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PROUDLY PRESENTS
SPECTRA
SONIC SURPRISE
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Welcome to PhysicsQuest:
Spectra's Current Crisis!

Your Mission

You are about to go on an adventure to learn about sound. Spectra has lost her powers as Kas gains some of his own. Learn about vibrations, sound, pitch, and even watch some lasers dance as you help our heroes save the school's Valentine's Day dance!

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 twelfth kit, ***PhysicsQuest: Spectra's Sonic Surprise***.

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, Spectra faces a new challenge, she losers her powers. But Kas, much to his surprise, gains superpowers of his own. Can Spectra save the school dance even without powers? In this kit you will follow their adventures through sound to find out.

About the American Physical Society (APS)

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

APS also runs PhysicsCentral (**www.physicscentral.com**), a website aimed at communicating the excitement and importance of physics to the general public.

At **www.physicscentral.com**, you can find out about APS educational programs, current physics research, people in physics, and more.

About PhysicsQuest

PhysicsQuest is a set of four activities designed to engage students in scientific inquiry. This year's activities are linked together via a storyline and comic book that follows Spectra, a laser super hero, and her swim team's coach with his unusual and destructive coaching methods. Spectra's super power is her ability to turn into a laser beam. Her powers are all real things that a laser beam does, so in addition to learning via the four activities students will also learn through the comic book.

PhysicsQuest is designed with flexibility in mind -- it can be done in one continuous session or split up over a number of weeks. The activities can be conducted in the classroom or as an extra credit or science club activity. The challenges can be completed in any order, but to get the correct final result, all of the challenges must be completed correctly.

If you would like to join up with other teachers and classes, there is now a Facebook group, PhysicsQuest. It's a great way to talk with other PhysicsQuest groups or learn helpful tips and tricks.

About the PhysicsQuest Competition

If you would like to submit your answers online for a chance at prizes, you may do so before September 30th. We will draw names from those submitting answers for first, second, and third place prizes.

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. Students will complete the activity and in the end they will need their answers to all four activities to help Spectra save the Valentine's Day dance.

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
10 Large Straws
5 Small Straws
Self-Inflating Balloon
2 Plastic Tubes
Mylar Square
Rubber Band
4 Push Pins
Binder Clip
Laser
Rubber Glove

Not included in this kit:

* Ruler
* Scissors
* Paper cups
* Book
* Styrofoam
* Lots of tape
* Smartphone
* Permanent marker

Before the Activity . . .

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

After the Activity . . .

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

The Science Behind . . .

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

Safety

This section highlights potential hazards and safety precautions.

Materials

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

Suggested Resources

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

The Student Guide

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

The Student Guide includes:

Key Question

This question highlights the goal of the activity.

Materials

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

Getting Started

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

The Experiment

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

Analyzing Your Results

This section leads students through data analysis and provides questions for them to answer based on their results.

PhysicsQuest Website and Facebook Group

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

PhysicsQuest Logistics Materials

The PhysicsQuest kit comes with only one set of materials. This means that if your students are working in four small groups (recommended), all groups should work simultaneously on different activities and then rotate activities, unless you provide additional materials.

The Materials List on the PhysicsQuest website includes specific descriptions of the materials and where they can be purchased. All materials can be reused.

Safety

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

Time Required

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

Small Groups

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

Group Work Model

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

Lab Director

Coordinates the group and keeps students on task.

Chief Experimenter

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

Measurement Officer

Monitors data collection and determines the values for each measurement.

Report Writer

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

Equipment Manager

Collects all equipment needed for the experiment. Makes sure -- quipment 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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American Physical Society
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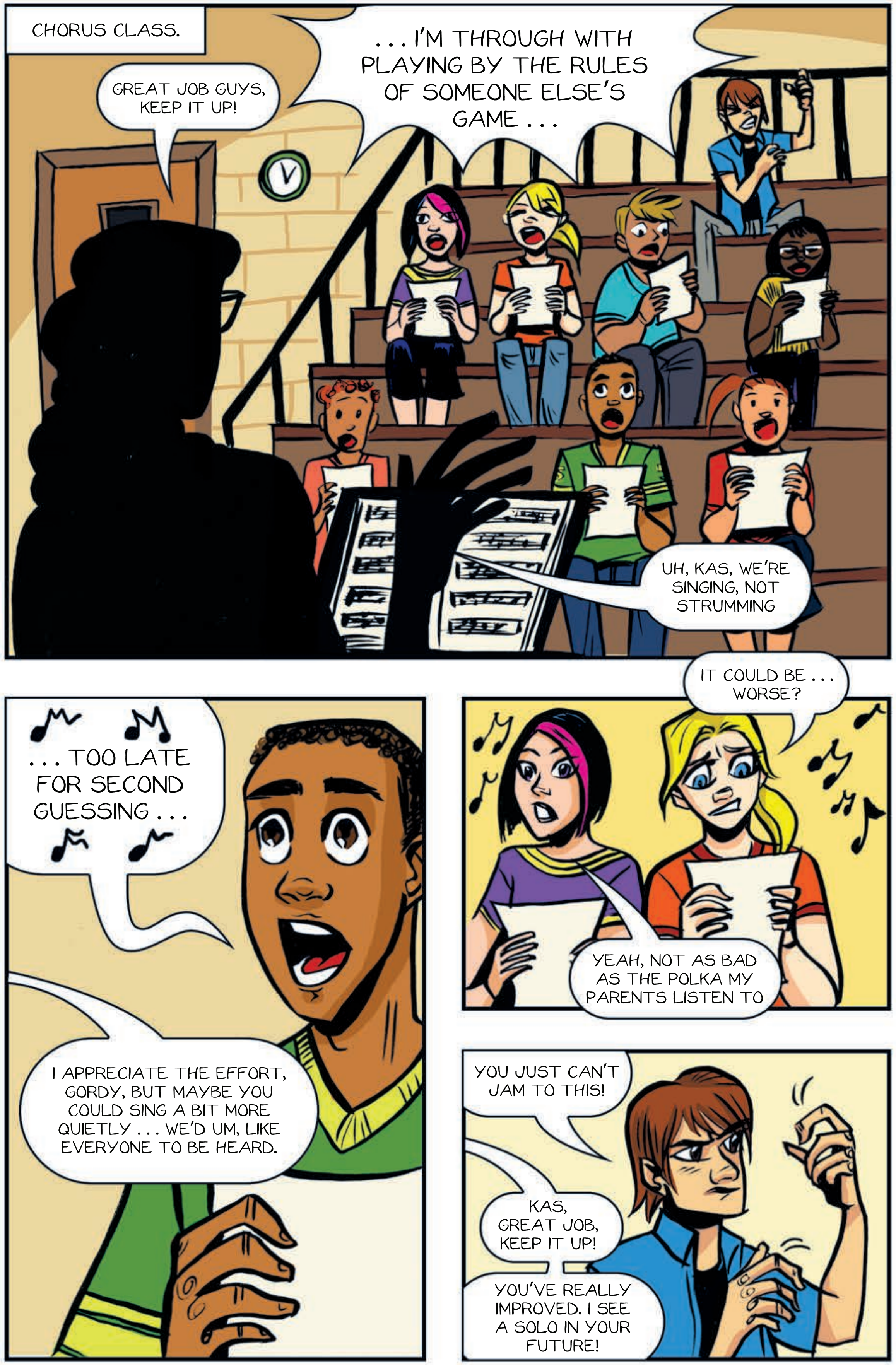
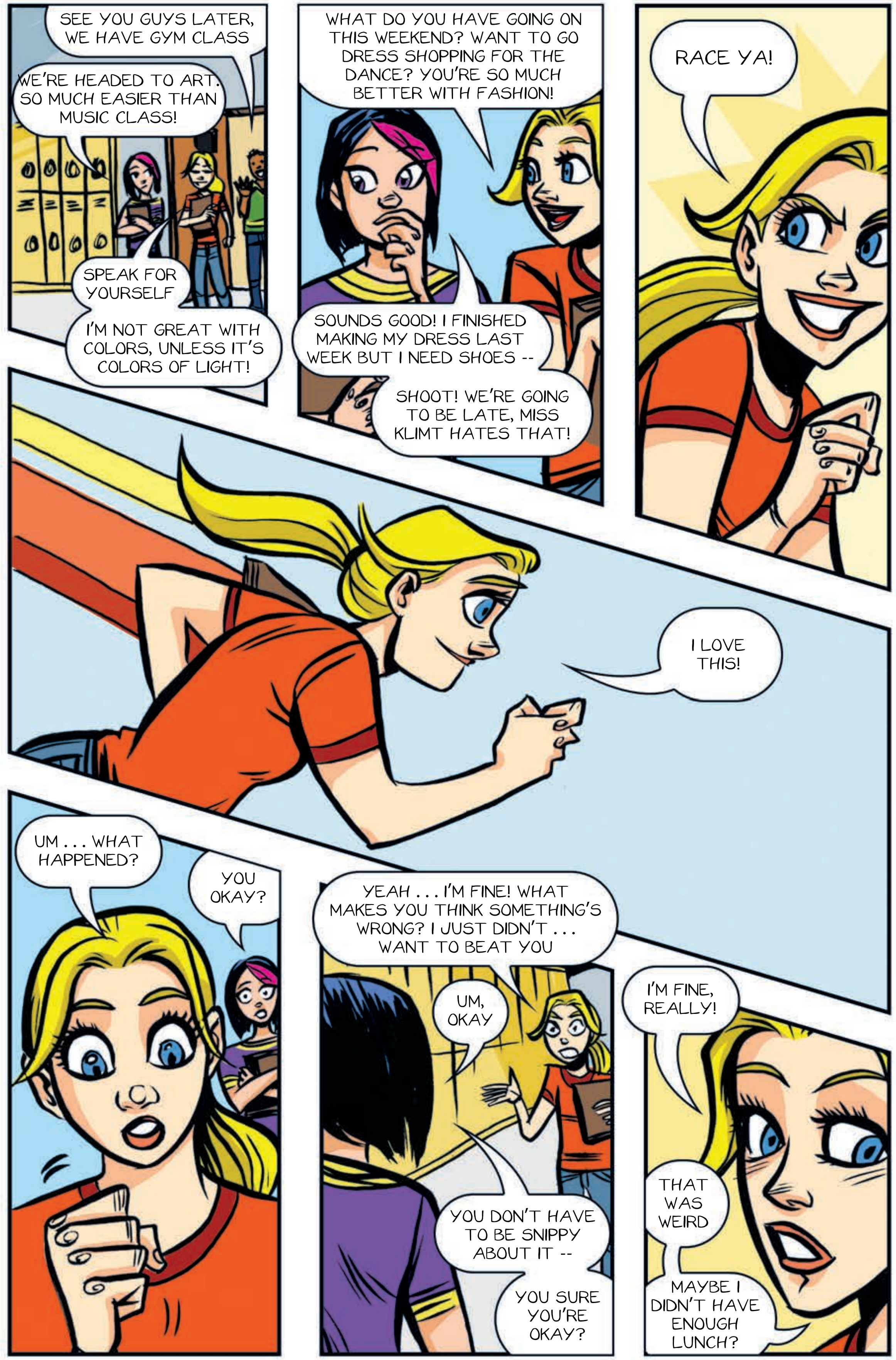

CHORUS CLASS.
GREAT JOB GUYS, KEEP IT UP!
. . . I'M THROUGH WITH PLAYING BY THE RULES OF SOMEONE ELSE'S GAME . . .
UH, KAS, WE'RE SINGING, NOT STRUMMING
. . . TOO LATE FOR SECOND GUESSING . . .
I APPRECIATE THE EFFORT, GORDY, BUT MAYBE YOU COULD SING A BIT MORE QUIETLY . . . WE'D UM, LIKE EVERYONE TO BE HEARD.
IT COULD BE . . . WORSE?
YEAH, NOT AS BAD AS THE POLKA MY PARENTS LISTEN TO
YOU JUST CAN'T JAM TO THIS!
KAS, GREAT JOB, KEEP IT UP!
YOU'VE REALLY IMPROVED. I SEE A SOLO IN YOUR FUTURE!


