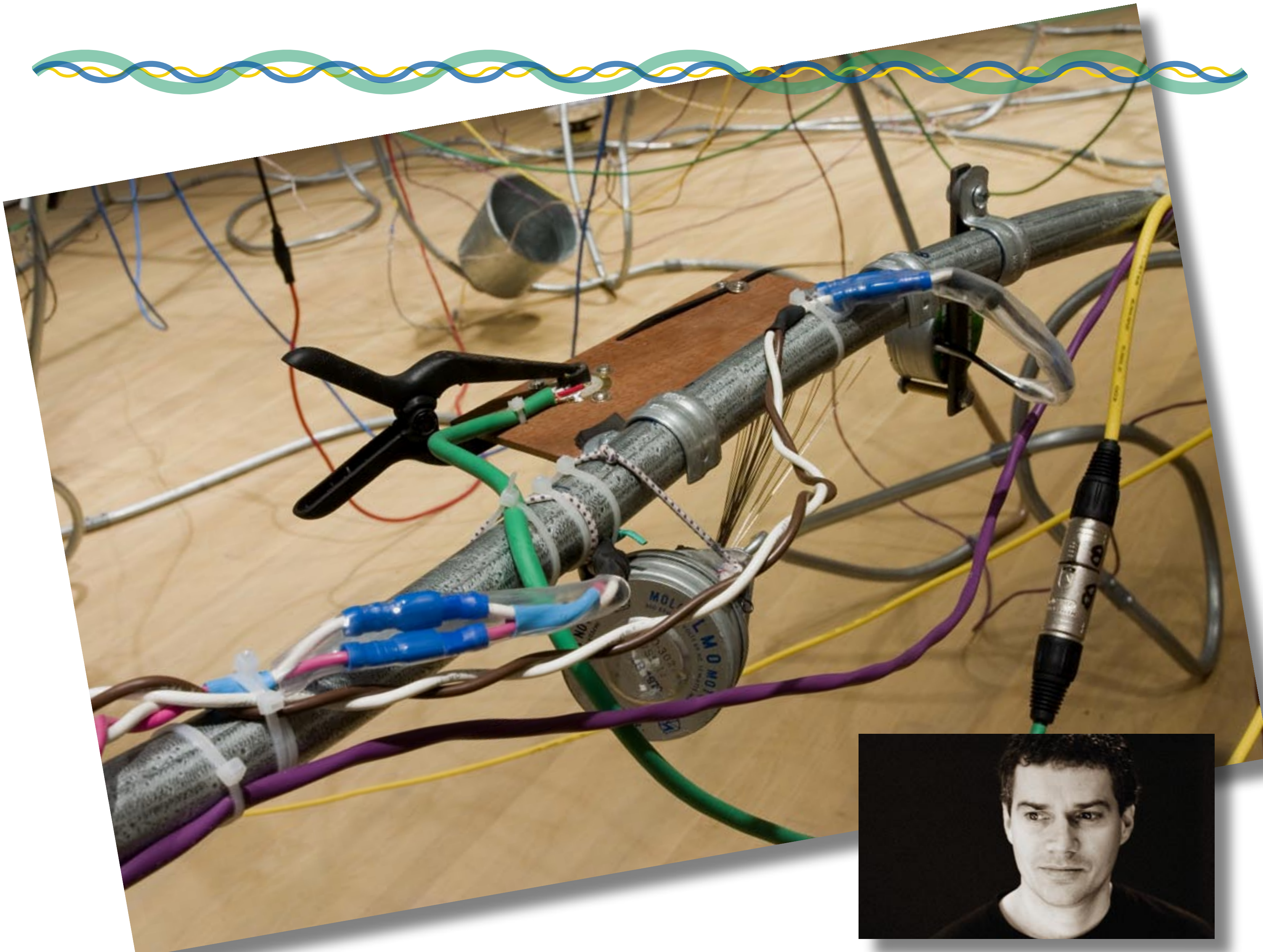

Jean-Pierre Gauthier: Machines at Play

WESTERN RESERVE

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http://www.WesternReservePublicMedia.org/machinesatplay

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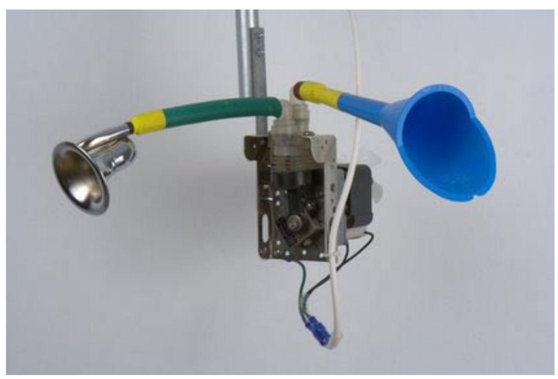
Jean-Pierre Gauthier: Machines at Play

Akron Art Museum

In September 2008, Montréal artist, inventor and musician Jean-Pierre Gauthier began installation of "Machines at Play" at the Akron Art Museum. The exhibition, the first survey of the award-winning artist's work, makes its exclusive U.S. appearance at the Akron Art Museum from Sept. 27, 2008 to Jan. 4, 2009.

Western Reserve Public Media recorded the full installation of the exhibit and created a half-hour documentary, **Jean-Piere Gauthier: Machines at Play**. Find out more at **WesternReservePublicMedia.org/machinesatplay**.

Gauthier's exhibit is an interactive display of kinetic art, which is art that contains moving parts or that depends on motion for its effect. The moving parts are generally powered by wind, by motor or by an observer. Kinetic art was first created in 1913 by Marcel Duchamp in his sculpture called "Bicycle Wheel." The movement then spread to Europe and North America.



Pictures are from **http://jeanpierregau.googlepages.com/chantsdetravail2007**

Jean-Pierre Gauthier is a kinetic artist. He uses motion sensors to track the movements that people make. Through their motion, the displays either move or make sounds or patterns.

The first picture below shows the horns that are attached to Gauthier's sculpture titled "Chants de Travail**."** The second picture shows children moving within the sculpture to cause them to blow.

To see a piano being played by a man who never touches it, go to "Battlements et Papillons (The Piano)" at **http://jeanpierregau.googlepages.com/battementsetpapillonsvideo.htm**. Double click on the arrow to watch the video.

Doesn't exactly sound like Mozart or even Hannah Montana, does it?

Let's look at what you have to know to make kinetic art"

- **How to use simple mechanical devices:** Gauthier uses pulleys, gears, wheel-and-axles, wedges, screw, levers and inclined planes throughout his work. You may have heard these tools referred to as simple machines.

