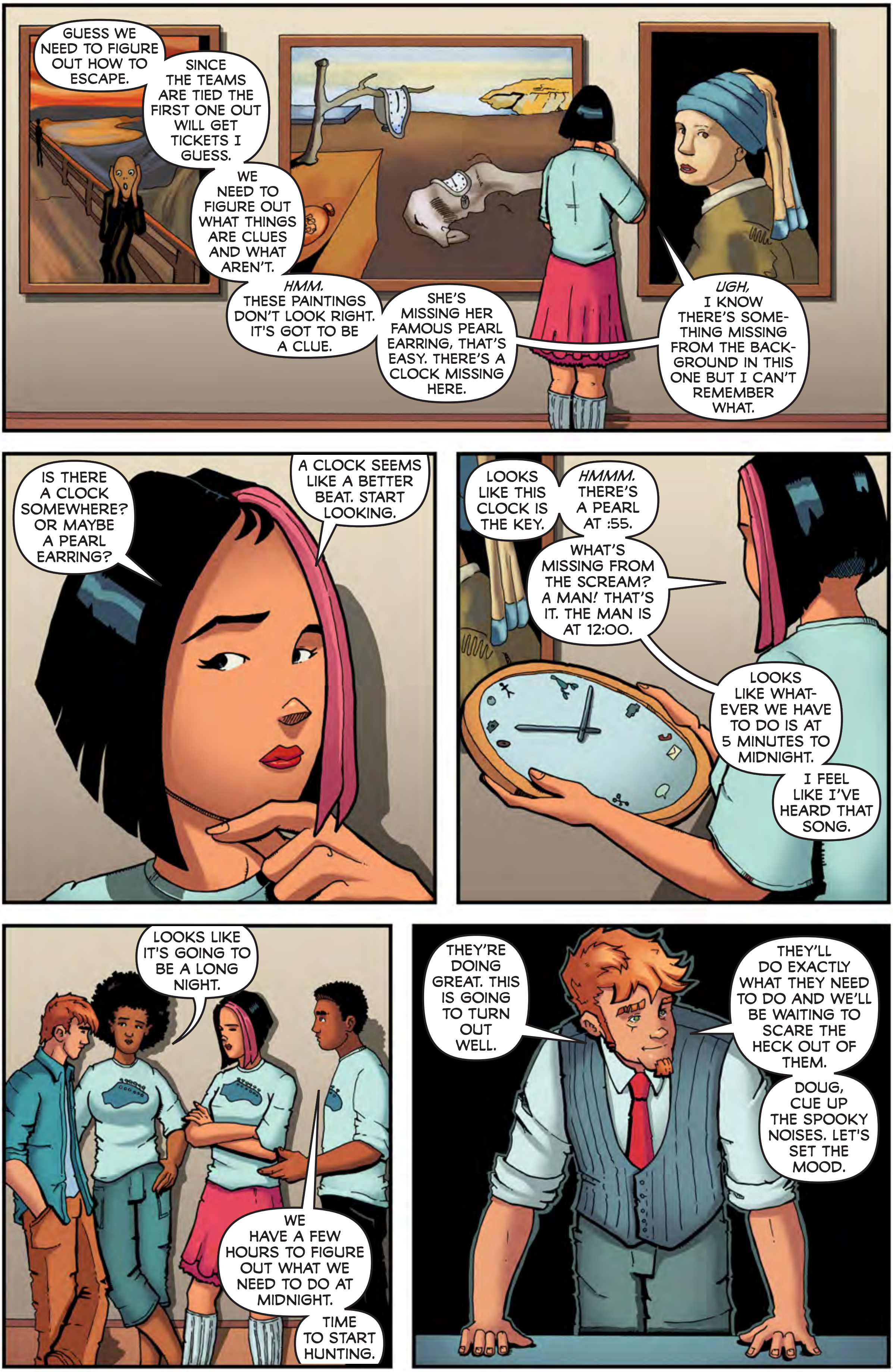

ROW FASTER! NO WONDER I ALWAYS BEAT YOU IN THE POOL. *FASTER!*
I'M DOING THE BEST I CAN. YOU AREN'T HELPING. IF YOU DON'T PAY ATTENTION TO WHAT YOU'RE DOING, YOU'RE GOING TO...
OUCH!
SMACK!
GET OFF ME YOU, YOU'RE GOING TO...
AHHH! YOU PULLED ME IN!!!
SPLASH
HOW DID YOU MANAGE TO SCREW THIS UP? WE JUST HAD TO ROW!
YOU HIT ME FIRST.
AND IF YOU HADN'T GRABBED ME I COULD HAVE WON.
JUST GET ACROSS. YOU'VE MADE IT CLEAR YOU KNOW HOW TO SWIM.
I CAN'T WAIT TILL THIS IS OVER.