SEE YOU GUYS LATER, WE HAVE GYM CLASS
WE'RE HEADED TO ART. SO MUCH EASIER THAN MUSIC CLASS!
SPEAK FOR YOURSELF
I'M NOT GREAT WITH COLORS, UNLESS IT'S COLORS OF LIGHT!
WHAT DO YOU HAVE GOING ON THIS WEEKEND? WANT TO GO DRESS SHOPPING FOR THE DANCE? YOU'RE SO MUCH BETTER WITH FASHION!
SOUNDS GOOD! I FINISHED MAKING MY DRESS LAST WEEK BUT I NEED SHOES --
SHOOT! WE'RE GOING TO BE LATE, MISS KLIMT HATES THAT!
RACE YA!
I LOVE THIS!
UM . . . WHAT HAPPENED?
YOU OKAY?
YEAH . . . I'M FINE! WHAT MAKES YOU THINK SOMETHING'S WRONG? I JUST DIDN'T . . . WANT TO BEAT YOU
UM, OKAY
YOU DON'T HAVE TO BE SNIPPY ABOUT IT --
YOU SURE YOU'RE OKAY?
I'M FINE, REALLY!
THAT WAS WEIRD
MAYBE I DIDN'T HAVE ENOUGH LUNCH?


THE PIZZA PI
YOU GUYS READY FOR THE SPRING CHORUS CONCERT?
I'M HAPPY JUST DOING COSTUMES. BUT I THINK I HAVE TO SING, TOO.
HOPEFULLY I CAN JUST PLAY
I'D REALLY LIKE THE SOLO. I'VE BEEN PRACTICING AT HOME AND EVERYTHING -- I THINK I CAN DO IT!
UH . . . YEAH . . . YOU GO FOR IT . . .
YEAH, GO FOR IT! SO ULTRAVIOLET CATASTROPHE IS GONNA TRY AND PLAY THE DANCE
I MEAN, DR. DANIEL HAS SAID NO TO US TWICE, BUT WE'VE BEEN KILLING IT RECENTLY AND I JUST GOTTA GET HER TO LISTEN TO US
I MEAN, I AM SO ON! ONLY PROBLEM IS MY GUITAR IS KINDA MESSED UP --
SOMETIMES THE AMP JUST DOESN'T WORK AND ONE STRING IS STICKY . . . GOTTA GET THAT FIXED FIRST
SPEAKING OF STRINGS -- I'VE HAD THIS ANNOYING STRING HANGING OFF MY JERSEY ALL DAY. ANYONE HAVE SCISSORS? OR I GUESS I COULD GO ASK THE OWNER, MR. BEYER . . .
NO PROBLEM!
LASER POWERS -- FOR SAVING THE WORLD, AMUSING CATS, AND SOLVING A STRING CRISIS!


. . . UM LET ME TRY AGAIN . . .
THIS IS STRANGE, I JUST CAN'T DO IT
SORRY GORDY, LOOKS LIKE I HAVEN'T EATEN ENOUGH -- I JUST DON'T HAVE THE ENERGY. GUESS YOU'LL NEED TO ASK FOR SCISSORS.
COULD YOU ORDER ME SOME MORE PIZZA WHILE YOU'RE UP?
SURE, NO PROBLEM! THANKS FOR TRYING!
YOU SURE EVERYTHING IS OKAY?
THIS IS THE SECOND TIME THIS HAS HAPPENED
YES!
JUST STOP ASKING!
I'M FINE, THANK YOU VERY MUCH!
PIZZA

Introduction

In instruments, the pitch is changed by changing the length of whatever is vibrating. In a piano, it is hitting different length strings with different keys; in a violin, it is changing the length of the string. In a trombone, it is changing the length of the air column by using the slide.

But not all students have the opportunity to play instruments and see this bit of physics in action. In this experiment, students will use straws to create their own slide trombones. It's a fun and loud experiment to show students exactly how changing length can change pitch.

Key Question

How does changing the length of a straw trombone change the pitch?

Materials

Smaller diameter straw
2x larger diameter straw

* Ruler
* Scissors

* *not included in the PhysicsQuest kit*

Key Terms

Wavelength: The distance between corresponding points in two consecutive waves. For example, the distance between two wave peaks.

Longitudinal Wave: A wave where the motion of particles is in the same direction as the motion of the wave. Compression waves, like sound waves, are longitudinal waves.

Resonant Frequency: Frequency at which something will naturally vibrate. In a tube, this frequency is determined by the length of the tube.

Materials

There are enough materials for five straw trombones so each group can make their own. If you'd like to get more materials, it can be tricky to find straws that fit inside other straws. The paper party straws from Target (the ones in fun colors) will fit inside Subway drinking straws very nicely.

TEACHER'S GUIDE
ACTIVITY 1: STRAW TROMBONE

Before the activity, students should know…

- Sound is made from vibration.
- The pitch of a sound is determined by how it vibrates.

After the activity, students should be able to…

- Say how the length of what's making sound effects pitch.
- Talk about how different instruments produce different pitches.

The Science Behind Pitch

At its heart, sound is vibration. Pitch and volume depend on how fast and how large those vibrations are. When something vibrates, it vibrates the air (or water or whatever it's in) around it at the same frequency. The vibrating air vibrates the air next to it and so on all the way till it hits your eardrum, which vibrates and your brain interprets that vibration as sound. The faster the vibration, the higher the pitch, the greater the amplitude, the louder the volume.

But how do musical instruments make different notes?

Sound is a compression wave. This means it's not a wave that goes up and down like a water wave, but a wave of compressions and rarefractions. During the compressions, the vibrating molecules are closer together and during the rarefractions they are farther apart. The movement of the molecules is in the same direction the wave is traveling, meaning it's a **longitudinal wave**.

Water waves and light waves are called **transverse waves** because the motion of the particles is perpendicular to the direction the wave is traveling.

When the students blow on the straws in this activity, they are making the air in the straws vibrate. When they do the activity they'll learn that they have to blow quite hard. When they blow on the little "v" at the top of the tube, they are making the "v" vibrate which causes the air in the tube to vibrate at the same frequency. But when they blow, they aren't making it vibrate at any specific pitch—they are making it vibrate at a lot of different frequencies, meaning a lot of different pitches. They will naturally, without even realizing it, blow in different ways to make the straw vibrate differently until they hear a loud note.

This vibration (note) is called the **resonant frequency** of the tube. When the straw and air vibrate from the student's air, the compression wave travels down the tube.

TEACHER'S GUIDE
ACTIVITY 1: STRAW TROMBONE

When it hits the bottom, it is reflected back and then reflected back again when it hits the top. When reflected back and forth, the waves interact with each other.

When the waves interact, sometimes they interact constructively, meaning they amplify each other, and sometimes they interact destructively, meaning they cancel each other out. When waves are interfering in a tube there are specific frequencies that interact constructively and these are amplified by the constructive interference. These are called the resonant frequencies of the tube.

The longer the tube, the lower the resonant frequencies. *(Fig 1)* The shorter the tube, the higher the frequencies. When the length of the straw trombone is changed, the resonant frequencies of the tube change. Because the air is vibrating at a different frequency, your ear hears a different sound.

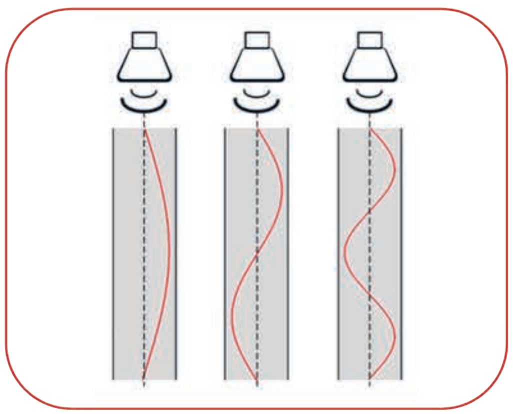


Figure 1

You can use this principle to make instruments out of all sorts of tubes. Try it next time you are drinking a bottle of soda. The less soda you have in the bottle, the longer the column of air and the lower the note. It also works well with PVC pipes of different lengths.

Boomwhackers are also quite fun. You can just bang them on a table to get the air vibrating and hear different notes with different lengths.

The straw trombone is one of the most fun ways to explore this topic -- though you might want to warn the teacher next door that you'll be doing this activity.

Suggested Resources

Physics Toolbox by Vieyra Software

A great sound simulation: *https://phet.colorado.edu/en/simulation/sound*

http://www.physicsclassroom.com/class/sound/Lesson-5/Resonance

STUDENT GUIDE
ACTIVITY 1: STRAW TROMBONE

Introduction

You've probably seen an instrument played, and if you are lucky you've been able to play an instrument yourself. In instruments like the violin or guitar, it's easy to see that changing the length of the string changes the pitch. But is this true for all instruments?

Do this experiment and find out!

Key Question

How does changing the length of a straw trombone change the pitch?

Getting Started

1. Name four or five different instruments you've seen played or have played yourself.

2. In each instrument, what is vibrating?

Materials

Smaller diameter straw
2x larger diameter straw

* Ruler
* Scissors

* *not included in the PhysicsQuest kit*

3. What does the player do to change the pitch? Hit a different key? Put their fingers in different places on the strings? Something else?

4. When the player does that, how does it change what's vibrating?

5. What makes the pitch get higher? What makes it get shorter?

Setting Up the Experiment

1. Take one of the white bendy straws and cut the tip in a "v" with the pointy end at the top.
2. Slide the black straw in the bottom of the bendy straw. It might be a bit hard to fit it in, but with a little help, it should.
3. Slide the second white straw on the bottom of the black straw.
4. You have now made a straw trombone. *(Fig. 1)*

Figure 1

Collecting Data

Qualitative:

1. Take the black straw out of the cut, bendy straw and blow through the cut end. You should hear a buzzing sound. If it doesn't work, keep trying. It's a bit tricky to get to work, but once you do, you'll know.
2. Put the black straw back in the end. Blow on the straw. How did the pitch change?
3. Now add the second white straw to the end of the trombone and blow. How did the pitch change?
4. Move the straw up and down, making the trombone longer and shorter. What makes the pitch higher? What makes it lower?

Quanitative:

1. Start with the straws as far apart as they can go so that your trombone is as long as possible. Measure the length. Blow and listen to the pitch. If you have access to a smartphone you can download pitch-detecting software and measure the pitch directly. I recommend the Physics Toolbox app for this, but use whatever pitch detecting software you'd like. It will give you the frequency of the sound you are making.
2. Now take out the black straw and make your trombone as short as possible without cutting the straw. Listen to the pitch. If possible, use the app to again measure the frequency of the sound you are making.
3. If you are not using a smartphone, rank the highest pitch you hear as a "10" and the lowest pitch you hear as a "1."
4. Put the trombone together again so it is as long as possible. Move the straw up by 1 cm and blow again.

5. Rank the pitch on a scale from 1 to 10 or record the measurement from the app.
6. Repeat step 4 until you can't make the trombone any shorter. Now you will make it shorter by cutting it. Cut 1 cm off the bottom of the top straw and record the pitch.
7. Do this until you can't make any noise. You should have a very short straw.