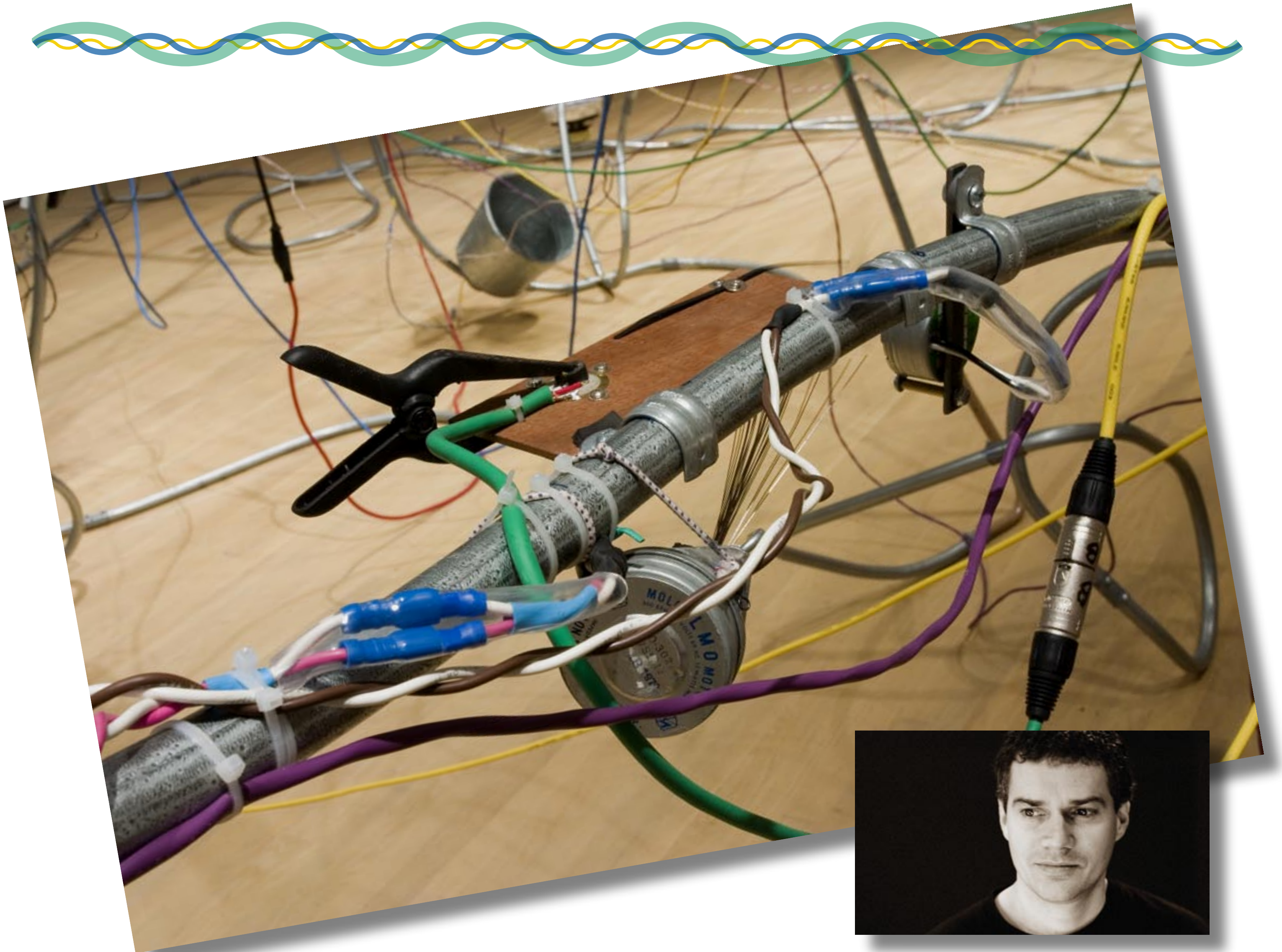
- **The principles of waves (light and sound):** What makes sound? How does light move? How are light and sound created? What do waves have to do with light and sound?

- **How to use mechanized devices:** Motors, microphones speakers and wires are used to create sound. You need to know the basic principles of electricity to get these pieces of equipment operational.

- **How to get things to move:** We need to look at the concepts of force and motion to determine what is necessary to make things move to create

- **The concept of kinetic art as "real" art**

Select the videos below to see time-lapse photos of the installations. (In case you wonder, photos are taken every 13 seconds. The complete video of these photos is shown at **WesternReservePublicMedia.org/machinesatplay**.



Jean-Pierre Gauthier: Machines at Play

Waves

http://www.WesternReservePublicMedia.org/machinesatplay

Introduction to Waves

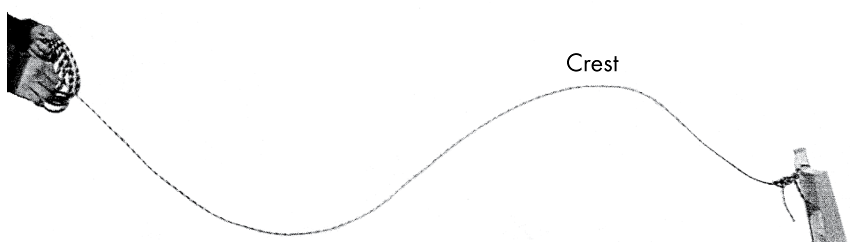
When you think of waves, you probably think of the ocean and its waves that hit the shore and are used for surfing. There are other waves that surround you all the time. Light waves allow you to see the world around you. Sound waves bring voices and music to your ears. Heat waves warm you.

So what is a wave? If you throw a pebble into water, a series of collisions between the molecules causes the energy to be carried through the water. You see the energy caused by the pebble move as a wave. A **wave** is a disturbance that transfers energy through matter or space.

Some waves move through a medium that includes solids, liquids or gasses. A **medium** is matter that is made up of molecules and takes up space.

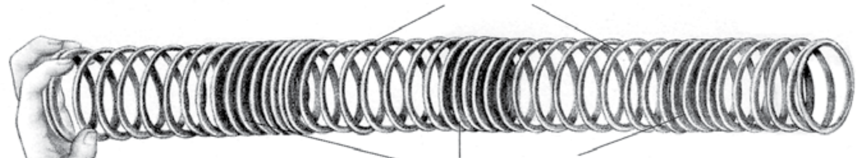
Types of Waves

There are two types of waves as determined by the way the energy disturbs the molecules. One is called a **transverse wave**. If you tie one end of a rope to a chair and hold the other end and move it up and down, you create a transverse wave in the rope. The fibers that make up the rope move up and down. The highest point of the wave is called the **crest** and the lowest point is called the **trough**.



You can see transverse waves in flags or tall grass when the wind blows. What medium would they be traveling though?

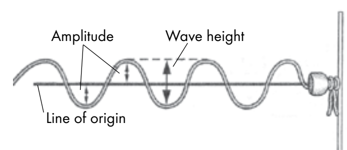
The second type of wave is called a **longitudinal wave**. The action of this type of wave can be seen in a spring (or a Slinky). If you compress (or push together) the coils in one part of the spring, the potential energy becomes kinetic energy that moves through the spring like a wave. When the coils are put together, this is called **compression**. When the waves spread apart in another part of the spring, this is called **rarefaction**.



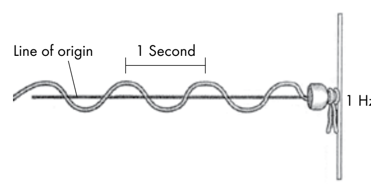
Properties of Waves

Following are some facts about the properties of waves:

- Waves transfer energy.
- Waves have varying **height**, **speed**, **length** and **frequency**.
- The **crest** of the wave is the highest point of the wave above the line of origin.
- The **line of origin** is the original position of the medium before a transverse wave moves through it.
- The **trough** of a transverse wave is the lowest point of the wave beneath the line of origin.
- The wavelength of a transverse wave is the distance between two neighboring crests or between two troughs.
- A **rarefaction** in a longitudinal wave is the area where the medium spreads apart. Rarefaction in a longitudinal wave compares to the troughs of a transverse wave.
- The wavelength of a longitudinal wave is the distance between two consecutive compressions or rarefactions.
- The compression in a longitudinal wave is the area where the medium is pushed together. Compressions in a longitudinal wave compare to the crests of a transverse wave.
- The **amplitude** of a transverse wave is the vertical distance between the line of origin and the crest of the wave. The higher the amplitude, the more energy sent to the medium.



- The **frequency** of the wave is the number of wavelengths that pass a point in a given amount of time. The unit for the frequency is the **hertz (Hz)**. A hertz is the number of wavelengths that pass a point in a given amount of time (such as a second). The more waves that pass through the medium in the same amount of time, the more energy that is released.