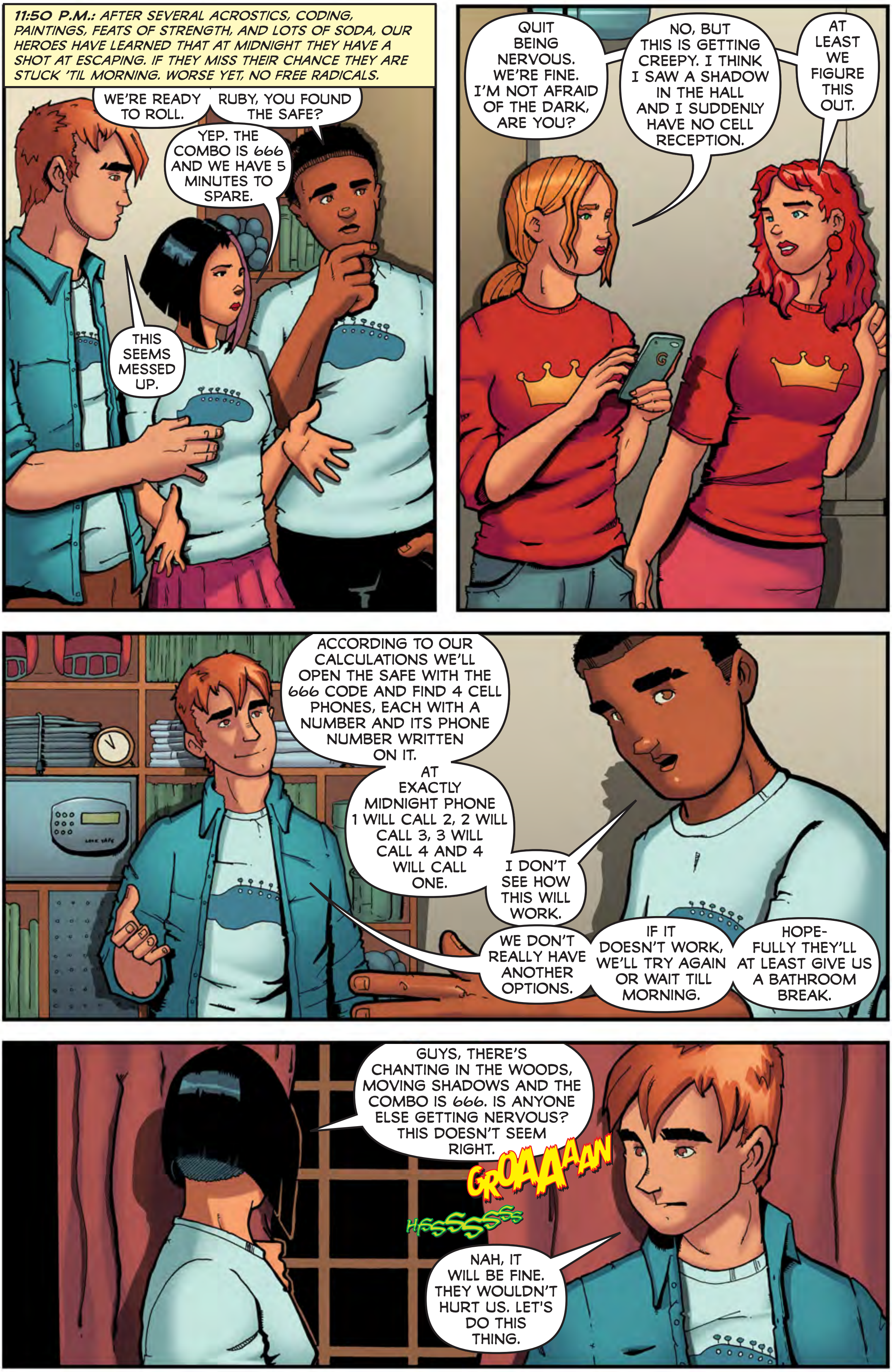

HOLD ON, RUBY, HERE WE GO!
IT'S WORKING.
THE POTENTIAL OF THE BRICK GIVES THE PROPELLER KINETIC ENERGY, AND RUBY THE LEAD, THROUGH WIND.
GO PHYSICS!!
WHEEEEEE! IT WORKS!
GORDY, YOU ARE A GENIUS!
WIND IT UP AGAIN! HURRY, THEY'RE GAINING.
ONE MORE DROP SHOULD DO IT.
OH, WAIT, NO NEED TO RUSH.
TIFFANY JUST PUSHED LUCY IN THE WATER.
AS LONG AS THIS WORKS WE'LL WIN!
HERE WE GO! I DON'T WANT TO WIN BY DEFAULT, I WANT TO REALLY WIN. READY, SET, DROP!
CONGRATULATIONS, TEAM AIR GUITARS!
YOU MADE IT AND YOU AREN'T EVEN WET. WELL DONE.
I'VE NEVER SEEN ANYTHING LIKE THAT.
WE LOOK FORWARD TO SEEING WHAT YOU'LL DO IN...
...THE NEXT CHALLENGE!
YOU'D BETTER NOT SCREW THE NEXT ONE UP, TOO.
GOOD JOB, GUYS! YOU ROCKED IT!


THE PENDULUMS NEED A SMALL FIX. ONE SHOULD BE HANGING DOWN AND ONE HELD UP.
I AM SO SORRY THAT WASN'T CLEAR IN THE OUTLINE AND I JUST CAUGHT IT NOW.
THE FIRST ONE SHOULD BE HELD UP.
THE SECOND ONE IN THE ROW SHOULD BE HANGING DOWN, NOT HELD UP.
TO MOVE ON TO DINNER, AND MORE IMPORTANTLY THE LAST CHALLENGE--
--YOU NEED TO GET THROUGH THE OBSTACLE COURSE.
OH! IT'S LIKE THAT OLD SHOW, *SUPER MESSY TRIPLE BET.* I LOVED THAT SHOW!
THE FIRST TEAM TO GRAB ALL THE FLAGS AND BREAK THE FINISH LINE TAPE WINS.
SQUISHER
AIR GUITARS ARE IN THE LEAD BUT PRINCESS PATROL HAS A CHANCE TO CATCH UP.
AND YOU ALL HAVE A CHANCE TO GET MESSY!
LUCY, YOU'D BETTER PULL OUT SOME SUPER-HERO STUFF AND WIN THIS.
I'D WIN IF I WERE RUNNING, BUT I DON'T GET MESSY.
THERE IS SLIME IN THAT POOL. NO WAY.
YOU READY, RUBY? WANT TO JUST STICK TOGETHER? WE CAN MAKE IT LOOK CLOSE AND MAKE SURE YOU WIN.
NAH, TIFFANY WOULD KILL US ALL. LET'S JUST DO OUR BEST? IT LOOKS FUN ANYWAY.
OK, BUT I HOPE YOU WIN.
WELL, I WOULDN'T BE SAD IF YOU WON AND AVOIDED THE WRATH OF TIFFANY.


IT'S A TRICK.
THE SECOND PENDULUM WILL START MOVING ANY MINUTE.
COUPLED PENDULUMS ARE NUTS.
WHOOOOOOOOOSH!!
OH NO! RUBY!! ARE YOU OK?
UFFF. I KNEW BETTER.
OH GOOD, RUBY'S CATCHING UP. TIFFANY REALLY WILL KILL ME IF I DON'T PULL OFF THE WIN.
AT LEAST THE GENERAL TAUGHT US ABOUT BOUNCING BALLS AND ENERGY.
THAT WAS A MEMORABLE LESSON FOR SURE.
AHHHHHH!!!! ALMOST THERE!
WOOHOO! DONE! ONE STEP CLOSER TO FREEDOM AND ONE LESS ANGRY TIFFANY! THANKS, PHYSICS!
FINISH


WE'RE GOOD TO GO, RIGHT?
THE FIRST TWO WERE JUST WARMUP, THIS IS THE BIG ONE AND I WANT IT ALL ON VIDEO.
LET'S SCARE THE BEJEEZUS OUT OF THEM.
THE MONSTERS, FAKE DOORS, CREEPY CELL PHONES, AND MAIN POWER SWITCH READY TO GO?
YEAH, BOSS, WE'RE READY TO ROLL. THEY WON'T KNOW WHAT HIT THEM.
I'M HAVING SOME PROBLEMS WITH CAMERA 1, BUT IT WILL BE UP AND RUNNING SOON. THEY HAVEN'T SEEN THE CAMERAS SO WE'RE IN THE CLEAR.
OK, THE FIRST HOUR WILL BE KINDA BORING. RUN GRAD DINNER AND THEN THE FUN WILL START.
THE DOORS JUST LOCKED. I HOPE EVERYONE GOT TO THE BATH-ROOM.
I THINK WE HAVE TO TRY AND GET OUT OF HERE. IT'S LIKE AN ESCAPE ROOM.
I'M GUESSING THE FIRST TEAM OUT GETS TICKETS.
THIS IS ALL YOU, NERDS. LUCY, ANNA, STEVE, GET TO IT. I HAVE SOME *TOY BLAST* TO CATCH UP ON.
FINE. ALRIGHT, GUYS, WHAT HAVE WE GOT HERE?
THIS IS CLEARLY A SERIES, BUT I DON'T REMEMBER WHICH ONE.
OH! IT'S THE ***FIBONACCI SERIES!*** I LEARNED ABOUT IT ON THAT MATH SHOW, ***CIRCLE 2.***
YOU ADD ONE NUMBER TO THE PREVIOUS NUMBER TO GET THE NEXT NUMBER.
1+1=2, 2+1=3.
WE'RE MISSING 13 AND 55. 5+8 IS 13 AND 21+34=55.
LET'S WRITE THAT DOWN AND FIGURE OUT WHAT IT MEANS.