Analyzing Your Results

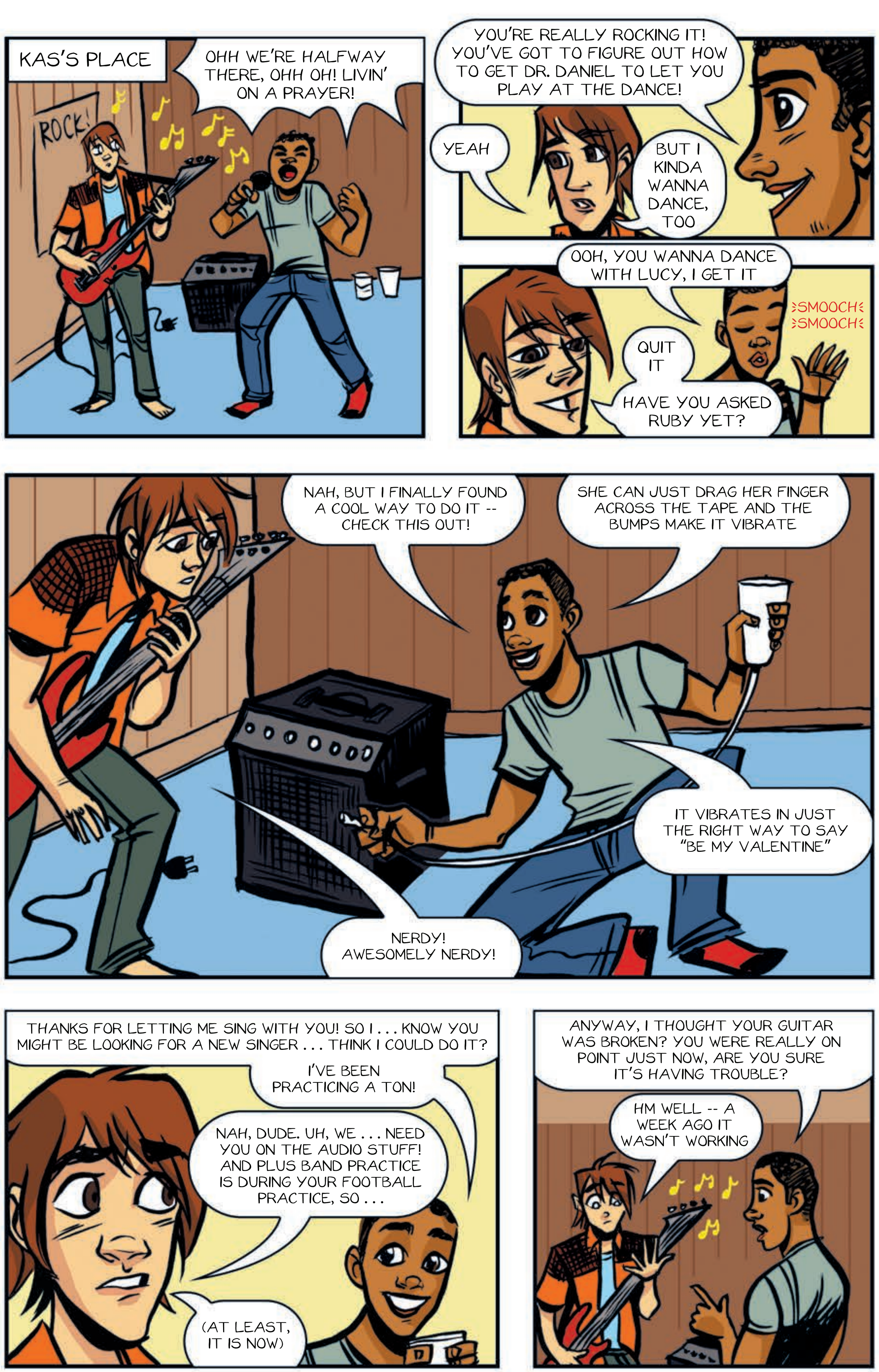
1. Qualitatively, how did the pitch change as the length of the straw changed?
2. Graph the frequency of the sound (pitch) vs the length of the straw.
3. What does the graph look like? Is it a line? A curve?
4. As the length of the straw changes, how does the pitch change?
5. Think back to the instruments you listed in the beginning of this activity. How do you think the pitch changes as the thing that is vibrating changes length?


OKAY, I'VE GOT THIS. YOU CAN'T JUST LOSE SUPERPOWERS OVERNIGHT.
I CAN CUT THIS METAL RULER. I KNOW I CAN.
CONCENTRATE. ARG! NO . . . I CAN'T.
ALRIGHT, I'LL TRY PLAYING A CD. LASERS CAN DO THAT! . . . DRAT!
OKAY FINE, I'LL GET AS LOW POWERED AS I CAN -- CAT TOY LASER, HERE I COME!
CRASH!
OW!
THIS IS NOT GOOD -- WHAT IS HAPPENING TO ME??
RUBY WAS RIGHT
I CAN'T BELIEVE I WAS SO MEAN TO HER, I REALLY NEED HER HELP!
RUBY
dialing...


HEY, I'M REALLY SORRY I WAS RUDE TODAY. I'M JUST SCARED AND DON'T REALLY KNOW WHAT'S GOING ON.
NO BIG DEAL, CHANGES ARE SCARY! HAVE YOU TRIED TO CHANGE INTO A LASER SINCE THE PIZZA?
YES -- NO LUCK! NO CD'S, NO CUTTING METAL, HECK -- I CAN'T EVEN TURN INTO A CAT TOY! I DON'T KNOW WHERE THESE POWERS CAME FROM, I DON'T KNOW WHERE THEY'VE GONE, AND NOW I DON'T KNOW HOW TO GET THEM BACK!
WELL . . . IT'S NOT THE END OF THE WORLD IF YOU'RE JUST NORMAL AGAIN
YES, ACTUALLY IT IS!
WHAT WOULD'VE HAPPENED IF I HADN'T STOPPED MISS ALIGNMENT?
OKAY, GOOD POINT. LET ME THINK ABOUT IT . . .
. . .
. . . I DON'T HAVE ANY SUGGESTIONS. UGH, SORRY!
I HAVE TO FINISH MY PHOTOGRAPHY HOMEWORK. BUT WE'LL HAVE TONS OF TIME TO TALK DURING THE AQUARIUM TRIP TOMORROW!


THE AQUARIUM
DOLPHINS CAN PRODUCE BOTH SOUNDS AND HIGH FREQUENCY SOUNDS FOR ECHOLOCATION.
THIS MEANS THEY CAN PRODUCE A SOUND, WHICH IS A VIBRATION --
-- THAT VIBRATES THE WATER, BOUNCES OFF SOMETHING, AND TELLS THE DOLPHIN WHERE IT IS.
BATS USE IT TOO!
OH COOL!
TO PRODUCE WHISTLES, THEY VIBRATE THEIR LARYNX.
AND TO PRODUCE ECHOLOCATION SOUNDS, THEY VIBRATE AIR SACKS IN THEIR HEADS.
EVERY DOLPHIN HAS A DISTINCT WHISTLE, JUST LIKE HUMANS HAVE DISTINCT VOICES.
≥WHISTLE≤ HERE, DOLPHIN DOLPHIN!
HOW YA DOING?
UH, HI GUYS! DON'T KNOW WHY YOU'RE INTERESTED IN ME, BUT COOL! WHAT'S IT LIKE LIVING IN THERE?
WOW, I'VE NEVER SEEN THEM DO THAT BEFORE! THEY USUALLY ONLY DO THAT WHEN THEY HEAR A DOLPHIN WHISTLE.
LOOKS LIKE WE'VE GOT OUR OWN LITTLE DOLPHIN WHISPERER HERE!
OR MAYBE HE JUST SMELLS LIKE FISH!
HA HA HA HA
OKAY, LET'S MOVE ALONG TO TURTLES --


THAT WAS REALLY STRANGE. IT WAS LIKE THEY UNDERSTOOD YOU!
YEAH, BUT ALL I DID WAS SAY "HELLO"
YOU AREN'T GOING ALL HARRY POTTER AND THE SNAKES ON US, ARE YOU?
I'M LIKE THAT SUPERHERO,
HYDRO-DUDE!
NOT HIM, HE'S THE LAMEST OF THE SUPERHEROES!
THIS IS REALLY WEIRD. DO YOU REMEMBER WHEN STRANGE THINGS STARTED HAPPENING TO ME?
I TURNED INTO A LASER!
SO FAR WE'VE SEEN A QUANTUM MECHANIC AND A WATER-CONTROLLING SWIM COACH IN THIS TOWN!
NO WAY, IT WAS JUST A FLUKE.
GET IT? FLUKE? LIKE THE FISH?
FIRST OFF, THAT'S A TERRIBLE JOKE (AND WORSE WHEN YOU EXPLAIN IT)
SECOND OFF, JUST WATCH OUT FOR MORE WEIRD STUFF HAPPENING. THIS COULD BE BIGGER THAN JUST DOLPHINS!


KAS'S PLACE
OHH WE'RE HALFWAY THERE, OHH OH! LIVIN' ON A PRAYER!
ROCK!
YOU'RE REALLY ROCKING IT! YOU'VE GOT TO FIGURE OUT HOW TO GET DR. DANIEL TO LET YOU PLAY AT THE DANCE!
YEAH
BUT I KINDA WANNA DANCE, TOO
OOH, YOU WANNA DANCE WITH LUCY, I GET IT
SMOOCH
SMOOCH
QUIT IT
HAVE YOU ASKED RUBY YET?
NAH, BUT I FINALLY FOUND A COOL WAY TO DO IT -- CHECK THIS OUT!
SHE CAN JUST DRAG HER FINGER ACROSS THE TAPE AND THE BUMPS MAKE IT VIBRATE
IT VIBRATES IN JUST THE RIGHT WAY TO SAY "BE MY VALENTINE"
NERDY! AWESOMELY NERDY!
THANKS FOR LETTING ME SING WITH YOU! SO I . . . KNOW YOU MIGHT BE LOOKING FOR A NEW SINGER . . . THINK I COULD DO IT?
I'VE BEEN PRACTICING A TON!
NAH, DUDE. UH, WE . . . NEED YOU ON THE AUDIO STUFF! AND PLUS BAND PRACTICE IS DURING YOUR FOOTBALL PRACTICE, SO . . .
(AT LEAST, IT IS NOW)
ANYWAY, I THOUGHT YOUR GUITAR WAS BROKEN? YOU WERE REALLY ON POINT JUST NOW, ARE YOU SURE IT'S HAVING TROUBLE?
HM WELL -- A WEEK AGO IT WASN'T WORKING


ARE YOU EVEN PLAYING?
YEAH I MEAN, I'M THINKING WHAT I SHOULD PLAY, AND IT PLAYS
MAYBE IT FIXED ITSELF!
GUITARS DON'T FIX THEMSELVES
MAYBE IT WAS YOUR AMP THAT WAS BROKEN?
UMMM . . .
OFF!
DUDE, SOMETHING IS UP
FIRST THE DOLPHINS, NOW YOUR AMP ISN'T EVEN ON AND YOU'RE PLAYING. THIS IS SOME WEIRD STUFF!
ROCK!
I HAVE NO IDEA
BUT I'M NOT COMPLAINING! THIS IS GREAT!
YOU KNOW WE'VE SEEN THIS BEFORE . . .
REMEMBER WHEN LUCY GOT HER POWERS?
LUCY AND I WOULD BE THE ULTIMATE POWER COUPLE!
FOCUS. THIS IS SERIOUS.
I THINK YOU'RE DEVELOPING SOUND POWERS. SOUND IS JUST VIBRATION. YOU THINK NOTES AND SOUNDS . . .
. . . AND CAN JUST KINDA MAKE STUFF VIBRATE.
WE NEED TO DO EXPERIMENTS
UH, HOW?

TEACHER'S GUIDE
ACTIVITY 2: TALKING TAPE

Introduction

Have you ever driven over those rumble strips on the side of highways? The divots in the road make your tires vibrate and that sound is amplified by the resonant cavities in your car. You hear it as that annoying noise that keeps you awake.

This activity uses the same system, only in miniature and with a hidden message. The part of the rumble strip is played by a "talking tape" which has tiny bumps on it with very specific spacing so that when you run your thumbnail down the tape, it "says" something. But this is only half of it. You have to make the vibrations resonate to be able to really hear and understand what the tape "says," like the spaces in your car that resonate when you drive over a rumble strip. In this activity, the students will use the PhysicsQuest box, a paper cup, and a balloon to see how the resonant cavity changes the sound.

Key Questions

How do the size and shape of resonant cavities affect sound?

How does speed of vibration affect sound?

Key Term

Waveguide: A device that causes waves to travel in a specific direction.

Materials

Talking tape
Self-inflating balloon
Empty PhysicsQuest box
Book

* Paper or plastic cup
* Scissors

* *not included in the PhysicsQuest kit*

Before the activity, students should know…

- Sound is caused by vibration.
- Different vibrations cause different pitches.