- **Wave speed** is simply how fast the wave is moving. The speed of the wave is measured in meters per second or Hz. The relationship between speed frequency and wavelength of a wave is expressed in the equation speed = frequency x wavelength.

Learning About Waves

Overview

Students perform a series of hands-on activities that allow them to see the types of waves and the effects of waves on the mediums of solid, gas and liquid.

Standards Addressed

Science — Physical Science

Grade 2

K-2 Benchmark B. *Recognize that light, sound and objects move in different ways.*

Y2003.CSC.S03.GKG-02.BB.L02.I01 Forces and Motion

01. Explore how things make sound (e.g., rubber bands, tuning forks and strings).

K-2 Benchmark C. *Recognize sources of energy and their uses.*

Y2003.CSC.S03.GKG-02.BC.L02.I02 Forces and Motion

02. Explore and describe sounds (e.g., high, low, soft and loud) produced by vibrating objects.

K-2 Benchmark B. *Recognize that light, sound and objects move in different ways.*

Y2003.CSC.S03.GKG-02.BB.L02.I03 Forces and Motion

03. Explore with flashlights and shadows that light travels in a straight line until it strikes an object.

Grade 5

5 Benchmark F. *Describe the properties of light and sound energy.*

Y2003.CSC.S03.G03-05.BF.L05.I07 Nature of Energy

07. Describe that changing the rate of vibration can vary the pitch of a sound.

Grade 8

8 Benchmark D. *Describe that energy takes many forms, some forms represent kinetic energy and some forms represent potential energy; and during energy transformations the total amount of energy remains constant.*

Y2003.CSC.S03.G06-08.BD.L08.I04 Nature of Energy

04. Demonstrate that waves transfer energy.

Y2003.CSC.S03.G06-08.BD.L08.I05 Nature of Energy

05. Demonstrate that vibrations in materials may produce waves that spread away from the source in all directions (e.g., earthquake waves and sound waves).

Activity 1: Two Types of Waves

Materials

- Waves student handout

Procedure

1. Have the students come to the front of the room and lock arms.
2. Pull and push on the first person in a side-to-side motion, thus creating a longitudinal wave. Students should watch what happens to each student as this happens.
3. Pull and push on the first person in a forward and backward motion, thus creating a transverse wave.
4. Instruct the students to use record their observations on the Waves student handout. Invite them to share with the class what they know about different types of waves.

Divide students into groups to explore the activities that follow. A recorder in each group can use the Waves student handout to document any discoveries or observations made by the group.

Activity 2: Ripple Tank

Materials

- Shallow pans
- Buckets or large pans
- Pebbles or marbles
- Corks

Procedure

1. Have each group of students fill a shallow pan with some water.
2. Instruct them to drop a pebble into the water and write a sentence to tell what happened.
3. Tell them to put a cork in the water and drop the pebble again. Before they drop it, they should make a prediction about where the cork will be after the pebble is dropped.
4. Have the groups increase the depth of the water and repeat the exercise.
5. Instruct them to write a sentence to describe their results.

Activity 3: Groovin'

Materials

- Paper folded so it has a groove
- Marbles

Procedure

1. Instruct the groups to place five or six marbles in a groove so that they touch each other.

2. Tell them to roll another marble against the end of the line of marbles and observe what happens. *(The vibration of waves will be transmitted through the line and the marbles on the end will roll away.)*

3. Have them roll two, then three, and so on. Instruct the students to write a sentence that tells what happened to the marbles.

Activity 4: Wave Machine (Simulating Ocean Waves)

Materials

- Masking tape
- Straws

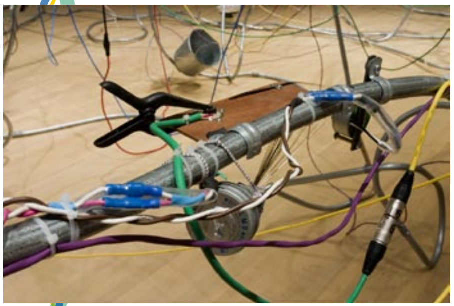
Procedure

1. Each group should place a strip of tape, three feet to four feet in length, on a table with the sticky side facing up.

2. One student should hold each end securely.

3. Instruct others in the group to place the middle of a straw perpendicularly every half inch on the tape.

4. When all straws are laid, instruct the students to take a second strip of tape of the same size and place it sticky side down on top of the straws and the first strip of tape. The finished product will resemble a spine (tape) and ribs (straws). A child holds each tape end horizontally while a third child pushes down on one end of the wave machine's straws, allowing a wave pattern to go from one end of the straws to the other. Be sure to remind students to look for waves and troughs!



Activity 5: Pitch and Volume

Materials

- Rubber bands of varying size and thickness
- Boxes of varying size
- Bottles of the same size
- Water

Procedure

1. Have students stretch different rubber bands over the empty boxes and pluck the bands.
2. Have them repeat the exercise with similar rubber bands that are placed the same distance apart.
3. For a second experiment, instruct the students to fill the bottles with different amounts of water and tap them.
4. Encourage them to use the handout to write about what they have observed.

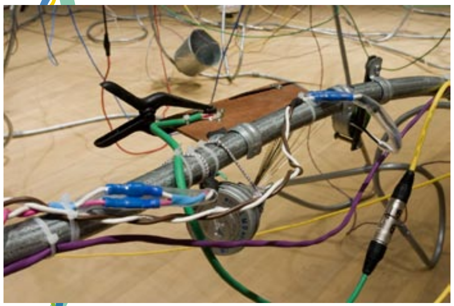
Enrichment: Speed

Materials

- Calculator (optional)
- Speed student handout

Procedure

1. Discuss why knowing the speed of a wave might be important. (Waves hitting shore in storms, finding the epicenter of earthquakes, etc.)
2. Review the concepts of frequency and wavelength.
3. Introduce the formula for finding the speed.
4. Go over the example on the student handout.
5. Have students work with a partner to find the answers and then have them write their own problem. Share some of the problems with the class.



Enrichment: Earthquakes

Materials

- Compass
- Earthquakes student handout

Procedure

1. Ask your students if they have ever been in an earthquake. Discuss why earthquakes happen.
2. Distribute the Earthquakes student handout. Read the top part together.
3. Introduce the concept of triangulation. This concept is used in a lot of mystery television shows when a criminal is using a cell phone and law enforcement officials triangulate the satellites hits for the cell phone to determine the criminal's location.
4. Discuss the scale of the map and the directions.
5. Distribute compasses and have the students find the epicenter of the earthquake.

Evaluation

A percentage of the number of correct answers on the student handout can serve as the evaluation for this activity.

Name ____

Waves

Activity 1: Two Types of Waves

What did you observe when the teacher pushed and pulled the group from side to side? What type of wave is this?

What did you observe when the teacher pushed and pulled the group forward and backward? What type of wave is this?

Activity 2: Ripple Tank

What happened to the water when you dropped the pebble in the shallow water?

What happened to the cork when you dropped the pebble in the shallow water?

What happened to the deeper water when you dropped the pebble in it?

What happened to the cork when you dropped the pebble in the deep water?

Activity 3: Groovin’

What happened to the marbles when you rolled one marble against the other marbles?

What happened to the marbles when you rolled more than one marble against the other marbles?

Activity 4: Wave Machine

What happened to the tape with the straws attached when you pushed down on one end?

Activity 5: Pitch and Volume

What happened when you used the same size rubber bands, but put them farther apart?

What happened when you used different-sized rubber bands but kept them the same distance apart?