GUESS WE NEED TO FIGURE OUT HOW TO ESCAPE.
SINCE THE TEAMS ARE TIED THE FIRST ONE OUT WILL GET TICKETS I GUESS.
WE NEED TO FIGURE OUT WHAT THINGS ARE CLUES AND WHAT AREN'T.
HMM. THESE PAINTINGS DON'T LOOK RIGHT. IT'S GOT TO BE A CLUE.
SHE'S MISSING HER FAMOUS PEARL EARRING, THAT'S EASY. THERE'S A CLOCK MISSING HERE.
UGH, I KNOW THERE'S SOME-THING MISSING FROM THE BACK-GROUND IN THIS ONE BUT I CAN'T REMEMBER WHAT.
IS THERE A CLOCK SOMEWHERE? OR MAYBE A PEARL EARRING?
A CLOCK SEEMS LIKE A BETTER BEAT. START LOOKING.
LOOKS LIKE THIS CLOCK IS THE KEY.
HMMM. THERE'S A PEARL AT :55.
WHAT'S MISSING FROM THE SCREAM? A MAN! THAT'S IT. THE MAN IS AT 12:00.
LOOKS LIKE WHAT-EVER WE HAVE TO DO IS AT 5 MINUTES TO MIDNIGHT.
I FEEL LIKE I'VE HEARD THAT SONG.
LOOKS LIKE IT'S GOING TO BE A LONG NIGHT.
WE HAVE A FEW HOURS TO FIGURE OUT WHAT WE NEED TO DO AT MIDNIGHT.
TIME TO START HUNTING.
THEY'RE DOING GREAT. THIS IS GOING TO TURN OUT WELL.
THEY'LL DO EXACTLY WHAT THEY NEED TO DO AND WE'LL BE WAITING TO SCARE THE HECK OUT OF THEM.
DOUG, CUE UP THE SPOOKY NOISES. LET'S SET THE MOOD.


11:50 P.M.: AFTER SEVERAL ACROSTICS, CODING, PAINTINGS, FEATS OF STRENGTH, AND LOTS OF SODA, OUR HEROES HAVE LEARNED THAT AT MIDNIGHT THEY HAVE A SHOT AT ESCAPING. IF THEY MISS THEIR CHANCE THEY ARE STUCK 'TIL MORNING. WORSE YET, NO FREE RADICALS.
WE'RE READY TO ROLL.
RUBY, YOU FOUND THE SAFE?
YEP. THE COMBO IS 666 AND WE HAVE 5 MINUTES TO SPARE.
THIS SEEMS MESSED UP.
QUIT BEING NERVOUS. WE'RE FINE. I'M NOT AFRAID OF THE DARK, ARE YOU?
NO, BUT THIS IS GETTING CREEPY. I THINK I SAW A SHADOW IN THE HALL AND I SUDDENLY HAVE NO CELL RECEPTION.
AT LEAST WE FIGURE THIS OUT.
ACCORDING TO OUR CALCULATIONS WE'LL OPEN THE SAFE WITH THE 666 CODE AND FIND 4 CELL PHONES, EACH WITH A NUMBER AND ITS PHONE NUMBER WRITTEN ON IT.
AT EXACTLY MIDNIGHT PHONE 1 WILL CALL 2, 2 WILL CALL 3, 3 WILL CALL 4 AND 4 WILL CALL ONE.
I DON'T SEE HOW THIS WILL WORK.
WE DON'T REALLY HAVE ANOTHER OPTIONS.
IF IT DOESN'T WORK, WE'LL TRY AGAIN OR WAIT TILL MORNING.
HOPE-FULLY THEY'LL AT LEAST GIVE US A BATHROOM BREAK.
GUYS, THERE'S CHANTING IN THE WOODS, MOVING SHADOWS AND THE COMBO IS 666. IS ANYONE ELSE GETTING NERVOUS? THIS DOESN'T SEEM RIGHT.
GROAAAAAN
HSSSSSSSS
NAH, IT WILL BE FINE. THEY WOULDN'T HURT US. LET'S DO THIS THING.

TEACHER'S GUIDE

ACTIVITY 4: PINWHEEL POWER

Introduction

Like most of what you've played with so far, this experiment looks at transferring energy from one type of energy to another. In this case, we will turn potential energy into kinetic energy and then into a different type of kinetic energy. Students will use a "handcopter" as a pinwheel to push a tiny piece of paper. The pinwheel will be turned by a weight on a string. It's a neat little experiment using common materials in different ways with a lot of changing from potential to kinetic energy.

Key Question

How does the initial potential energy of a weight affect the final potential energy of a piece of paper?

Key Terms

Inverse Relationship: When one quantity decreases as the other increases, it's an inverse relationship.

Air Resistance: When air runs into an object, it slows it down. The object's energy is lost to the air molecules via transfer of kinetic energy and friction.

Materials

Handcopter
Yo-yo string
4 nuts
Binder clips

- * ruler
- * scissors
- * tape
- * several books

* *not included in the PhysicsQuest kit*

TEACHER'S GUIDE

Before the activity, students should know…

- Potential energy is energy of position.
- Kinetic energy is energy of motion.
- Energy can be transformed from one type to another, but is never created nor destroyed.

After the activity, students should be able to…

- Discuss how energy can be changed from potential to kinetic and back again in a very complicated system.

The Science behind Pinwheel Energy

As far as physics concepts go, there isn't a great deal of new physics in this activity. If you haven't had a chance to do the other activities, it would be worth skimming through the teacher's sections to review the basics of energy. I won't spend time rehashing that here.

This activity is neat and instructive because of the way potential energy is transformed into kinetic. In most cases, when we talk about potential energy changing to kinetic energy, we're talking about the thing that started with potential energy losing potential and gaining kinetic. In this activity the potential energy of the weight will be changed to kinetic energy of its motion but also kinetic energy of the pinwheel's motion.

This is a lot like a water wheel where the kinetic energy of water is changed to the kinetic energy of a wheel and is then used for other useful work.

This activity starts with a weight tied to the pinwheel by a string. As the weight is let go, the unwinding string turns the pinwheel, giving it kinetic energy. The kinetic energy of the pinwheel gives the air molecules kinetic energy and then are blown forward, creating a breeze. The breeze moves a tiny piece of paper, giving it kinetic energy as well.

Eventually the paper stops moving due to air resistance. At that point, the energy has been lost to the friction of the air molecules rubbing against the piece of paper. It's a straightforward, interesting and fun system.

There are a few pitfalls students might run into when doing this experiment. Both come from the fact they are being asked to measure the distance from the top of the shaft of the pinwheel to the weight.

TEACHER'S GUIDE

The longer this distance, the LESS potential energy the system is starting with. Potential energy depends on the height about the floor. When the string is longer at the beginning, the lower the weight, and the less potential energy.

This means that in the graph, the shorter the distance, the farther the paper will move across the book. This will give a graph with a negative slope—an inverse relationship—which will be different from what's expected by your students.

If you think this will be confusing for your students, it is easy to change the directions so that they are measuring the starting height above the floor.

The instructions are written the way they are for two reasons. First, it is much easier to measure a string than the height above the floor. Second, it will make your students think very hard about what they are measuring and what it means. It will be the opposite of what they might expect and they will have to reason through why. Again, it's an easy fix if you want to do it in the more straightforward way.

Suggested Resources

Information about water wheels and energy transfer:
https://wonderopolis.org/wonder/what-is-a-waterwheel

Physics of ceiling fans. In this activity, a weight is used instead of an electric current:
www.butterflyfields.com/resources/how-does-a-ceiling-fan-work/

STUDENT GUIDE

ACTIVITY 4: PINWHEEL POWER

Introduction

So far, you've seen potential energy change to kinetic energy and back again in a few different systems. Mostly you've been dropping things and watching what happens: either they swing like in a pendulum, or they bounce like with the bouncy ball. In this activity you'll take it a step further and potential energy will change to kinetic and then add kinetic energy to yet something else.