After the activity, students should be able to…

- Define a "resonant cavity" and discuss the meaning of resonance.
- Discuss how different cavities affect sound.
- Discuss how the speed of vibration affects the pitch.

TEACHER'S GUIDE
ACTIVITY 2: TALKING TAPE

The Science Behind Resonance and Pitch

As we talked about in Activity 1, sound is created by vibration. Changing the speed and intensity of those vibrations changes the sound. In this activity, the sound is caused by running your thumbnail down the talking tape, over the ridges, and vibrating the tape in a certain way. The students will experiment with running their thumbnails down the strip faster and slower, harder and softer so they can see these differences *(Fig. 1)*.

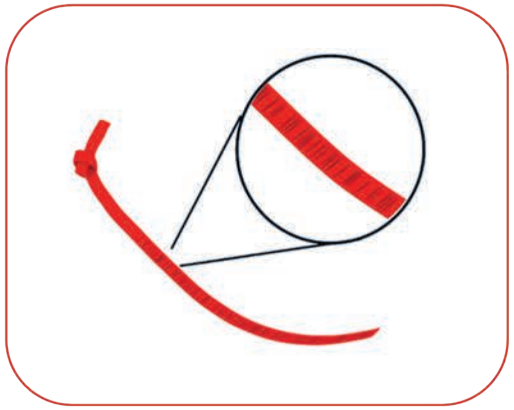


Figure 1

This experiment doesn't just deal with how specific sounds are created but with how we can better hear those sounds. If you run your finger down the talking tape while holding it, you may hear it "talk," but softly. The tape is vibrating your fingers and the air around it and that vibration is traveling to your ear and your brain hears it as words. When you hold the talking tape, the sounds travels out in every direction. Only a small amount reaches your ear.

Because the vibration is not very strong, you don't hear the sound as very loud.

When the talking tape is attached to the PhysicsQuest box, the sound is much louder. When the sound waves come off the talking tape, they don't just make the air around the tape vibrate, they make the whole box vibrate. When the box vibrates, it can vibrate much more air than the tape on its own. With all that air vibrating, your ear can hear it as a louder sound. Because the box is empty and made of something that reflects sound waves easily, the waves bounce around without absorbing.

This is very similar to plucking a string on a guitar. If you just pluck the string unattached to the guitar body, you will only hear a soft sound but when that string makes the whole guitar vibrate, you can hear beautiful music.

The louder sound created when the tape is held up to the cup or the balloon is made a little bit differently. Sure, there's the same effect as the guitar, but there is something else going on. When the tape vibrates the air inside the cup, the sound doesn't just radiate out all over. Instead -- just like light waves -- it reflects back and forth on the sides of the cup. It keeps doing that till it comes out the top of the cup and to your ear.

TEACHER'S GUIDE
ACTIVITY 2: TALKING TAPE

The sound is guided down the cup and when you hear it, the waves are more intense and your ear hears it as a louder sound. The cup acts as a **waveguide**.

When the tape is held up to the balloon, the waves bounce around inside the balloon just like with the cup. If you look at how the balloon is shaped you can see it is very similar to a lens that you would use to focus light. The balloon is actually focusing the sound waves as they bounce around inside. When you hear the sound, it sounds very loud -- just like focused light rays seem very bright.

When the tape is held to the book and vibrated, the sound is much quieter. With the cup, box, and balloon, sound waves were moving around inside and reflecting off the surfaces. Most was in some way making the air around it vibrate.
The vibrations you put in were in some way amplified, either by reflecting around, being guided to your ear, or making more air vibrate.

With the book, the sound isn't able to reflect around and amplify -- it is absorbed. Soft materials like cloth or paper are good at absorbing sound because the sound waves make them vibrate but they aren't stiff enough to make the air around them vibrate. The soft pages of the book absorb the sound so it is much more difficult to hear.

Safety

Be careful not to pop the balloon.

Suggested Resources

How a guitar works:
http://ffden-2.phys.uaf.edu/211.web.stuff/billington/main.htm

How balloons focus sound:
https://www.physics.byu.edu/faculty/gee/BallOOnLens.aspx

https://www.exploratorium.edu/snacks/conversation-piece

STUDENT GUIDE
ACTIVITY 2: TALKING TAPE

Introduction

Have you ever ridden in a car that's gone over a rumble strip on the highway? Have you ridden in a bus that's done the same thing? Have you noticed a difference? How does the pitch change if you are going faster or slower? What makes it so loud?
In this activity you are going to play with talking tapes, which are like rumble strips only much more fun.

Key Questions

How does changing the length of a straw trombone change the pitch?

How does speed of vibration affect sound?

Getting Started

1. When you drive over a rumble strip, how is the sound created?

2. What do you think might happen if you changed the spacing of the divots on the rumble strip?

Materials

Talking tape
Self-inflating balloon
Empty PhysicsQuest box
Book

* Paper or plastic cup
* Scissors

* *not included in the PhysicsQuest kit*

3. What might change if you sped up or slowed down?

4. How do sounds sound different in an empty room vs. a space full of stuff? A carpeted room vs. one with tile or wood?

5. What does "resonance" mean?

STUDENT GUIDE
ACTIVITY 2: TALKING TAPE

Setting Up the Experiment

1. Put the self-inflating balloon on a flat table and lean on it until the packet in the middle pops. This will start a chemical reaction that will inflate the balloon. It may take a few minutes to inflate. Shake the balloon a bit to make sure the chemicals are mixing well.

2. Find the notched end of the red "talking tape."

3. Cut a small square out of the top of the PhysicsQuest box and a small hole in the other side. *(Fig. 1)*

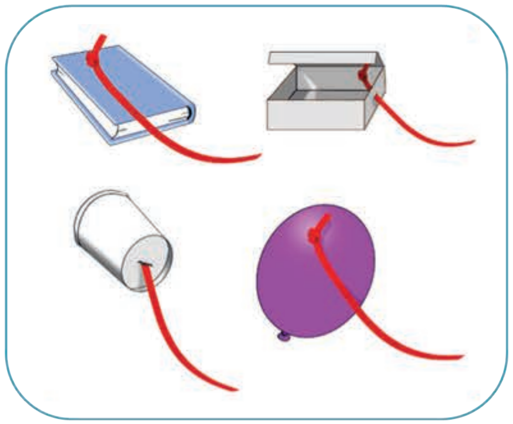


Figure 1

4. Cut a small hole in the bottom of the paper cup.

Collecting Data

Pitch:

1. Poke a small hole in the bottom of the paper cup.
2. Thread the notched end of the talking tape through the hole and knot it so it stays inside the cup. *(Fig. 1)*
3. Put the cup up to your ear.
4. Run your thumbnail down the strip.
5. What do you hear?

6. Now run your thumb down it very slowly. Does the sound change? How?

7. Now run your thumb down it very quickly. Does the sound change? How?

STUDENT GUIDE
ACTIVITY 2: TALKING TAPE

8. What is the talking tape "saying"?

Resonance:

1. Run your thumb down the talking tape at a speed that lets you hear what the tape is saying. What's the best way to hear the sound? With the cup held next to your ear or held in front of you?

2. Now hold the notched end of the tape in the PhysicsQuest box and run your thumb down it. What do you hear? How does it compare?

3. Do this again with your ear next to the hole you cut in the box. How is the sound different?

4. Repeat step 2 with the tape held against the book. What do you hear? How does it compare?

5. Repeat step 2 with the tape held against the balloon. What do you hear? How does it compare?

6. Put your ear next to the balloon opposite the tape and pull your thumbnail down the tape. What do you hear? How does it compare to the sound you heard when your ear wasn't next to the balloon?

7. Repeat step 6 with your ear on the top of the balloon. What do you hear? How does it compare to the sound you heard when your ear on the side of the balloon?

STUDENT GUIDE
ACTIVITY 2: TALKING TAPE

Analyzing Your Results

Pitch:

1. How did the pitch change when you changed the speed of your thumbnail?

2. How did the speed of vibration change when you moved it faster or slower?

3. Why do you think the pitch changed the way it did?

Resonance:

1. Rank the items used in this activity from loudest to softest.

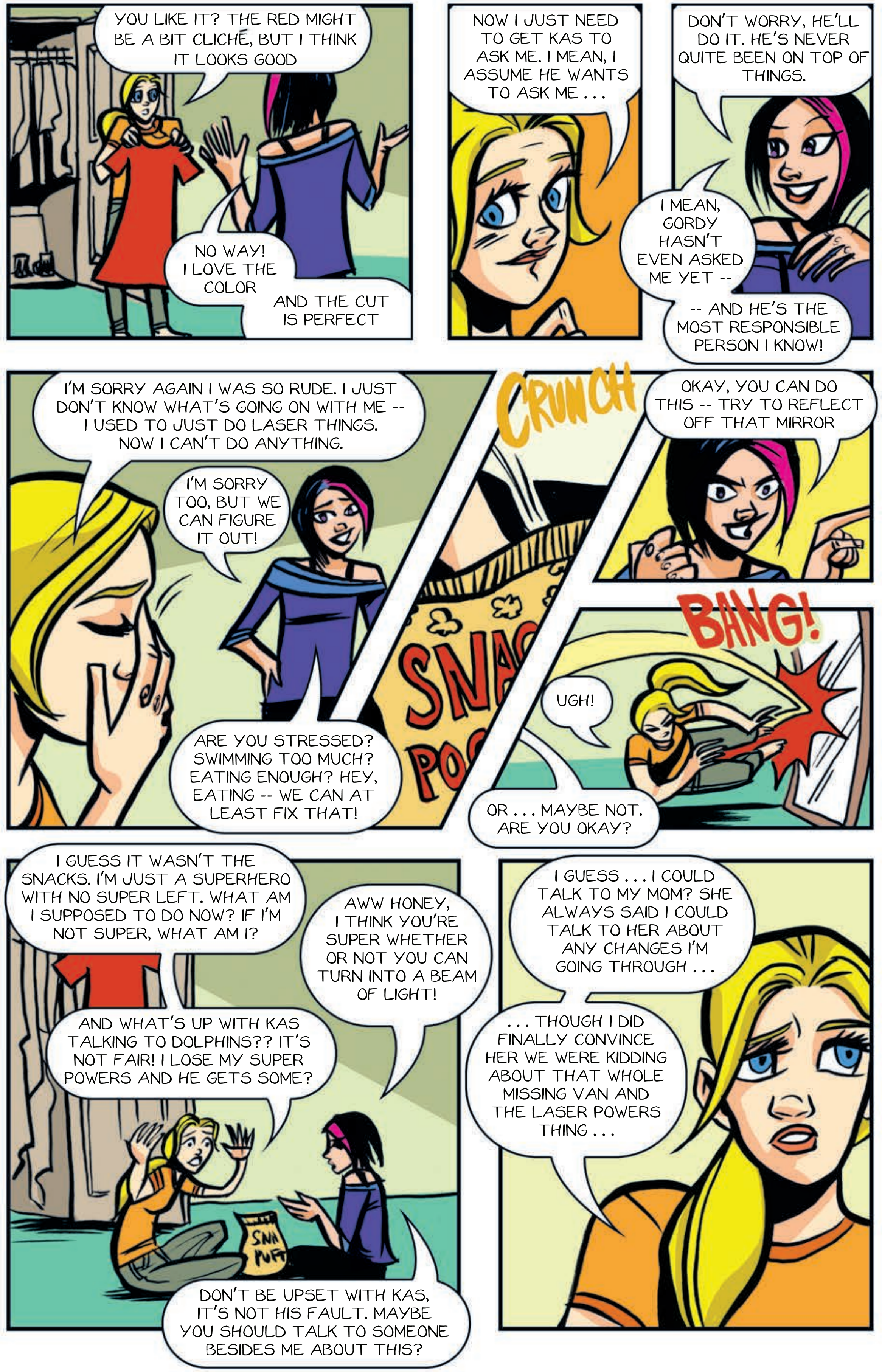
____ Cup
____ Cup with ear next to it
____ Box
____ Box with ear next to hole
____ Book
____ Balloon with ear on side
____ Balloon with ear on top