What happened when you tapped the bottles with different amounts of liquid in them?

Name(s) ____

Speed

The waves are coming in. You're ready to "hang 10," so you calculate the wavelength and try to figure out the frequency so you can surf the wave. This is probably not how most people would approach surfing; however, the sport does involve wavelength and frequency. More commonly, they would be a useful measure if you were trying to determine when a wave might hit the shore.

Remember the **wavelength** is the distance between two neighboring **crests** and the **frequency** is the number of waves per second, or the **hertz (Hz)**. The speed of the wave is equal to the frequency times the wavelength. The speed of the wave is measured in meters per second.

Example: A motor boat passes you. The frequency is 2 Hz (or two waves per second). The wavelength or the distance between two crests is three meters.

Speed = frequency x wavelength

Speed = 2 waves/second times 3 meters/wave

Speed = 6 meters/second

Your turn

1. There is a rock concert at your school. The frequency of the band's music is 700 Hz and the wavelength is .5 meters in air. What's the speed of the sound wave?

2. An earthquake wave has a frequency of 25 Hz and a wavelength of 50 km. What is the speed of the wave?

3. Create your own example. Don't forget to solve it!

Adapted from: DiSpezio, Michael, et al. *Science Insights: Exploring Matter and Energy*. Menlo Park, CA: Scott Foresman, Addison Wesley, 1999.

Name(s) ______________________________

Earthquakes

An **earthquake** is the result of a sudden release of energy in the earth's crust that creates seismic waves. **Seismic waves** are waves that travel through the earth. Earthquakes are caused mostly by the rupture of geological faults, huge amounts of gas migration, mainly methane deep within the earth, but also by volcanic activity, landslides, mine blasts and nuclear experiments.

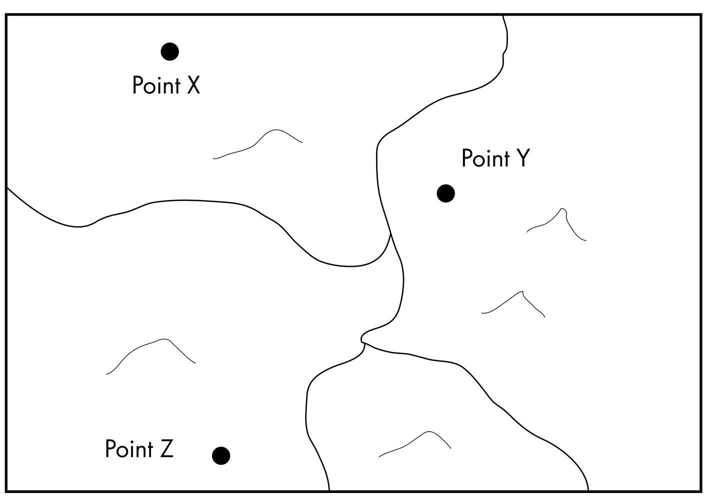
An earthquake's point of initial rupture is called its focus or hypocenter. The term **epicenter** means the point at ground level directly above this.

Earthquakes produce both fast-moving longitudinal waves and slow-moving transverse waves. To find the epicenter of an earthquake, scientists calculate the time difference between when the two types of waves hit a location. This is done at three points and is "triangulated" to determine the epicenter.

Use the map below to find the epicenter of this earthquake.

- The two types of waves arrived at Point X three seconds apart, so the epicenter was 15 km away.
- The epicenter for Point Y was 45 km away.
- The epicenter for Point Z was 60 km away.

Directions: Draw a circle around each point on your map with a compass. The size of the circle is important. The radius of each circle is the distance from the station to the origin. Use the scale provided on the map. Mark a star where the three circles intersect. This is the epicenter.



1 cm = 15 km

Adapted from: DiSpezio, Michael, et al. *Science Insights: Exploring Matter and Energy*. Menlo Park, CA: Scott Foresman, Addison Wesley, 1999.

Wave Vocabulary

Amplitude of a transverse wave: The vertical distance between the line of origin and the crest of the wave. The higher the amplitude, the more energy sent to the medium.

Compression in a longitudinal wave: The area where the medium is pushed together. Compressions in a longitudinal wave compare to the crests of a transverse wave.

Crest: The highest point of the wave above the line of origin.

Frequency: The number of wavelengths that pass a point in a given amount of time. The unit for the frequency is the **hertz (Hz)**.

Hertz (Hz): The number of wavelengths that pass a point in a given amount of time (such as a second). The more waves that pass through the medium in the same amount of time, the more energy that is released.

Line of origin: The original position of the medium before a transverse wave moves through it.

Longitudinal wave: A wave such as a sound wave that is moving in the same direction in which the particles of the medium vibrate. Mechanical longitudinal waves have been also referred to as **compressional waves** or **pressure waves**.

Medium: Matter that is made up of molecules and takes up space. Some waves move through a medium that includes solids, liquids and gasses

Rarefaction in a longitudinal wave: The area where the medium spreads apart. Rarefaction in a longitudinal wave compare to the troughs of a transverse wave.

Transverse wave: A wave that makes the medium through which it travels vibrate in a direction at right angles to the direction of its travel

Trough of a transverse wave: The lowest point of the wave beneath the line of origin.

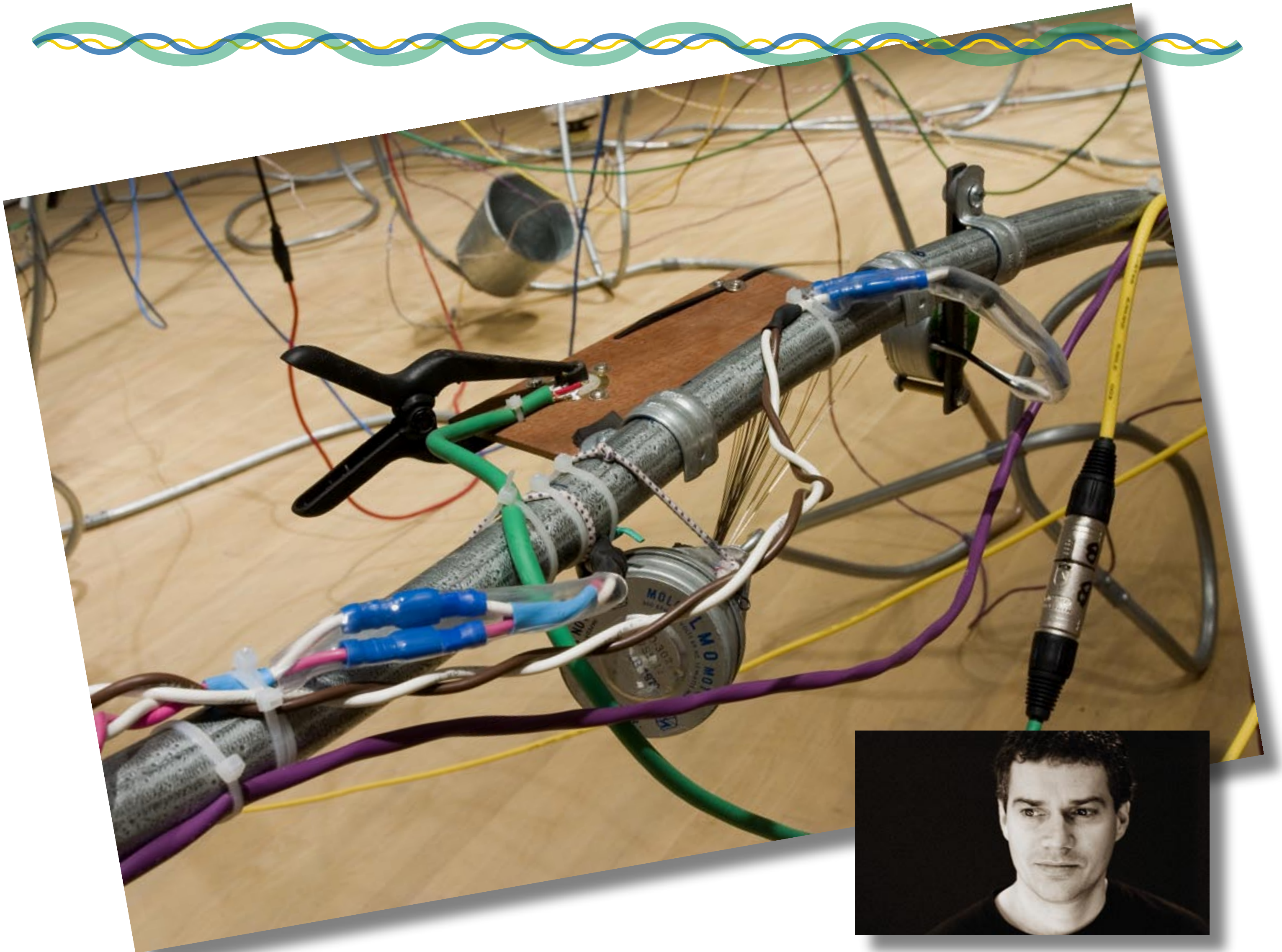
Wave: A disturbance that transfers energy through matter or through space.