Materials

Handcopter
Yo-yo string
4 nuts
Binder clips

* ruler
* scissors
* tape
* several books

** not included in the PhysicsQuest kit*

Key Question

How does the initial potential energy of a weight affect the final potential energy of a piece of paper?

Getting Started

1. What happens when you are standing in front of a fan? What are the types of energy involved?

____
____
____
____
____

2. When a weight drops, what type of energy is involved?

____
____
____
____
____

3. In a water wheel, what types of energy are involved?

____
____
____
____
____

4. What are different ways you might figure out to turn a pinwheel or a fan blade?

____
____
____
____
____

STUDENT GUIDE

Setting Up the Experiment

1. Tie the nuts to one end of the yo-yo string.
2. Tape the other end of the yo-yo string to the middle of the shaft on the handcopter.
3. Put two books on their ends on two tables with a space between the tables.
4. Tape a binder clip to the spine of each book.
5. Lay the handcopter on its side across the books so that the string and nuts hang down between the tables and books and the shaft of the copter is through the binder clips. (Fig. 1).

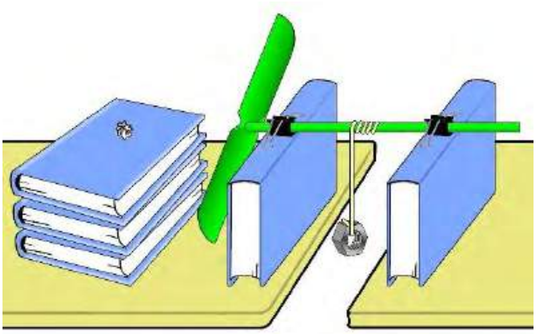


Figure 1

6. Stack books until the stack is slightly lower than the copter blade. When the copter blade turns, it should blow across the top of the stack of books.
7. Wind up the yo-yo string and let it drop. The copter blade should spin and blow across the top of the stack of books. The blade or shaft might stick or wobble funny and you might have to hold it lightly. Adjust things until you are able to make the blade turn by dropping the weight.
8. Take a piece of tissue paper and fold it into a tiny "v" so it will stand on the top of the books.
9. Wind the weight up and drop it. The blade should gently blow the piece of paper.

Collecting Data

Qualitative:

1. Wind the weight all the way to the top of the shaft and drop it. How far did the piece of paper move?
2. Bring the piece of paper back to its starting point. Wind the weight up so it's about halfway to the top and let it drop. How far did the paper move? How did that compare to the initial paper movement?
3. Now wind the weight up only a small amount and move the paper back to its starting point. Drop the weight. How far did the paper move? How did that compare to the first two times?

STUDENT GUIDE

Quantitative:

1. Move the piece of paper back to the starting point and mark where it starts.
2. Wind the weight all the way up to the top of the shaft.
3. Drop the weight and watch the paper move.
4. Record how far it moved. Do this four more times and take the average.
5. Below, make a chart with string length in one column and paper movement distance in the other. Record the average in the chart.
6. Wind the weight up so there is 5 cm of string between the shaft and the weight.

String Length (in cm)	Paper Movement Distance (in cm)

7. Repeat steps 1-5 at the new distance and then again for 5 cm intervals until the string is at its full length. Record how far the paper moves each time.

Analyzing Your Results

1. On the next page, make a graph of length of string when the weight started (in cm) vs the distance the paper moved (in cm). What does your graph look like?

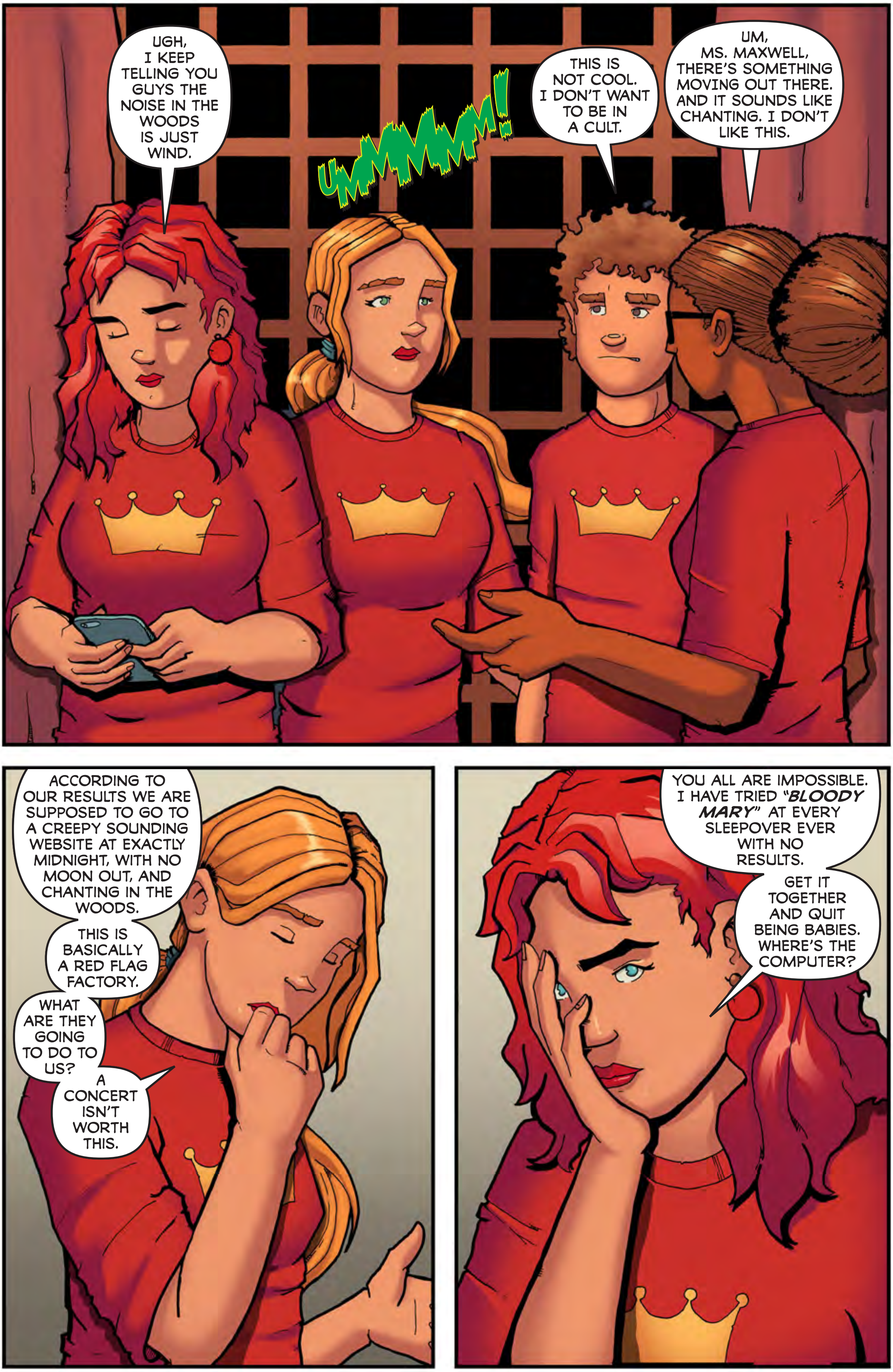
2. How does the potential energy with a longer starting string compare to the potential energy of a shorter starting string? Remember, potential energy depends on the height of the weight off the ground, not the length of the string.