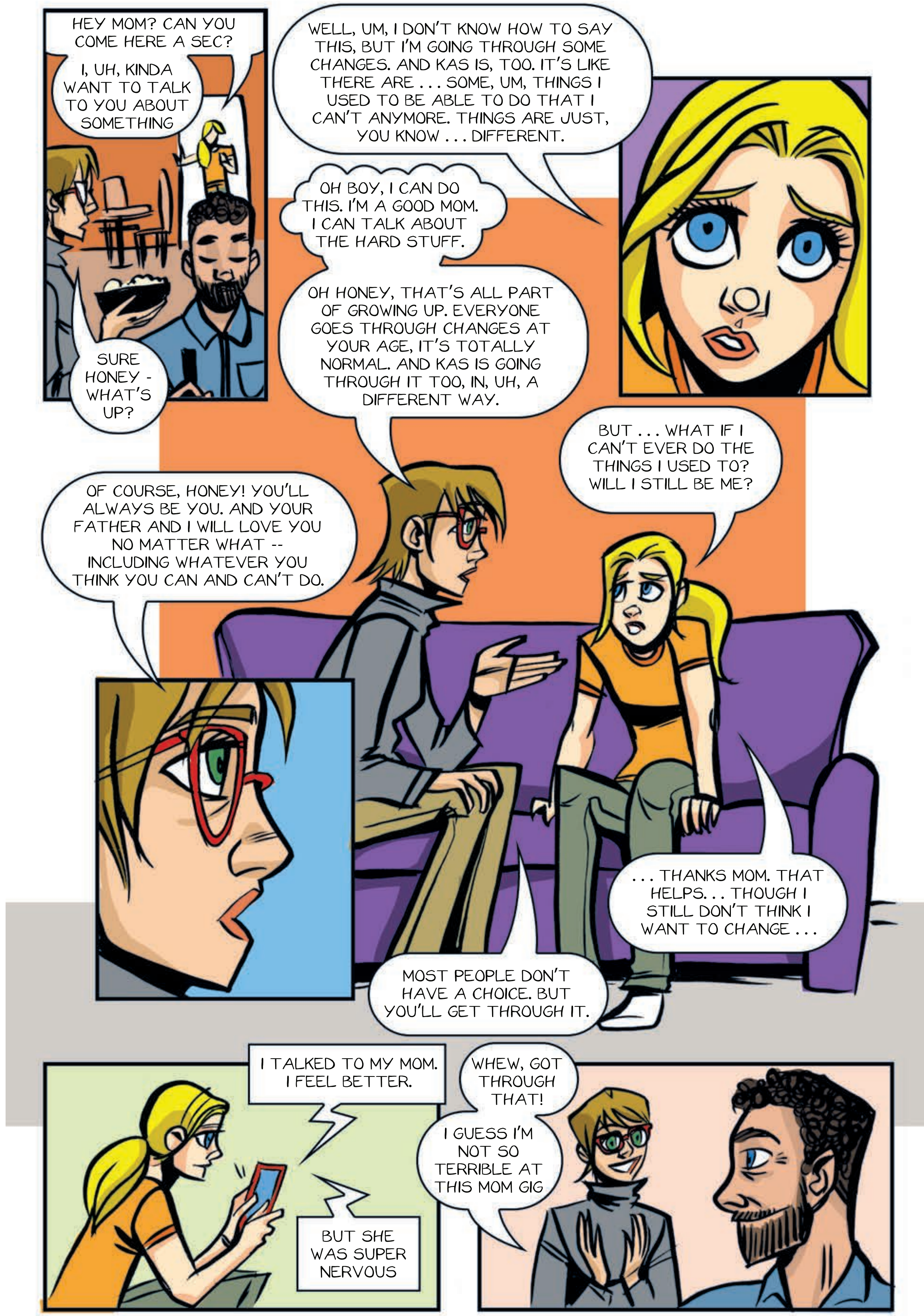
2. What do all the loudest things have in common?

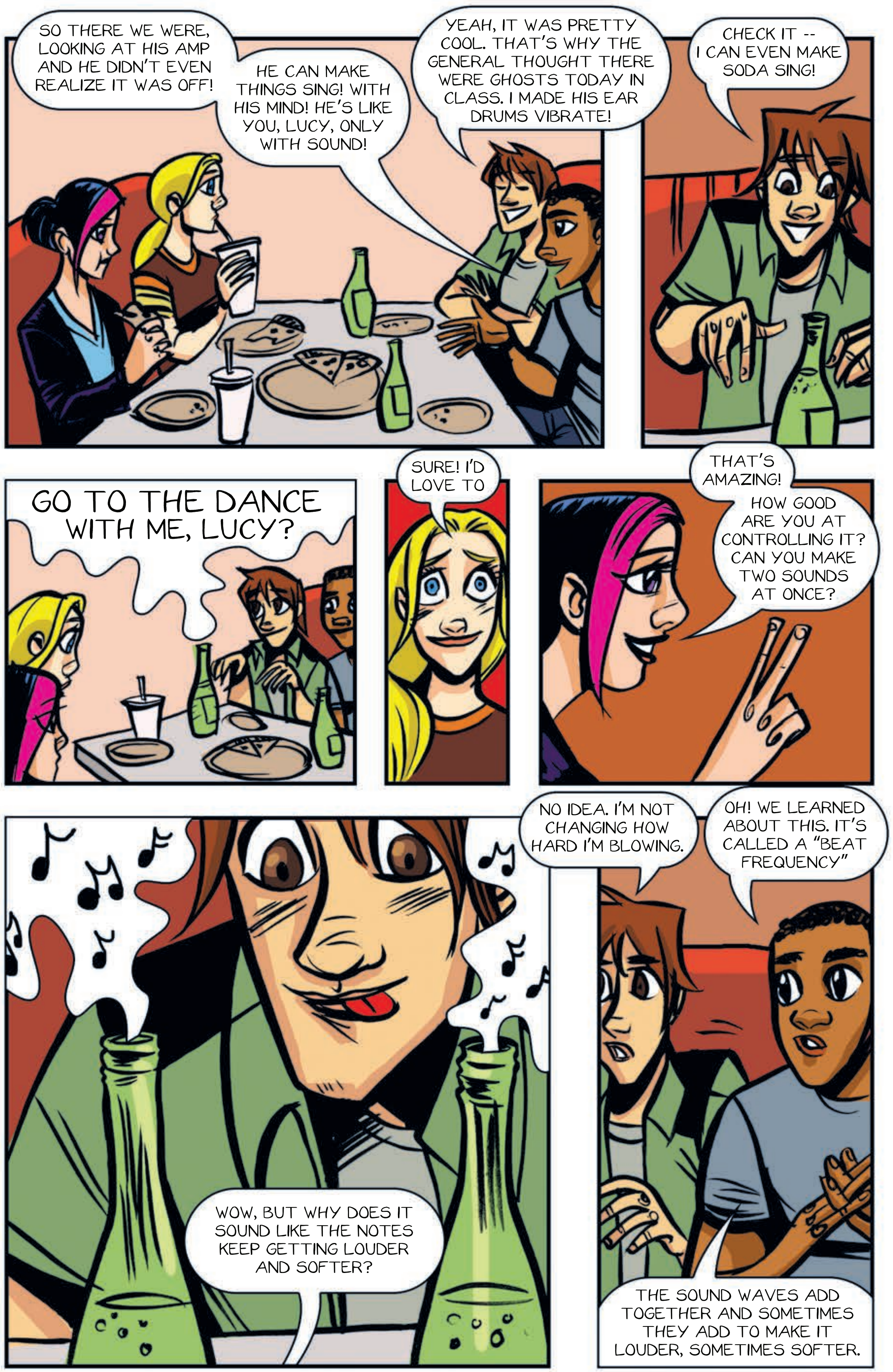
3. What do you think is happening to the sound waves in the object when the talking tape is pulled?

4. Why do you think the hollow things sound louder?

5. Why do you think having your ear next to the cup (vs not near the cup) made the sound louder?


YOU LIKE IT? THE RED MIGHT BE A BIT CLICHÉ, BUT I THINK IT LOOKS GOOD
NO WAY! I LOVE THE COLOR
AND THE CUT IS PERFECT
NOW I JUST NEED TO GET KAS TO ASK ME. I MEAN, I ASSUME HE WANTS TO ASK ME . . .
DON'T WORRY, HE'LL DO IT. HE'S NEVER QUITE BEEN ON TOP OF THINGS.
I MEAN, GORDY HASN'T EVEN ASKED ME YET --
-- AND HE'S THE MOST RESPONSIBLE PERSON I KNOW!
I'M SORRY AGAIN I WAS SO RUDE. I JUST DON'T KNOW WHAT'S GOING ON WITH ME -- I USED TO JUST DO LASER THINGS. NOW I CAN'T DO ANYTHING.
I'M SORRY TOO, BUT WE CAN FIGURE IT OUT!
ARE YOU STRESSED? SWIMMING TOO MUCH? EATING ENOUGH? HEY, EATING -- WE CAN AT LEAST FIX THAT!
CRUNCH
OKAY, YOU CAN DO THIS -- TRY TO REFLECT OFF THAT MIRROR
BANG!
UGH!
OR . . . MAYBE NOT. ARE YOU OKAY?
I GUESS IT WASN'T THE SNACKS. I'M JUST A SUPERHERO WITH NO SUPER LEFT. WHAT AM I SUPPOSED TO DO NOW? IF I'M NOT SUPER, WHAT AM I?
AWW HONEY, I THINK YOU'RE SUPER WHETHER OR NOT YOU CAN TURN INTO A BEAM OF LIGHT!
AND WHAT'S UP WITH KAS TALKING TO DOLPHINS?? IT'S NOT FAIR! I LOSE MY SUPER POWERS AND HE GETS SOME?
DON'T BE UPSET WITH KAS, IT'S NOT HIS FAULT. MAYBE YOU SHOULD TALK TO SOMEONE BESIDES ME ABOUT THIS?
I GUESS . . . I COULD TALK TO MY MOM? SHE ALWAYS SAID I COULD TALK TO HER ABOUT ANY CHANGES I'M GOING THROUGH . . .
. . . THOUGH I DID FINALLY CONVINCE HER WE WERE KIDDING ABOUT THAT WHOLE MISSING VAN AND THE LASER POWERS THING . . .


HEY MOM? CAN YOU COME HERE A SEC?
I, UH, KINDA WANT TO TALK TO YOU ABOUT SOMETHING
SURE HONEY - WHAT'S UP?
WELL, UM, I DON'T KNOW HOW TO SAY THIS, BUT I'M GOING THROUGH SOME CHANGES. AND KAS IS, TOO. IT'S LIKE THERE ARE . . . SOME, UM, THINGS I USED TO BE ABLE TO DO THAT I CAN'T ANYMORE. THINGS ARE JUST, YOU KNOW . . . DIFFERENT.
OH BOY, I CAN DO THIS. I'M A GOOD MOM. I CAN TALK ABOUT THE HARD STUFF.
OH HONEY, THAT'S ALL PART OF GROWING UP. EVERYONE GOES THROUGH CHANGES AT YOUR AGE, IT'S TOTALLY NORMAL. AND KAS IS GOING THROUGH IT TOO, IN, UH, A DIFFERENT WAY.
BUT . . . WHAT IF I CAN'T EVER DO THE THINGS I USED TO? WILL I STILL BE ME?
OF COURSE, HONEY! YOU'LL ALWAYS BE YOU. AND YOUR FATHER AND I WILL LOVE YOU NO MATTER WHAT -- INCLUDING WHATEVER YOU THINK YOU CAN AND CAN'T DO.
. . . THANKS MOM. THAT HELPS. . . THOUGH I STILL DON'T THINK I WANT TO CHANGE . . .
MOST PEOPLE DON'T HAVE A CHOICE. BUT YOU'LL GET THROUGH IT.
I TALKED TO MY MOM. I FEEL BETTER.
BUT SHE WAS SUPER NERVOUS
WHEW, GOT THROUGH THAT!
I GUESS I'M NOT SO TERRIBLE AT THIS MOM GIG



TEACHER'S GUIDE
ACTIVITY 3: BEAT FREQUENCY

Introduction

Activity 1 talked about how sounds are made and how pitches can be changed. This activity explores what we hear when two sounds have pitches that are very close to one another. Just like waves on the ocean, sound waves can add together and produce waves that have different amplitudes and frequencies. In water waves you can see this, but with sound waves you have to listen for it. This activity will use vibrating air from two tubes of similar length to hear these new frequencies.