Wavelength of a transverse wave: The distance between two neighboring crests or between two troughs.

Wavelength of a longitudinal wave: The distance between two consecutive compressions or rarefactions.

Wave speed: How fast the wave is moving. The speed of the wave is measured in meters per second, or Hz. The relationship between speed frequency and wavelength of a wave is expressed in the equation speed = frequency x wavelength.

Sources: *Science State Standards*, **dictionary.com** and *Science Insights: Exploring Matter and Energy* by Scott Foresman, Addison-Wesley Publishing Co., Inc.



Jean-Pierre Gauthier: Machines at Play

Sound

Introduction to Sound

Sounds are everywhere, all around us. People make sounds. Animals make sounds. Machines make sounds. Wind, rain and other natural things make sounds. We communicate with sounds and we listen to the beautiful sounds of music and of nature.

What is sound? Sound is vibration, or a rapid back-and-forth movement. Whenever you hear a sound, something is vibrating, whether it's a quiet sound like the tapping of your computer keyboard or a loud sound like the horn of a car.

How do I hear sound? Maybe you think that those two oval-shaped things on the sides of your head are what allow you to hear sound. Sorry, not so! They do act, however, as excellent sound catchers. Your real hearing mechanism is done *inside* of your head.

Let's trace the path of a sound, from its original source all the way to your brain, to see how all the parts of the ear work together.

1. An object produces sound when it vibrates in matter. This matter could be a solid (such as the earth), a liquid (such as water) or a gas (such as air). We most often hear sounds traveling through the air.

2. When something vibrates in the air, it moves the particles of air around it.

3. The affected air particles then move the next particles until it reaches the hearer's ears. This is called **compression**. You really hear through both of your ears. This allows you to hear in "stereo," just like head phones give you stereo sound. Sound is collected by the **outer ear**. It travels through the air in your **ear canal** to your **ear drum**.

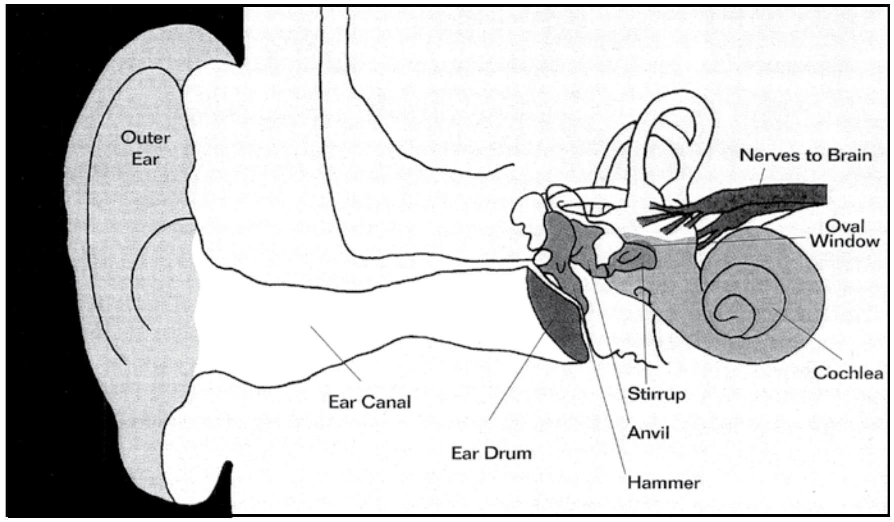
4. Three small bones are connected to the ear drum. They are called the **hammer**, **anvil** and **stirrup** because of their shapes.

5. Next to these bones is the **cochlea** that looks like a large snail shell.

6. The stirrup touches the cochlea at a small membrane covering called the **oval window**.

7. The space inside the cochlea is filled with a thick fluid. Along the inside wall of the cochlea are more than 10,000 tiny, sensitive hairs that stick into the fluid. Attached to these hair cells are nerves that come together at the back of the cochlea and go to the brain stem.

8. The sound makes the eardrum vibrate. The vibrating ear drum makes the hammer, anvil and stirrup vibrate. The vibrating stirrup causes the oval window to vibrate. The vibrating oval window causes the fluid in the cochlea to vibrate. The hair cells sense the vibrating fluid and send nerve signals to the brain. The signals from both ears are combined in the brain stem and sent to the brain, which interprets the signal as sounds.



Wow! All of that happens each time you hear any kind of sound.

Now Hear This!

Standards Addressed

Science — Physical Science

Grade 5

3-5 Benchmark — *F. Describe the properties of light and sound energy.*

Y2003.CSC.S03.G03-05.BF.L05.I06 Nature of Energy

06. Describe and summarize observations of the transmission, reflection and absorption of sound.

Y2003.CSC.S03.G03-05.BF.L05.I07 Nature of Energy

07. Describe that changing the rate of vibration can vary the pitch of a sound.

Grade 8

9-10 Benchmark — *G. Demonstrate that waves (e.g., sound, seismic, water and light) have energy and waves can transfer energy when they interact with matter.*

Y2003.CSC.S03.G09-10.BG.L09.I19 Nature of Energy

19. Show how the properties of a wave depend on the properties of the medium through which it travels. Recognize that electromagnetic waves can be propagated without a medium.

Overview

Students conduct hands-on activities that show that sound is caused by vibrations that move as waves. Changes in the rate of vibration cause changes in pitch.

Activity 1: Slinky

Materials

- Slinky
- Mixing bowls less than 1 ft. in diameter
- Aluminum foil
- Sugar
- Rice

Procedure

1. Talk about three types of sound: noise, music and speech.

   a. Noise: Have the children clap their hands, all talk at once or stomp their feet.

   b. Music: Sing a song together or play an instrument.

   c. Speech: Recite the Pledge of Allegiance

2. Invite two students to the front of the room to hold each end of the Slinky and stretch it until it is nearly flat.

    a. Squeeze together two or three coils at one end and then let go quickly. The wave will travel all the way to the end and back several times. This is called a longitudinal wave. Have the students describe the motion. *(As the wave moves back and forth, the coils are alternately squeezed together, which is compression, or spread apart, which is rarefaction.)* This is called a compression wave.

    b. Now do the same experiment, only have the students watch carefully as you compress the coils in the middle of the Slinky. Ask them to tell what they see. *(The Slinky moving rapidly back and forth, but in a confined area.)*

3. To affirm that sound is vibration, have the students cover a large mixing bowl with a one-foot-square piece of aluminum foil. Instruct them to fold the foil tightly around the edge.