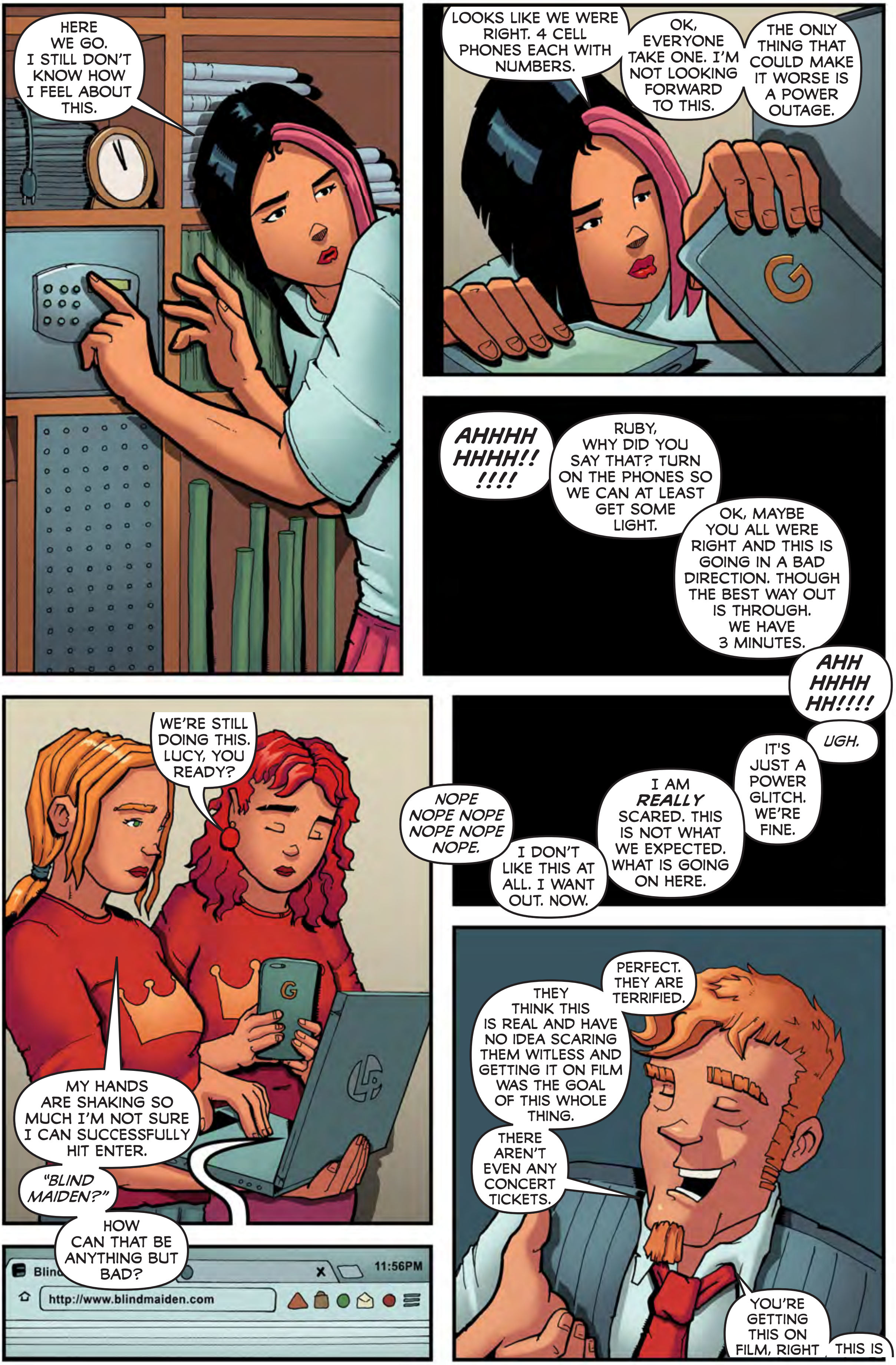
3. How does the distance the paper moved compare to the length of the string? The height off the ground?