Key Question

What do you hear when there are two sounds that have similar, but not identical, pitches?

Materials

Two clear plastic tubes

* Two cups
* Water

** not included in the PhysicsQuest kit*

Key Terms

Interference: When two waves hit each other, they interfere. Sometimes they add together, sometimes they cancel each other out.

Constructive Interference: When waves line up peak to peak and trough to trough, they make a bigger wave. This is constructive interference.

Destructive Interference: When waves are completely out of phase, peak to trough and trough to peak, they cancel out. This is destructive interference.

Beat frequency: When two waves of similar length interfere, they create a resulting wave that varies in intensity. The frequency with which it varies is called the beat frequency.

Before the activity, students should know…

- Sound is a wave.
- Different pitches can be created by changing the length of what's creating the sound.

After the activity, students should be able to…

- Discuss how sound waves add and subtract.
- Define "beat frequencies".

TEACHER'S GUIDE
ACTIVITY 3: BEAT FREQUENCY

The Science Behind Beat Frequencies

In Activities 1 and 2, students explored the wave nature of sound. They looked at how sound is a wave and how the frequency and amplitude of that wave determine what our ears hear. In this activity, students will learn about what happens when those waves interact with each other.

Though light waves are transverse waves and sound waves are longitudinal waves, the way they interact is very similar. If you'd like to learn more about how light waves interact, see Activity 1 of Spectra the Laser Superhero PhysicsQuest manual.

Like light waves, when sound waves run into each other they interact. As students learned in Activity 1, sound waves are compression waves -- meaning they are made up of compressed material and relaxed material. If two waves hit each other, it will either be a relaxed part interacting with a compressed part or two compressed parts interacting with each other.

Just like with light waves, when two waves interact at the same point in the waves, the waves add together constructively and create a bigger wave. When compressions hit each other, the air (or whatever sound is traveling in) is compressed even more and relaxed even more.

Because the amplitude of the wave is now bigger, your ear hears the sound as louder. The two sounds waves have interfered **constructively**.

If one sound wave is compressed when it hits the relaxed portion of the other wave, the two waves cancel each other out. They interfere **destructively**. Your ear doesn't hear any sound at all.

If you have two tuba players in two different chairs playing the same note and you are standing some distance away, you are going to hear one really loud tuba note. *(Fig. 1)* That's because it's very easy for waves of the same wavelength to interfere constructively. It's easy to line up two waves that are the same wavelength.

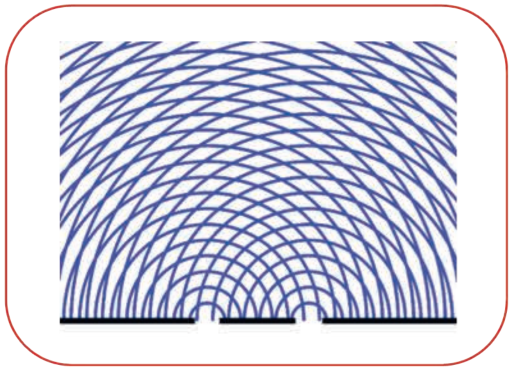


Figure 1

But what would happen if the tubas were playing two different pitches? It wouldn't be so easy to line up the two waves. It would be like trying to line up three-ring binder paper when

TEACHER'S GUIDE
ACTIVITY 3: BEAT FREQUENCY

one piece had holes just a little off from the other. It's never going to work out quite right. But what would we hear in a situation like this?

If you were to take two waves of slightly different wavelengths and put them on top of each other, at some points they would line up so that you would have compressions on top of compressions, and at some points they wouldn't. The waves are constructively interfering at some points and destructively interfering at other points *(Fig. 2)*.

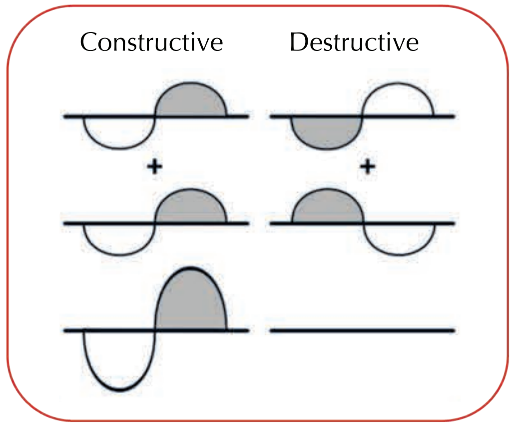


Figure 2

If you were to hear these waves, you would hear these types of interference as the note getting louder and softer; sometimes it's amplified, sometimes it's canceled out.

If one of the tuba players is a bit off key, you would hear the note but would hear it getting louder and softer.

The frequency at which the note gets louder and softer is called the beat frequency. People that tune instruments such as pianos can listen for the beats to see if two notes are actually in tune.

In this experiment, students will use two tubes to create pitches and hear beat frequencies. They will put two identical tubes in two cups of water at different heights. Just like in Activity 1, the different length columns of air will cause the tubes to play slightly different notes when the air is vibrated by the students blowing across the top. Because the two notes are so close, students will be able to hear the resulting sound getting louder and softer.

Safety

Be careful when blowing through the tubes.

Suggested Resources

http://hyperphysics.phy-astr.gsu.edu/hbase/Sound/beat.html

http://www.physicsclassroom.com/class/sound/Lesson-3/Interference-and-Beats

STUDENT GUIDE
ACTIVITY 3: BEAT FREQUENCY

Introduction

Have you ever heard an out-of-tune orchestra or a duet that isn't quite right? Usually it's just an assault on the ears but if you get past that and listen closely, you can hear some interesting physics. In this activity, you'll use the music you usually make with soda bottles to explore what happens when two notes are close but not quite right.

Materials

Two clear plastic tubes

* Two cups
* Water

** not included in the PhysicsQuest kit*

Key Question

What do you hear when there are two sounds that have similar, but not identical, pitches?

Getting Started

1. What causes a sound?

2. What is "pitch"?

3. If you did Activity 1, think back to what you learned. What does it mean to say sound is a wave?

4. What happens when two waves of any kind interact with each other?

STUDENT GUIDE
ACTIVITY 3: BEAT FREQUENCY

Setting Up the Experiment

You will need a partner to do this experiment.

1. Fill each cup with 1" of water.

2. Place one plastic tube in each cup of water. Make sure the tubes are flat against the bottom of the cups. *(Fig. 1)*

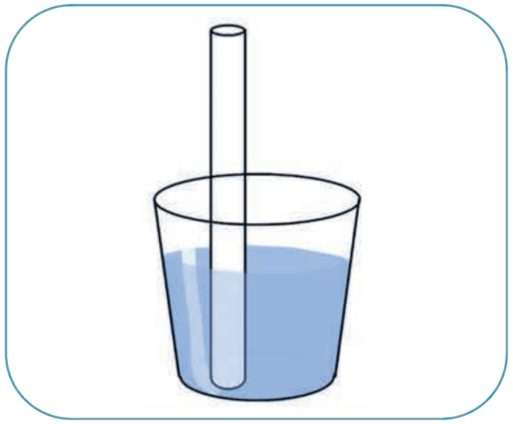


Figure 1

Collecting Data

Qualitative:

1. Blow over the top of one of the tubes until you hear a sound. What do you hear? Why?

2. Blow over the top of the other tube. What do you hear? How does it compare to the first tube? Can you hear a difference?

Figure 2

3. With a friend, blow over both tubes at the same time. *(Fig. 2)* What do you hear?

4. Add a little bit of water to one of the cups. With a friend, blow over the two tubes at the same time. What do you hear?

STUDENT GUIDE
ACTIVITY 3: BEAT FREQUENCY

Quantitative:

1. Add 1/16″ of water to one of the cups.

2. Blow over the tops of two tubes at once. How many notes do you hear? How does the third tone compare to the other two?

3. Add another 1/16″ of an inch of water to the cup and blow over the tops. How many notes do you hear? How do they compare?

4. Keep the first cup at 1″ and add water until it is 2 3/8″ deep in the second cup. How many notes do you hear? How do they sound together?

Analyzing Your Results

1. What happens when you blow on two tubes with the same length full of air (length from the top of water to the top of tube)? How do they sound together?

2. What happens when the lengths of the air columns in the tubes is a little different? What did you hear?

3. What happens when you change that length a little bit more? What did you hear?

4. What about when the lengths were very different, like in step 4?

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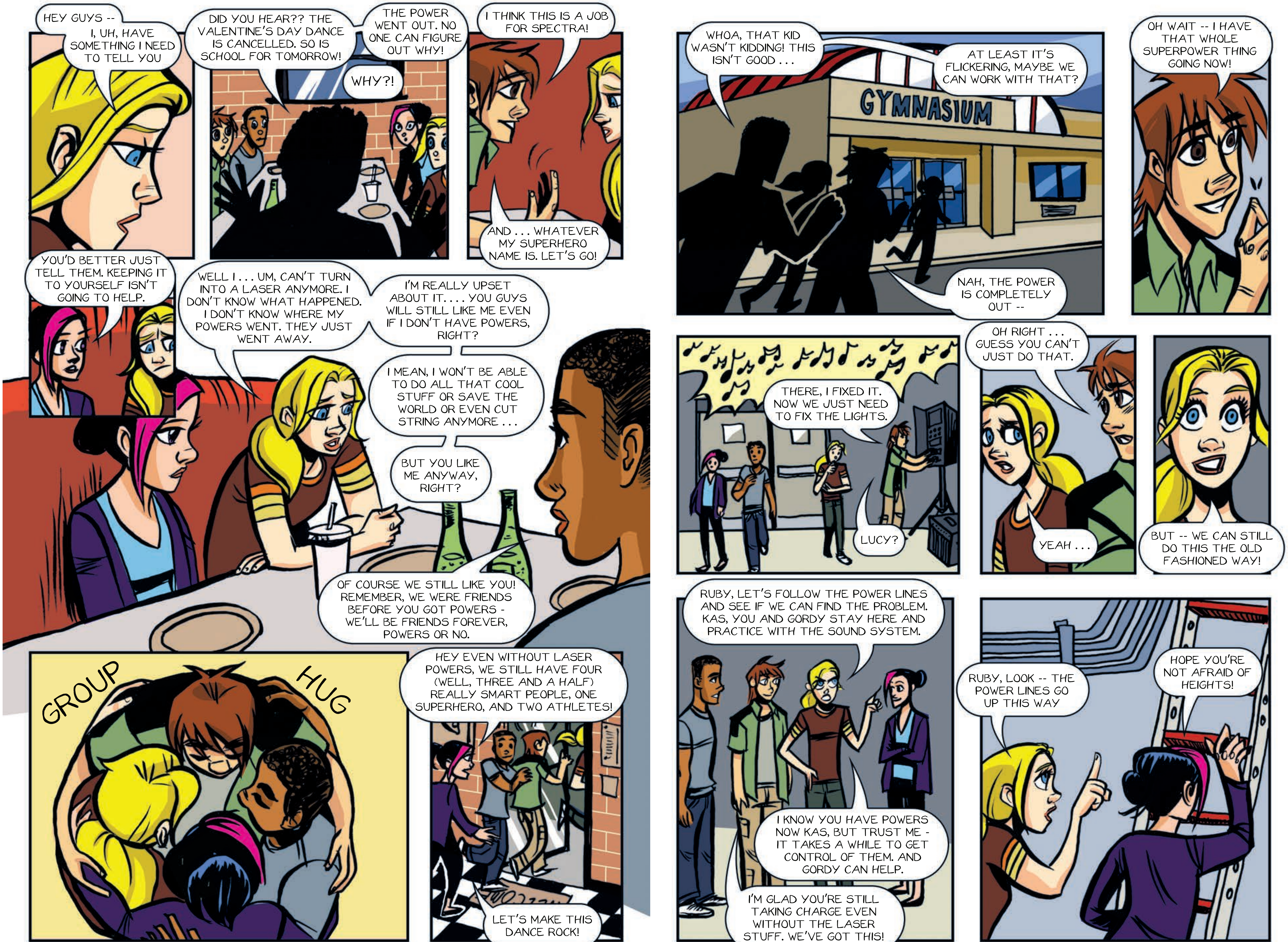
ACTIVITY 3: BEAT FREQUENCY