4. Next they should sprinkle about one teaspoon of sugar on the top of the foil.

5. Tell them to clap their hands above the sugar and watch what happens. *(The sugar jumps on the foil.)*

6. Have them try it again, but this time hit a large pan with a wooden spoon directly above the sugar.

7. Try the same experiment using rice instead of sugar.

Activity 2: The Medium

Materials

- Ziplock plastic bags
- Water
- Sand or dirt

Procedure

1. Discuss the fact that sound is transmitted through solids, liquids and gas.

2. Divide the students into groups.

3. Have each group make the following headings on a piece of paper, leaving room for writing about what they heard.

Medium	With Ear Covered	With Ear Uncovered
Bag of Dirt		
Bag of Water		
Bag of Air		
Head on Table		

4. Set up stations in the room. One set of stations should have small ziplock bags filled about half full with sand or dirt. Push all of the extra air out. A second set of stations should have ziplock bags of equal size filled half full with water. Once again, push all excess air out of the bag. For the third set of ziplock bags, blow them half full of air.

5. Lay the bags on their side. Instruct the students to put one ear gently on each of the bags, cover the other ear and with their free hand, gently tap on the table and listen for the sound. They should then record their impression of what they heard on their charts.

6. Have the students repeat the experiment with their ear uncovered and record what they heard.

7. Discuss the following with the class:

    a. How well did you hear the sound?

    b. Through which bag did you hear the sound the best?

    c. Through which bag was the sound hardest to hear?

    d. In the olden days, Native American people used to put their heads to the ground to tell if buffalo or horses were coming. Why would they do this?

For your information: Sound will not travel through a vacuum. It needs a medium. We tend to think that sound travels fastest through the air; however, it travels faster through water or steel. It takes about five seconds for sound to travel one mile through the air. In water, sound can go a mile in just over one second. Through steel, sound can go almost four miles in second. (That's fast!)

Adapted from "Wonder Science", May, 1996. Volume 10, Number 8 from the American Chemical Society/American Institution of Physics

Activity 3: Pitch

Materials

- Paper cups
- Push pins
- Paper clips
- Rulers
- Masking tape

Procedure

1. Ask the students to think about a grand piano. You can show them a picture at the site **http://www.123rf.com/photo_752841.html**. Ask which notes are lower, which are higher and why. *(The shorter the string, the higher the pitch.)* Ask if they know what this is called. *(The highness and the lowness of sounds is called pitch.)*

2. Divide the students into pairs or groups of three.

3. Instruct them to follow the directions on the Making a "Pitch" Instrument student handout.

4. Ask the following questions:

    a. How does changing the length of the vibrating part of the rubber band change the pitch of the sound?

    b. How do you think the sound will change if, instead of pressing the rubber band down closer and closer to the cup, you press the rubber band down farther away from the cup?

    c. How is this similar to the way a guitar player can change the pitch of a string on a guitar?

5. **Enrichment:** Use the idea of the shorter the string, the higher the pitch to make a guitar.

Adapted from "Wonder Science," May, 1996. Volume 10, Number 8 from the American Chemical Society/American Institution of Physics

Activity 4: Amplitude

Materials

- Tuning fork (preferably low-pitched)
- Ping-pong ball taped to a string
- Glass microscope slide covered on top with petroleum jelly
- Masking tape
- Scissors

Procedure

1. Introduce the concept of amplitude as the loudness or softness of the sound.
2. Touch a softly vibrating tuning fork to a suspended ping-pong ball.
3. Now touch the ping-pong ball to a tuning fork that is vibrating loudly. Discuss with the class what they observed.
4. Put a thin masking tape arrow on one prong of the tuning fork so it overlaps about 1.5 cm. Then let the fork vibrate on the greased glass slide. What does the pattern look like? Try it both loudly and softly, then have the class compare the two.

Adapted from **http://www.fi.edu/fellows/fellow2/apr99/lesson.html**

Evaluation

These questions can be used as formative or summative evaluations. They can be printed or given orally.

1. By what process is energy transferred when sound waves travel through air? *(Consecutive, repeating collisions or interactions of air particles)*
2. What causes sound? (*Vibrations*)
3. What vibrates to produce sound in different instruments? (*Strings, membranes, vocal cords, air)*
4. Does sound travel faster through air, water or steel? *(Steel)*
5. What is it called when sound goes through air, water or solids – compression, transmission or refraction? (*Transmission)*
6. A piano has strings of many lengths. How does the length of the string effect the pitch? (*The shorter the string, the higher the pitch.)*
7. What does amplitude mean? *(The loudness or softness of the sound)*

8. How does your body receive sound? (*The outer ear captures it and it is processed through the inner ear and sent to the brain.*)

Summative Evaluation

Ask the students to create an experiment that would show one of the concepts they have learned about sound.

CATEGORY	4	3	2	1
Construction Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Modification/ Testing	Clear evidence of troubleshooting, testing and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.
Scientific Knowledge	Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.

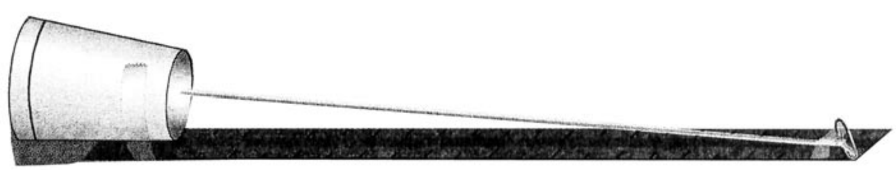
Names ____

Making a "Pitch" Instrument

Pitch is the highness or the lowness of a sound. Do this activity to see what determines the pitch.

Directions:

1. Use a push pin to poke a hole in the bottom of the cup.
2. Tie a large knot in the rubber band and push the rubber band through the hole, making sure the knot is inside the cup.
3. Tape the cup to one end of the ruler so that the bottom of the cup is at the 2 cm line.
4. Place a paper clip on the end of the rubber band that is *not* in the cup. Place that paper clip on the end of the ruler opposite the paper clip. Make sure the rubber band is pulled tight.
5. Tape the end of the rubber band with the paper clip to the end of the ruler.
6. Hold the cup up to your ear. Pluck the rubber band once. Press the rubber band down onto the ruler near the end opposite the cup. Pluck the rubber band again.
7. Press the rubber band down as you move your finger closer and closer to the cup. Pluck the rubber band each time you move your hand and notice what happens to the pitch.



Based on your observations, answer the following questions:

1. How does changing the length of the vibrating part of the rubber band change the pitch of the sound?

2. How do you think the sound will change if, instead of pressing the rubber band down closer and closer to the cup, you press the rubber band down farther away from the cup?

3. How is this similar to the way a guitar player can change the pitch of a string on a guitar?

Sound Vocabulary

Amplify: Make a sound louder.

Amplitude: The maximum height of a wave crest or depth of a trough. Increasing any sound wave's amplitude increases its loudness.

Anvil bone: One of the three main bones inside the ear. Technically known as the incus.

Cochlea: A curly tube inside the ear that is filled with liquid and lined with tiny hairs. It turns the vibrations made by sound waves against the eardrum into nerve pulses.

Compression (sound): When molecules are pressed together during the transmission of sound.

Decibel: The unit for measuring how loud or soft a sound is.

Ear drum: The part of the ear inside the head that vibrates when struck by sound waves.