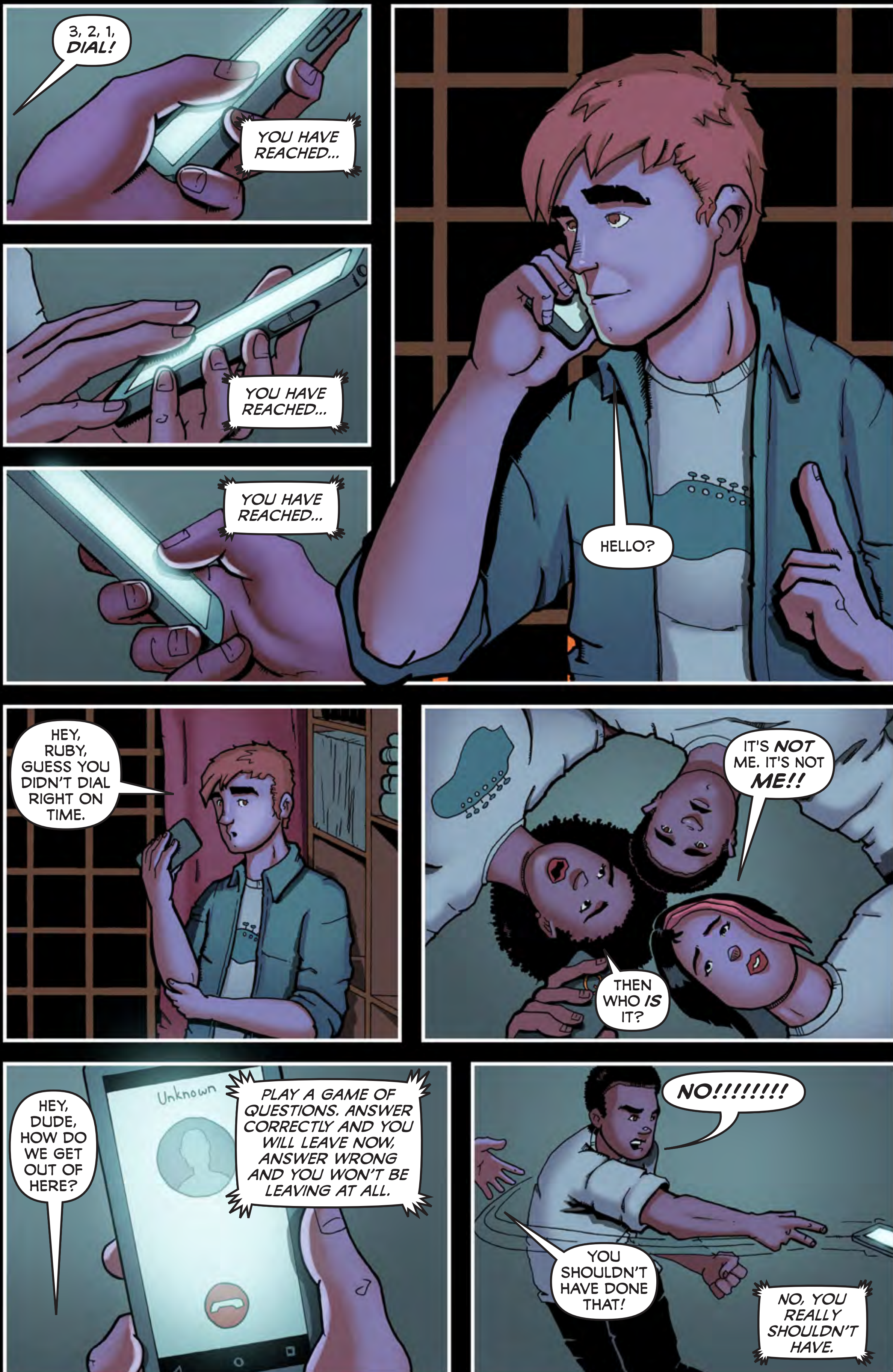
STUDENT GUIDE

4. What can you say about the potential and kinetic energy of each piece of the system from start to finish?

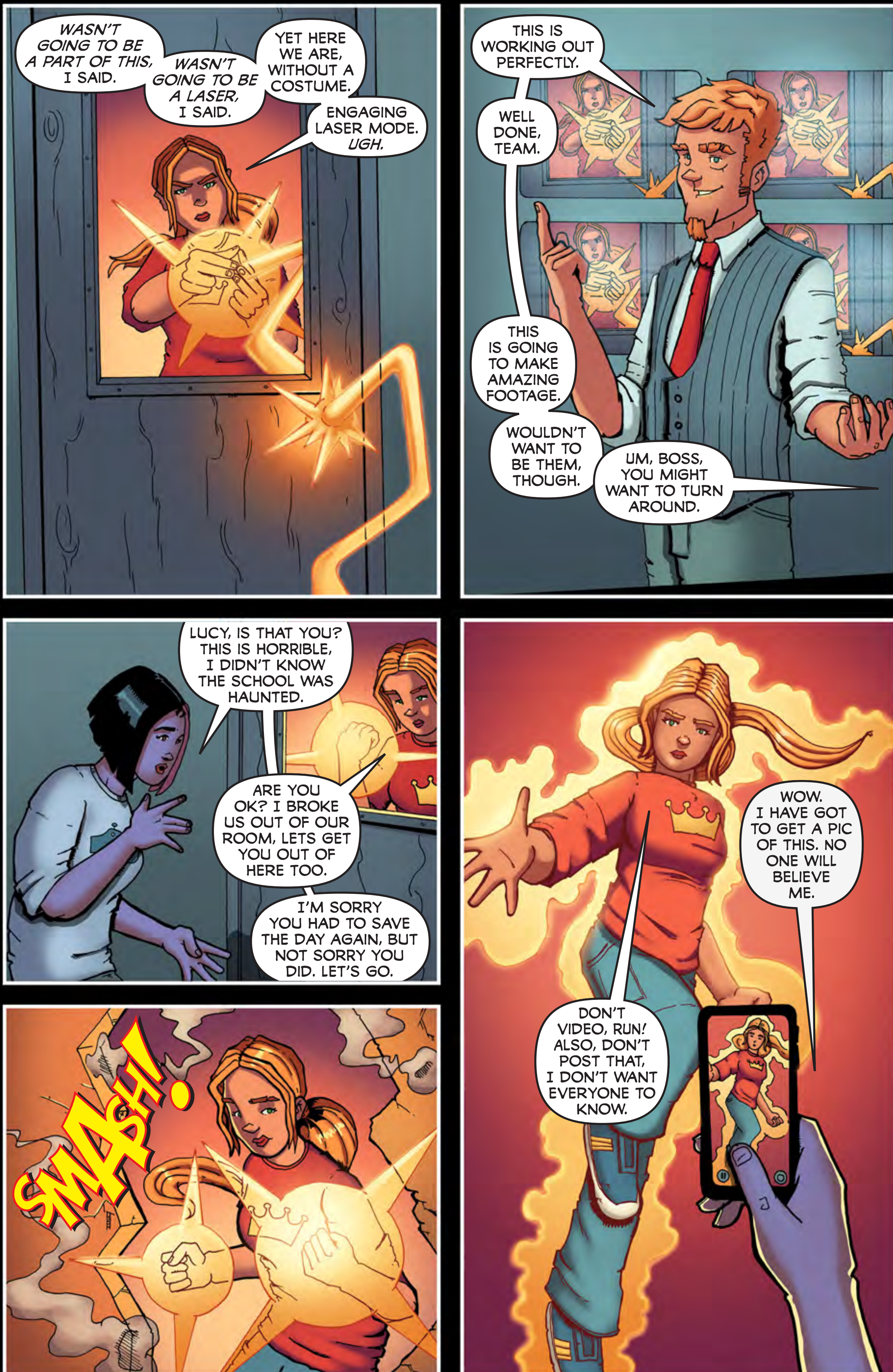
5. Where did the energy go when the paper stopped?