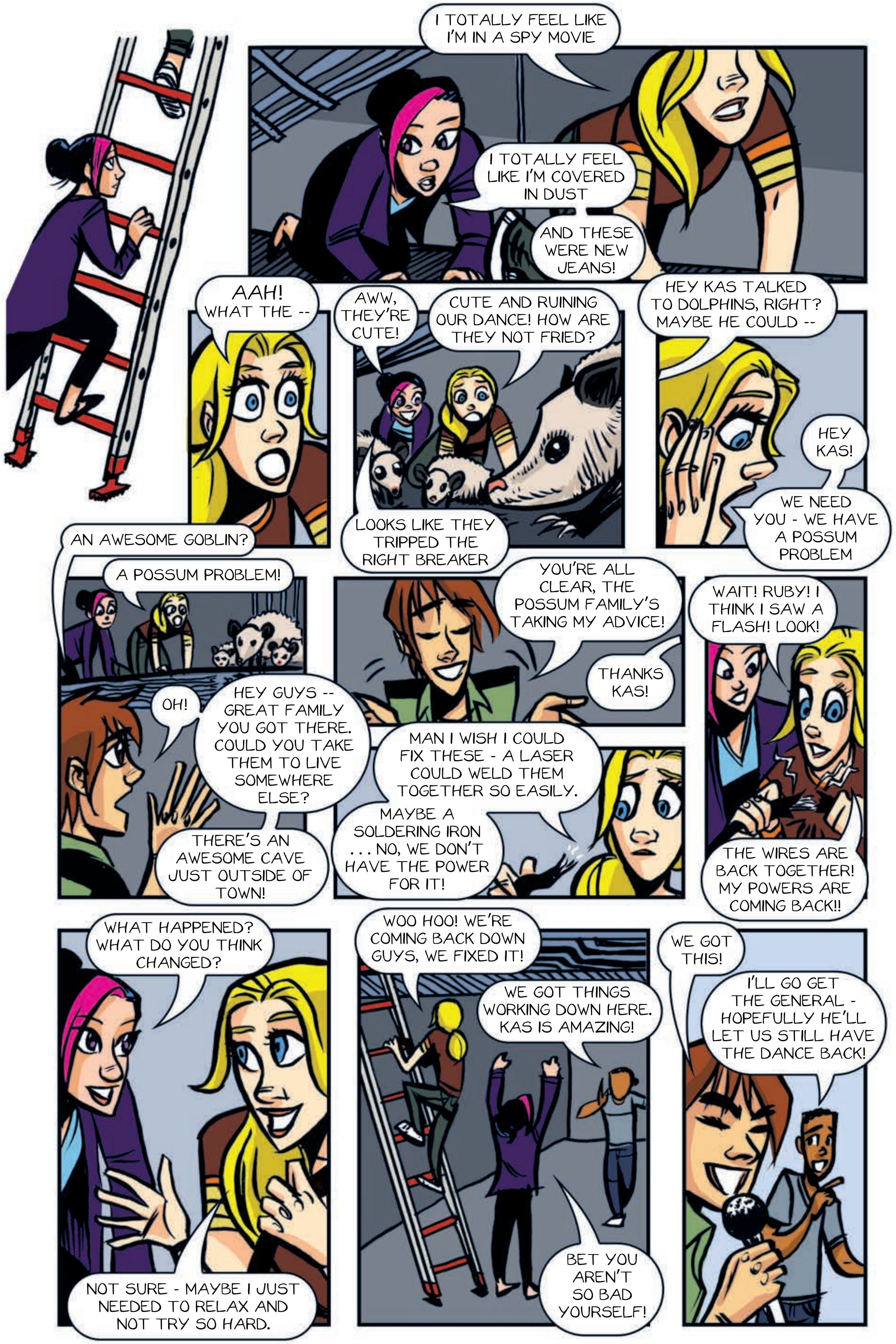
5. In this activity you learned that sound is a wave and the length of the wave and therefore the pitch you hear is based on the length of the air column vibrating. How do the pitches of the same length tubes compare?

6. Since sound is a wave, two different sound waves and can add subtract, just like water waves. How are the sound waves of different pitches interacting when the pitches are close but not the same?

7. Why do you think you heard a third pitch when you "played" two similar, but not the same, pitches using two tubes of close, but not identical, lengths?



HEY GUYS --
I, UH, HAVE SOMETHING I NEED TO TELL YOU
DID YOU HEAR?? THE VALENTINE'S DAY DANCE IS CANCELLED. SO IS SCHOOL FOR TOMORROW!
THE POWER WENT OUT. NO ONE CAN FIGURE OUT WHY!
WHY?!
I THINK THIS IS A JOB FOR SPECTRA!
AND . . . WHATEVER MY SUPERHERO NAME IS. LET'S GO!
YOU'D BETTER JUST TELL THEM. KEEPING IT TO YOURSELF ISN'T GOING TO HELP.
WELL I . . . UM, CAN'T TURN INTO A LASER ANYMORE. I DON'T KNOW WHAT HAPPENED. I DON'T KNOW WHERE MY POWERS WENT. THEY JUST WENT AWAY.
I'M REALLY UPSET ABOUT IT. . . . YOU GUYS WILL STILL LIKE ME EVEN IF I DON'T HAVE POWERS, RIGHT?
I MEAN, I WON'T BE ABLE TO DO ALL THAT COOL STUFF OR SAVE THE WORLD OR EVEN CUT STRING ANYMORE . . .
BUT YOU LIKE ME ANYWAY, RIGHT?
OF COURSE WE STILL LIKE YOU! REMEMBER, WE WERE FRIENDS BEFORE YOU GOT POWERS - WE'LL BE FRIENDS FOREVER, POWERS OR NO.
GROUP HUG
HEY EVEN WITHOUT LASER POWERS, WE STILL HAVE FOUR (WELL, THREE AND A HALF) REALLY SMART PEOPLE, ONE SUPERHERO, AND TWO ATHLETES!
LET'S MAKE THIS DANCE ROCK!
WHOA, THAT KID WASN'T KIDDING! THIS ISN'T GOOD . . .
AT LEAST IT'S FLICKERING, MAYBE WE CAN WORK WITH THAT?
GYMNASIUM
NAH, THE POWER IS COMPLETELY OUT --
OH WAIT -- I HAVE THAT WHOLE SUPERPOWER THING GOING NOW!
THERE, I FIXED IT. NOW WE JUST NEED TO FIX THE LIGHTS.
LUCY?
OH RIGHT . . . GUESS YOU CAN'T JUST DO THAT.
YEAH . . .
BUT -- WE CAN STILL DO THIS THE OLD FASHIONED WAY!
RUBY, LET'S FOLLOW THE POWER LINES AND SEE IF WE CAN FIND THE PROBLEM. KAS, YOU AND GORDY STAY HERE AND PRACTICE WITH THE SOUND SYSTEM.
I KNOW YOU HAVE POWERS NOW KAS, BUT TRUST ME - IT TAKES A WHILE TO GET CONTROL OF THEM. AND GORDY CAN HELP.
I'M GLAD YOU'RE STILL TAKING CHARGE EVEN WITHOUT THE LASER STUFF. WE'VE GOT THIS!
RUBY, LOOK -- THE POWER LINES GO UP THIS WAY
HOPE YOU'RE NOT AFRAID OF HEIGHTS!


I TOTALLY FEEL LIKE I'M IN A SPY MOVIE
I TOTALLY FEEL LIKE I'M COVERED IN DUST
AND THESE WERE NEW JEANS!
AAH! WHAT THE --
AWW, THEY'RE CUTE!
CUTE AND RUINING OUR DANCE! HOW ARE THEY NOT FRIED?
LOOKS LIKE THEY TRIPPED THE RIGHT BREAKER
HEY KAS TALKED TO DOLPHINS, RIGHT? MAYBE HE COULD --
HEY KAS!
WE NEED YOU - WE HAVE A POSSUM PROBLEM
AN AWESOME GOBLIN?
A POSSUM PROBLEM!
OH!
HEY GUYS -- GREAT FAMILY YOU GOT THERE. COULD YOU TAKE THEM TO LIVE SOMEWHERE ELSE?
THERE'S AN AWESOME CAVE JUST OUTSIDE OF TOWN!
YOU'RE ALL CLEAR, THE POSSUM FAMILY'S TAKING MY ADVICE!
THANKS KAS!
MAN I WISH I COULD FIX THESE - A LASER COULD WELD THEM TOGETHER SO EASILY.
MAYBE A SOLDERING IRON . . . NO, WE DON'T HAVE THE POWER FOR IT!
WAIT! RUBY! I THINK I SAW A FLASH! LOOK!
THE WIRES ARE BACK TOGETHER! MY POWERS ARE COMING BACK!!
WHAT HAPPENED? WHAT DO YOU THINK CHANGED?
NOT SURE - MAYBE I JUST NEEDED TO RELAX AND NOT TRY SO HARD.
WOO HOO! WE'RE COMING BACK DOWN GUYS, WE FIXED IT!
WE GOT THINGS WORKING DOWN HERE. KAS IS AMAZING!
BET YOU AREN'T SO BAD YOURSELF!
WE GOT THIS!
I'LL GO GET THE GENERAL - HOPEFULLY HE'LL LET US STILL HAVE THE DANCE BACK!


. . . SO YOU SEE, UNCLE LESLIE, THE GYM SYSTEM IS NOW FIXED SO THERE'S NO REASON WE CAN'T HAVE THE DANCE, RIGHT?
WELL . . .
DRAT, THE LIGHTS ARE STILL FLICKERING
I PROBABLY SHOULD HAVE SPENT MORE TIME ON THE WIRES . . .
WELL, THE LIGHTS ARE MOSTLY WORKING. BUT ACCORDING TO THE BUILDING PLANS, THE SOUND SYSTEM IS ON A DIFFERENT CIRCUIT - AND POSSIBLY NOT UP TO CODE.
AND I'M PRETTY CERTAIN THAT MUSIC IS REQUIRED FOR A DANCE.
ON IT!
THAT SOUNDS SATISFACTORY! YOUR PLAYING IS ALSO UP TO REGULATION.
UNFORTUNATELY, WE HAVE ALREADY CANCELLED THE BAND. I COULD GET MY ARMY BAND TOGETHER, I'M QUITE GOOD AT THE TUBA!
AND EVERYONE LOVES DANCING TO A GOOD, OLD FASHIONED MARCH!
UM, UNCLE LESLIE?
HM? . . . OH! YES, OF COURSE --
KAS'S PLAYING IS ALSO ACCEPTABLE AND POSSIBLY A MORE MODERN ALTERNATIVE.
SO THEREFORE, THE LIGHTS ARE WORKING, THE SOUND SYSTEM IS FUNCTIONAL . . .
AND WE WILL HAVE ULTRAVIOLET CATASTROPHE HEADLINING! THE DANCE IS BACK ON!


THE DANCE!
GUESS SOMEONE COULDN'T GET A DATE
HUH?
ACTUALLY, I'M WITH THE BAND. AND IT WOULDN'T MATTER IF I WAS SOLO --
I HAVE THE BEST FRIENDS IN THE WORLD, AND WE'RE ALL HERE TO HAVE FUN!
IF YOU FEEL THE NEED TO MAKE FUN OF ME FOR THAT, IT'S A YOU PROBLEM. NOT A ME PROBLEM.
I . . . UH . . .