Hammer bone: One of the bones inside the ear. Technically known as the malleus.

Pitch: How high or how low a note is. Different-shaped sound waves make notes at different pitches.

Rarefaction: When molecules are spread apart during the transmission of sound.

Sound: Mechanical energy that is transmitted by longitudinal pressure waves in a material medium (such as air) and is the cause of hearing.

Sound waves: Longitudinal pressure waves in any material medium.

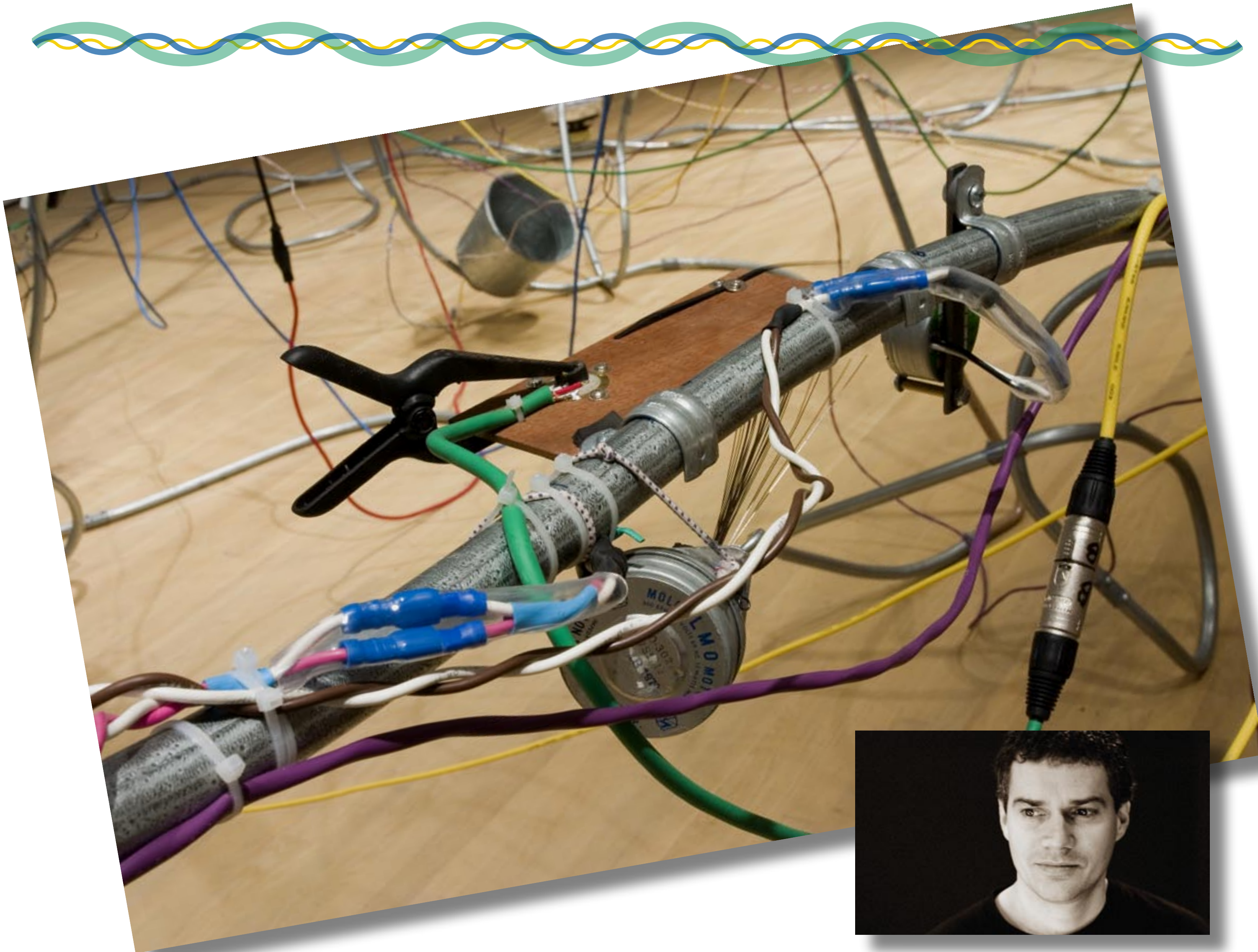
Transmission: When sound moves through a solid, liquid or gas medium.

Vacuum: A completely empty space that does not contain air. Outer space is a vacuum.

Wave: traveling disturbance that carries energy from one place to another.

Wavelength: Distance between two consecutive similar points on a wave.

Sources: *Science State Standards*, **dictionary.com** and *Science Insights: Exploring Matter and Energy* by Scott Foresman, Addison-Wesley Publishing Co., Inc. and *Make It Work: Sound* by Alexandra Parsons.



Jean-Pierre Gauthier: Machines at Play

Electricity

http://www.WesternReservePublicMedia.org/machinesatplay

Electricity: Simply Shocking

What do lightning, a magnet, a lamp and a battery have in common? Did you happen to look at the title of this page? If so, you know the answer is that they all have something to do with electricity.

What Is Electricity?

All matter is made up of atoms that contain electrons, neutrons and protons. Protons have a positive electrical charge, electrons have a negative electrical charge and neutrons have no electrical charge.

The positive and negative charges can produce a force between objects. If an atom has more protons, its charge is positive. More electrons cause the charge to be negative and an equal number of protons and electrons means the charge is neutral. Atoms with positive charges are attracted to those with a negative charge and pushed away, or repelled, by those with the same charge.

Static Electricity

Static means not moving. When electrons gather in one location, they build up and create static electricity. These electrons build up because of friction, conduction or induction. **Friction** occurs when objects rub together and electrons move from the surface of one object to the surface of the other. **Conduction** occurs when electrons are transferred from one material to another by direct contact. Did you ever rub your shoes on the carpet and then get a shock when you touched something? That is conduction. **Induction** occurs when the charges are rearranged without physical contact.

Some materials do not conduct electricity well. These are called **electrical insulators**. This happens because the electrons are tightly bound to the atoms. The electrons don't move, so they don't conduct electricity well. Some insulators are wood, glass, plastic, ceramic, air and cotton.

Some materials make it easy for electricity to flow through them. In this case, the electrons detach from the atom and move around. These are called **free electrons**. These materials make excellent **conductors** of electricity. The moving electrons transmit electrical energy from one point to another. Some good conductors are gold, silver, copper, aluminum and iron.

Electricity needs a **conductor** in order to move. There also has to be something to make the electricity flow from one point to another through the conductor. One way to get electricity flowing is to use a **generator**. A generator is a simple device that moves a magnet near a wire to create a steady flow of electrons.

Electric Circuits

Electric **current** (electrons moving through a wire) flow through a closed, continuous path called a **circuit**. To keep electricity moving, there needs to be some "electrical pressure" (**electrical potential)** that moves the electrons between the terminals in a circuit, producing the current. This is called the **voltage**. Voltage is a measure of the difference in electric potential between two points in space, a material, or an electric circuit. This measure is expressed in **volts**.

Sources of Current

Electricity can be generated by a chemical reaction. An **electrochemical cell** changes chemical energy into electric energy. There are two kinds of electrochemical cells: **wet cells** and **dry cells**. A car battery is a wet cell that contains lead and lead oxide plates called **electrodes.** (Remember, lead is a good conductor of electricity.) The plates are in a liquid conductor, sulfuric acid. Dry cells work in a similar manner. The electrodes are made of zinc and carbon and use a dry base such as ammonium chloride.