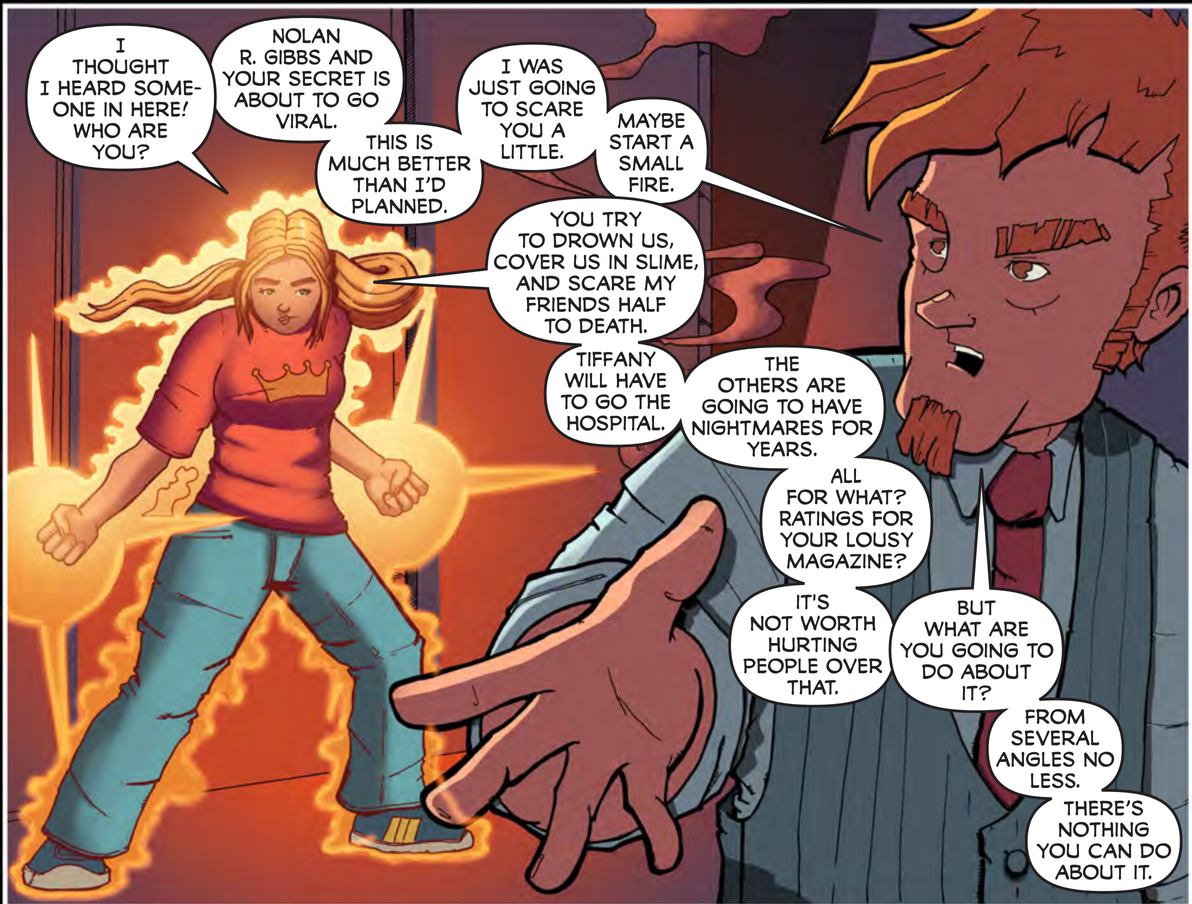

UGH, I KEEP TELLING YOU GUYS THE NOISE IN THE WOODS IS JUST WIND.
UMMMMM!
THIS IS NOT COOL. I DON'T WANT TO BE IN A CULT.
UM, MS. MAXWELL, THERE'S SOMETHING MOVING OUT THERE. AND IT SOUNDS LIKE CHANTING. I DON'T LIKE THIS.
ACCORDING TO OUR RESULTS WE ARE SUPPOSED TO GO TO A CREEPY SOUNDING WEBSITE AT EXACTLY MIDNIGHT, WITH NO MOON OUT, AND CHANTING IN THE WOODS.
THIS IS BASICALLY A RED FLAG FACTORY.
WHAT ARE THEY GOING TO DO TO US?
A CONCERT ISN'T WORTH THIS.
YOU ALL ARE IMPOSSIBLE. I HAVE TRIED "*BLOODY MARY*" AT EVERY SLEEPOVER EVER WITH NO RESULTS.
GET IT TOGETHER AND QUIT BEING BABIES. WHERE'S THE COMPUTER?

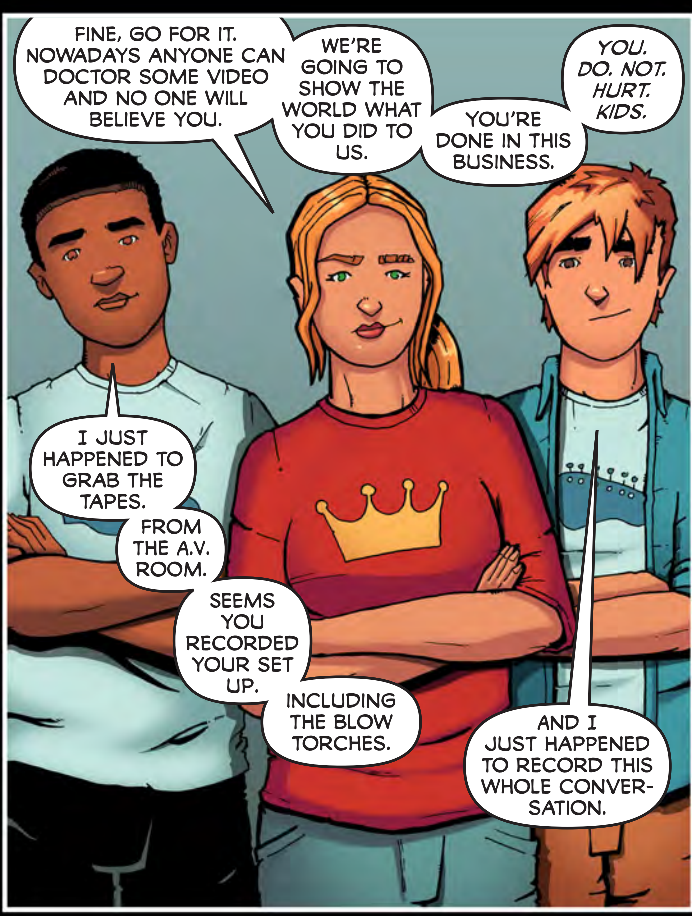

HERE WE GO. I STILL DON'T KNOW HOW I FEEL ABOUT THIS.
LOOKS LIKE WE WERE RIGHT. 4 CELL PHONES EACH WITH NUMBERS.
OK, EVERYONE TAKE ONE. I'M NOT LOOKING FORWARD TO THIS.
THE ONLY THING THAT COULD MAKE IT WORSE IS A POWER OUTAGE.
AHHHH HHHH!! !!!!
RUBY, WHY DID YOU SAY THAT? TURN ON THE PHONES SO WE CAN AT LEAST GET SOME LIGHT.
OK, MAYBE YOU ALL WERE RIGHT AND THIS IS GOING IN A BAD DIRECTION. THOUGH THE BEST WAY OUT IS THROUGH. WE HAVE 3 MINUTES.
WE'RE STILL DOING THIS. LUCY, YOU READY?
MY HANDS ARE SHAKING SO MUCH I'M NOT SURE I CAN SUCCESSFULLY HIT ENTER.
"BLIND MAIDEN?"
HOW CAN THAT BE ANYTHING BUT BAD?
Blin
11:56PM
http://www.blindmaiden.com
AHH HHHH HH!!!!
UGH.
IT'S JUST A POWER GLITCH. WE'RE FINE.
I AM REALLY SCARED. THIS IS NOT WHAT WE EXPECTED. WHAT IS GOING ON HERE.
NOPE NOPE NOPE NOPE NOPE NOPE.
I DON'T LIKE THIS AT ALL. I WANT OUT. NOW.
PERFECT. THEY ARE TERRIFIED.
THEY THINK THIS IS REAL AND HAVE NO IDEA SCARING THEM WITLESS AND GETTING IT ON FILM WAS THE GOAL OF THIS WHOLE THING.
THERE AREN'T EVEN ANY CONCERT TICKETS.
YOU'RE GETTING THIS ON FILM, RIGHT
THIS IS


3, 2, 1, DIAL!
YOU HAVE REACHED...
YOU HAVE REACHED...
YOU HAVE REACHED...
HELLO?
HEY, RUBY, GUESS YOU DIDN'T DIAL RIGHT ON TIME.
IT'S NOT ME. IT'S NOT ME!!
THEN WHO IS IT?
Unknown
HEY, DUDE, HOW DO WE GET OUT OF HERE?
PLAY A GAME OF QUESTIONS. ANSWER CORRECTLY AND YOU WILL LEAVE NOW, ANSWER WRONG AND YOU WON'T BE LEAVING AT ALL.
NO!!!!!!!!
YOU SHOULDN'T HAVE DONE THAT!
NO, YOU REALLY SHOULDN'T HAVE.