WE'RE GONNA TAKE FIVE, I GOT SOMEONE I NEED TO SAY HI TO.
HERE ARE A FEW OF MY FAVORITE TUNES WHILE YOU WAIT
HUG
HI LUCY!
YOU LOOK AMAZING!
I RIGGED UP A SURPRISE FOR YOU -- IT WAS GORDY'S IDEA.
I PUT A BALLOON OVER THE SPEAKER AND THEN PUT A MIRROR ON IT
IF YOU BOUNCE OFF OF IT, WE CAN GIVE THEM QUITE A SHOW.
YOU UP FOR IT?
HECK YES! LET'S GO!
THE END!

Introduction

Sound is vibration. The past three activities have investigated how changing the way something vibrates changes the sound. From sound waves adding to changing the frequency of vibration to changing the space in which the vibration occurs, it's all been explored. But because these vibrations are really small, we haven't been able to actually see something vibrate. This activity uses a cup as a resonant cavity, a balloon, and a laser to allow students to see sound vibrations caused from a music player.

Materials

Mylar square
Rubber band
4 Push pins
Binder clip
Laser
Rubber glove

* MP3 download (see "Suggested Resources")
* Paper cup
* Scissors
* Music player (Smartphone, MP3 player, computer with external speaker, etc.)

** not included in the PhysicsQuest kit*

Key Question

What do sound vibrations look like?

Key Terms

Frequency: The speed at which something vibrates

Amplitude: The height of the vibration

Before the activity, students should know…

- Sound is a caused by vibration.
- Faster vibrations cause a higher pitch.
- Louder sounds have bigger vibrations.

After the activity, students should be able to…

- Quantitatively discuss how volume changes the amplitude of vibrations.
- Quantitatively discuss how pitch changes the speed of vibration.

The Science Behind Dancing Lasers

This whole PhysicsQuest kit has been about learning how different vibrations cause different sounds. We've looked at how size changes sound, how sound can be amplified, and how sound waves can interact. We've heard a whole lot of sounds. But we haven't actually seen them. We've learned that lower notes mean slower vibrations and louder sounds mean bigger vibrations, but it would be neat to actually see that. If sound is caused by vibrations, shouldn't we be able to see those vibrations? We can see things vibrating, right? Well, this whole activity is about actually seeing the sound.

The problem with actually seeing the vibrations that create sound is that in a lot of cases things are vibrating too fast or too little. You can't look at the little speakers in your headphones and see them vibrating. There needs to be a way to visually amplify these vibrations and that's where this activity comes in. In this activity, we are taking small vibrations -- those from a smartphone or speaker -- and using them to make something bigger and more elastic vibrate: the rubber glove. But the vibrations still aren't quite big enough. To really be able to see the vibrations, we can reflect
a laser off a vibrating rubber glove.

Think about playing with a cat with a laser pointer. If you haven't done this, look up some videos of it on YouTube. I guarantee you won't regret it. A small flick of the wrist causes the spot of the laser pointer to move a huge distance. This is the same principle we are using for the experiment. Wen laser pointer bounces off the mirror on the rubber glove, the vibrations move it a tiny amount. However, when the laser is moved just a little bit at the cup, you can see the laser spot move a lot more on the wall. Students will actually see how the rubber glove is vibrating to cause the laser pointer to move and make patterns.

The MP3 download from the PhysicsQuest site has different notes and different volumes. The goal is to have students really see how the rate of vibration, or frequency, changes when the pitch is changed. The lower notes will have slower vibrations and the higher notes may be vibrating so fast that it's even hard to see in the laser pointer pattern. They should also be able to see the difference in vibration amplitude as the volume is changed. The louder something is, the bigger the vibration.

TEACHER'S GUIDE
ACTIVITY 4: LASER DANCE PARTY

It's going to be a lot easier to see the lower notes because the vibrations are much slower and our eyes have an easier time processes the movement. I would highly recommend playing some fun music and seeing how the laser dances. Pick something loud with some great bass and the light show will be great.

Safety

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

Consequences for students recklessly playing with the lasers should be outlined before giving out the supplies for the activity.

If you are concerned, you may prefer to complete the portions of the procedure with the laser for your students and have them do the analysis.

Suggested Resources

MP3 download available here: *www.physicscentral.com/physicsquest*

Great explanations of pitch, volume, frequency, and amplitude: *http://www.physicsclassroom.com/class/sound/Lesson-2/Pitch-and-Frequency*

http://www.howmusicworks.org/103/Sound-and-Music/Amplitude-and-Frequency

Video of speaker vibrating in slow motion: *https://www.youtube.com/watch?v=J2BUvWRCBGM*

STUDENT GUIDE
ACTIVITY 4: LASER DANCE PARTY

Introduction

You've spent three activities learning about how sound works. You've heard all sorts of interesting things make noise. You know that sound is caused by vibrations and that sound travels as a wave. All this investigation has been done with your ears. In this activity you'll be able to use a laser to actually see the vibrations that make sound.

Materials

Mylar square
Rubber band
4 Push pins
Binder clip
Laser
Rubber glove

* MP3 download (see "Suggested Resources")
* Paper cup
* Scissors
* Music player (Smartphone, MP3 player, computer with external speaker, etc.)

* *not included in the PhysicsQuest kit*

Key Question

What do sound vibrations look like?

Getting Started

1. Think back to the other activities you've done in this PhysicsQuest. What is sound?

____

2. How can you create a different pitch?

____

3. How can you make something louder or softer?

____

4. What might sound look like if you could see it?

____

5. If you could see sound, how would higher notes look different than lower notes? How would loud notes look different than lower notes?

Setting Up the Experiment

This should be done in a dimly lit room.

1. Unscrew the battery compartment of the laser and remove the tiny piece of paper between the batteries. Screw the battery compartment back together.
2. Cut a horizontal slit in the paper cup about halfway between the lip and the bottom of the cup. The slit should be big enough to slip in a smartphone or other MP3 player or speaker. *(Fig. 1)*

Figure 1

3. Cut out the palm of the rubber glove.
4. Put the rubber glove palm over the open end of the cup and hold it in place with the rubber band. It should look like a paper cup drum with slit in the side.
5. Peel off the backing from the Mylar square and stick it to the rubber glove, slightly off center.
6. Put the push pins in the side of the cup opposite the slit to make four little legs to support the cup.
7. Put the laser in the binder clip so that the button is pressed by the edge of the binder clip. The laser is now on, so be very careful! Never look directly at a laser beam.
8. Put the binder clip and laser on top of a book and aim the laser at the Mylar square so that it reflects off the Mylar.
9. Aim the reflection at a wall. You should now have a laser projected on the wall. It might take some readjustments of the push pin legs to get everything to balance. (Fig. 2)

Figure 2

Collecting Data

Qualitative:

1. Pick your favorite song with lots of bass and get it ready to play on your MP3 player.
2. Put the MP3 player or speaker in the hole you cut in the cup. This may be a bit of a balancing act. Once you have it balanced, make sure the laser is still pointing at the wall.
3. Hit “play” and watch the laser. What happened?
4. Now pick a song with less bass and more treble and hit “play.” How was the laser’s movement different?

Quantitative:

1. Download the MP3 from *www.physicscentral.com/physicsquest*
2. Use the same setup as in the qualitative section -- only this time use the MP3 instead of your favorite tune.
3. Set the volume in the middle of your MP3 player’s range.
4. Hit “play.” You will hear a series of pitches. The file will tell you the frequency of each pitch.
5. Record what happens to the laser with each frequency/pitch.

Increase the volume to 2/3 of your MP3 player’s range.

Repeat steps 4 and 5.

How does the laser movement you see compare to the movement when the volume was set at the middle of your MP3 player’s range?

Set the volume at max and repeat steps 4 and 5.

How does the laser movement you see compare to the movement when the volume was set at the middle of your MP3 player’s range? When it was set at 2/3 of the range?

Analyzing Your Results

1. Why did the laser move?
2. When did it move the most?

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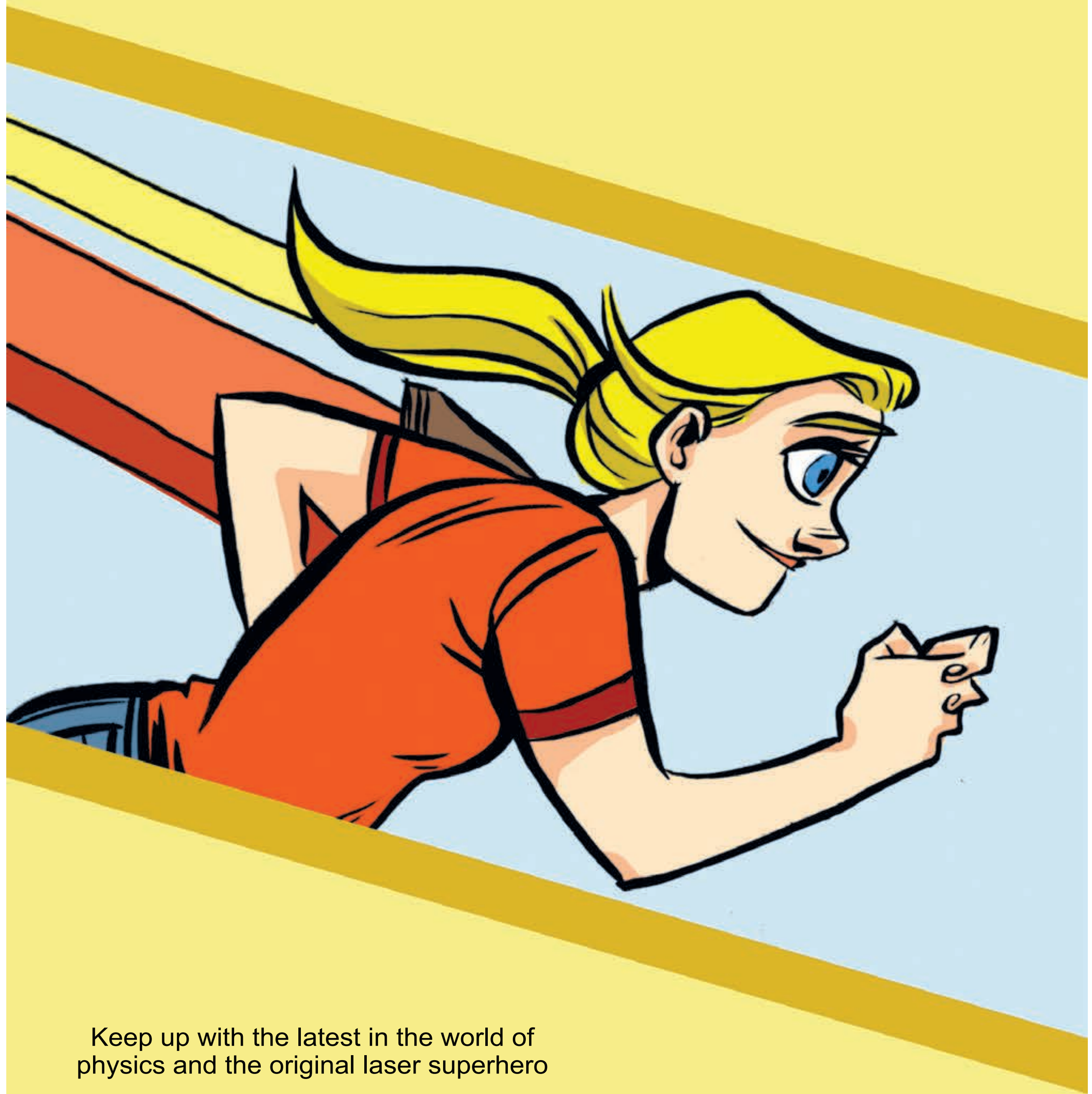
ACTIVITY 3: BEAT FREQUENCY

3. How were low notes different than higher notes? Why?

4. How did the volume affect the laser? Why?

5. Do you think you could get the laser to move in a specific pattern if you wanted to? How?

6. If you wanted to make the most impressive laser dance party, how might you do it?



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