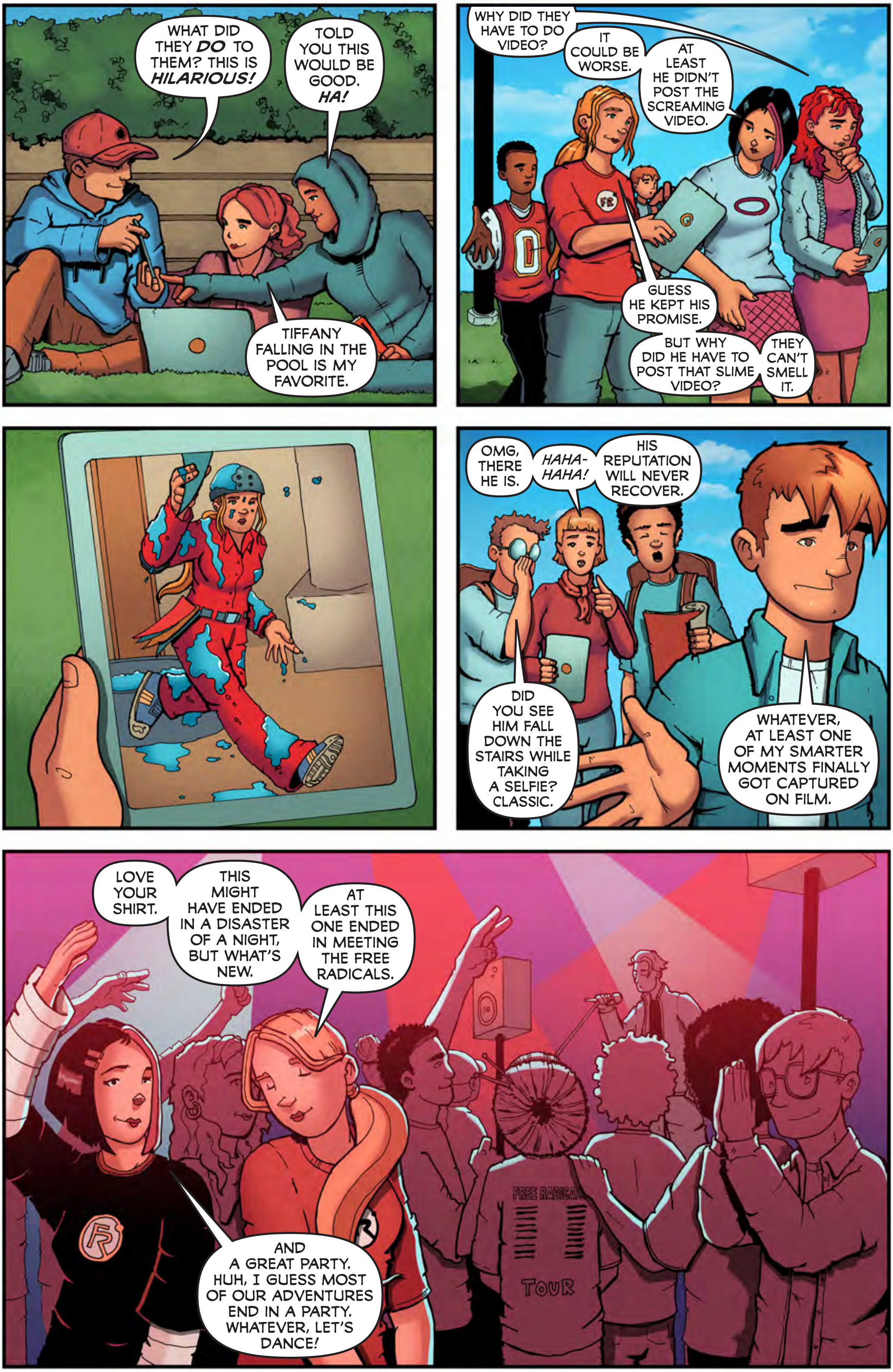

3...
2...1...
GO!
AHHHH!
NOT OK!
THAT'S US. THAT'S US! WHAT IS THIS?
NO
NO
NO!
HE'S HERE!
HE'S BEHIND US!
PANT, GASP, HUFF...
LET ME OUT LET ME OUT LET ME OUT!
I... CAN'T... BREATHE... ASTHMA... CAN'T... BREATHE...
OH NO, WE HAVE TO GET HELP! WHAT IS THIS MESS? WHAT'S EVEN HAPPENING?
STAND BACK. I CAN DO THIS.
STEVE, ANNA, YOU'RE ABOUT TO SEE SOMETHING WEIRD.
PLEASE DON'T TELL ANYONE, 'K?
I WOULDN'T DO THIS IF I DIDN'T HAVE TO.


WASN'T GOING TO BE A PART OF THIS, I SAID.
WASN'T GOING TO BE A LASER, I SAID.
YET HERE WE ARE, WITHOUT A COSTUME.
ENGAGING LASER MODE. UGH.
THIS IS WORKING OUT PERFECTLY.
WELL DONE, TEAM.
THIS IS GOING TO MAKE AMAZING FOOTAGE.
WOULDN'T WANT TO BE THEM, THOUGH.
UM, BOSS, YOU MIGHT WANT TO TURN AROUND.
LUCY, IS THAT YOU? THIS IS HORRIBLE, I DIDN'T KNOW THE SCHOOL WAS HAUNTED.
ARE YOU OK? I BROKE US OUT OF OUR ROOM, LETS GET YOU OUT OF HERE TOO.
I'M SORRY YOU HAD TO SAVE THE DAY AGAIN, BUT NOT SORRY YOU DID. LET'S GO.
SMASH!
WOW. I HAVE GOT TO GET A PIC OF THIS. NO ONE WILL BELIEVE ME.
DON'T VIDEO, RUN! ALSO, DON'T POST THAT, I DON'T WANT EVERYONE TO KNOW.


I THOUGHT I HEARD SOME-ONE IN HERE! WHO ARE YOU?
NOLAN R. GIBBS AND YOUR SECRET IS ABOUT TO GO VIRAL.
THIS IS MUCH BETTER THAN I'D PLANNED.
I WAS JUST GOING TO SCARE YOU A LITTLE.
MAYBE START A SMALL FIRE.
YOU TRY TO DROWN US, COVER US IN SLIME, AND SCARE MY FRIENDS HALF TO DEATH.
TIFFANY WILL HAVE TO GO THE HOSPITAL.
THE OTHERS ARE GOING TO HAVE NIGHTMARES FOR YEARS.
ALL FOR WHAT? RATINGS FOR YOUR LOUSY MAGAZINE?
IT'S NOT WORTH HURTING PEOPLE OVER THAT.
BUT WHAT ARE YOU GOING TO DO ABOUT IT?
FROM SEVERAL ANGLES NO LESS.
THERE'S NOTHING YOU CAN DO ABOUT IT.


FINE, GO FOR IT. NOWADAYS ANYONE CAN DOCTOR SOME VIDEO AND NO ONE WILL BELIEVE YOU.
WE'RE GOING TO SHOW THE WORLD WHAT YOU DID TO US.
YOU'RE DONE IN THIS BUSINESS.
YOU. DO. NOT. HURT. KIDS.
I JUST HAPPENED TO GRAB THE TAPES.
FROM THE A.V. ROOM.
SEEMS YOU RECORDED YOUR SET UP.
INCLUDING THE BLOW TORCHES.
AND I JUST HAPPENED TO RECORD THIS WHOLE CONVER-SATION.


OH, AND WE'LL TAKE 8 BACKSTAGE PASSES TO THE CONCERT, PLEASE. YOU OWE US.
NOLAN R. GIBBS? ***N.R.G.?*** ENERGY? *HEH HEH.* YOUR NAME'S A DAD JOKE.



WHAT DID THEY *DO* TO THEM? THIS IS *HILARIOUS!*
TOLD YOU THIS WOULD BE GOOD. *HA!*
TIFFANY FALLING IN THE POOL IS MY FAVORITE.
WHY DID THEY HAVE TO DO VIDEO?
IT COULD BE WORSE.
AT LEAST HE DIDN'T POST THE SCREAMING VIDEO.
GUESS HE KEPT HIS PROMISE.
BUT WHY DID HE HAVE TO POST THAT SLIME VIDEO?
THEY CAN'T SMELL IT.
OMG, THERE HE IS.
HAHA-HAHA!
HIS REPUTATION WILL NEVER RECOVER.
DID YOU SEE HIM FALL DOWN THE STAIRS WHILE TAKING A SELFIE? CLASSIC.
WHATEVER, AT LEAST ONE OF MY SMARTER MOMENTS FINALLY GOT CAPTURED ON FILM.
LOVE YOUR SHIRT.
THIS MIGHT HAVE ENDED IN A DISASTER OF A NIGHT, BUT WHAT'S NEW.
AT LEAST THIS ONE ENDED IN MEETING THE FREE RADICALS.
AND A GREAT PARTY. HUH, I GUESS MOST OF OUR ADVENTURES END IN A PARTY. WHATEVER, LET'S DANCE!
FREE RADICALS
TOUR

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