Types of Currents

When an electrochemical cell is connected to a circuit, it causes a steady flow of electric current. This type of current flows in one direction and produces **direct current (DC)**. Current can change direction. Electrons in a wire that move first in one direction and then in the other produce **alternating current** (**AC)**. The electricity in your house is alternating current. The electrons change directions about 120 times each second.

Measuring Currents

The number of electrons that pass a specific point in a circuit in one second indicates the amount of electric current. This is measured in **amperes (amps)** by an **ammeter**.

Electrons need an energy source to force them through the wire. The positive terminal of a dry cell has high potential. The negative terminal has low potential. The difference between high and low potential is the **voltage** of the cell. Voltage is the amount of electric energy available to move charges and is measured by a **voltmeter**.

Electrons flow easily through copper wire to the filament. When they hit the filament, they slow down due to **resistance** (the force opposing the movement) and convert the energy into light and heat. Good conductors have low resistance. Poor conductors, called **resistors**, have a high resistance.

George Ohm, a German school teacher, discovered that when he divided the voltage (V) by the current (*I*), he always got the same number. He identified this number as resistance (R). This relationship among voltage, current and resistance is called **Ohm's law**. The formula is ***I* = V/R** or **current = voltage divided by resistance**. The **ohm meter** measures the amount of resistance in a light bulb.

How Electrical Circuits Work

To water your garden, you need a hose that is connected to a source that pushes the water through the hose. Electric circuits operate in a similar manner. The electrons move through a wire from a source. They are pushed through the wire by voltage. Just as the water would stop flowing if there were a hole in the hose, so the electrons would stop flowing if the path were broken.

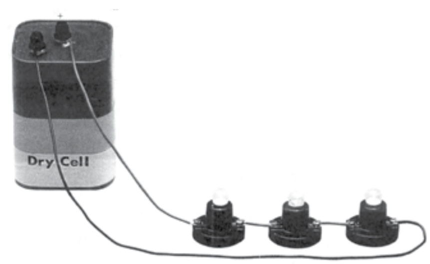
The Path of the Circuit

The following is needed to create a circuit:

- An **energy source:** For our purposes, the energy source will be a dry cell (battery) which provides the voltage needed to move the electrons.
- A **switch:** This opens and closes the flow.
- **Wires:** One wire will lead from the negative (-) and one from the positive (+) terminal.
- A **resistor:** This could be a bell or a light or anything that allows "work" to take place.

Types of Circuits

There are two types of circuits: series and parallel. Let their names help you remember what they do. A **series circuit** allows multiple things to happen, like a series of lights going on. In this series, if one light goes off, the current in the circuit stops at that point and all of the lights go off.



With a **parallel circuit**, you can still have a series of lights, but each light is wired separately. So if one light goes off, the others remain on.

Learn About Electricity

Overview

Students conduct a series of hands-on activities that include the concepts of attraction and repulsion, electrical fields, static electricity, conductors and insulators and electrical circuits. Enrichment activities include calculations of power and energy.

Standards Addressed

Science — Physical Science

Grade 5

3-5 Benchmark — *E. Trace how electrical energy flows through a simple electrical circuit and describe how the electrical energy can produce thermal energy, light, sound and magnetic forces.*

Y2003.CSC.S03.G03-05.BE.L05.I03 — Nature of Energy

03. Describe that electrical current in a circuit can produce thermal energy, light, sound and/or magnetic forces.

Y2003.CSC.S03.G03-05.BE.L05.I04 — Nature of Energy

04. Trace how electrical current travels by creating a simple electric circuit that will light a bulb.

Grade 9

9-10 Benchmark — *A. Describe that matter is made of minute particles called atoms and atoms are comprised of even smaller components. Explain the structure and properties of atoms.*

Y2003.CSC.S03.G09-10.BA.L09.I02 — Nature of Matter

02. Illustrate that atoms with the same number of positively charged protons and negatively charged electrons are electrically neutral.

For the following activities, divide students into pairs or groups. Have each group complete the Electricity student handout as they work through the activities.

Activity 1: Physical Forces

Materials

- Balloons
- Wool cloth

Procedure

Instruct the students as follows:

1. Hang an inflated balloon so it can swing freely. Hold up a piece of cloth near, but not touching, the balloon. There should be no movement of the balloon, because both the balloon and the cloth are neutral.

2. Rub the balloon with the cloth. Vigorous rubbing by the cloth changes the charge of both objects. Some electrons from the cloth move to the balloon. The balloon now has a negative charge and the cloth a positive charge.

3. Notice that the balloon moved from its original position toward the balloon (attraction). This is because the positively charged cloth attracts the negatively charged balloon.

4. Rub the cloth on a second balloon. Once again, the cloth will lose electrons to the balloon.

5. Bring the second balloon toward the first balloon. Notice that the first balloon will move away from the second balloon (repulsion**)**. This is because they are both positively charged and therefore will repel each other.

Activity 2: Static Electricity

Materials

- Plastic comb
- Wool cloth or wool sweater
- Water source
- String
- Cereal such as Cheerios or Froot Loops

Procedure

Instruct the students as follows:

1. Tie a piece of cereal to one end of a foot-long piece of thread. Attach the other end to a table or something that allows the cereal to swing freely.

2. Get a large plastic comb and make sure that it is clean. Run the comb through long hair or rub it with a piece of wool. A balloon will also work. This charges the comb.

3. Slowly bring the comb near the cereal. Hold it still until the cereal jumps away from the comb.

4. Now move the comb to the cereal again. Combing your hair moved electrons from your hair to the comb. The comb had a negative static charge. The neutral cereal was attracted to it. When they touched, electrons slowly moved from the comb to the cereal. Now both objects had the same negative charge, and the cereal was repelled.

5. Do the same experiment, but this time, turn the water on so that there is about a 1/8-inch stream coming from the faucet. The water is neutral and is attracted to the charged comb. It therefore moves toward it.

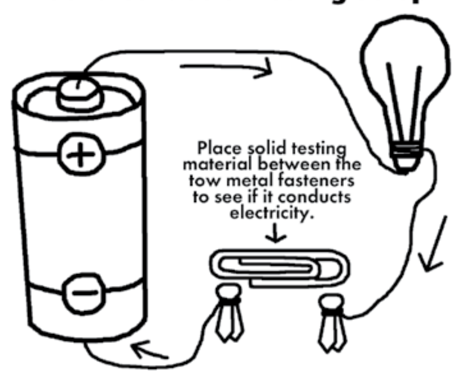
Activity 3: Insulators and Conductors

Materials

- Batteries
- Wires
- Lights
- Paper fasteners
- A variety of items such as erasers, plastic letters, metal pens, paper clips, chalk, aluminum foil, rubber bands, pencils, coins, etc.

Procedure

Solid Conductor Testing Setup



1. Have each student create a simple circuit using wires a bulb and a battery.

2. Review the concept of insulators and conductors with the students.

3. Ask the students to select five items and predict whether each will be a conductor or an insulator.

4. Have them test each item using the circuit they created.

5. Instruct them to record the item name and whether it was a conductor or an insulator on the student handout.

6. Have a debriefing at the end so that students can tell what they tested and whether they were accurate in their predictions.

Activity 4: Series and Parallel Circuits

Materials

- Name badges
- Rope
- Batteries
- Wires
- Lights

Procedure

1. Review the information on series and parallel circuits. Have the students create a human serial circuit by coming to the front of the room. Have one student wear a badge similar to this: + Battery – . Have three students wear badges that say "light." Use rope to represent the wire.

2. Now make a human parallel circuit. The battery and the lights will remain the same, but the wire (rope) will be different.

3. Ask each student group to gather needed materials: two lights, two large and four small wires and a battery.

4. Ask each group to look at the example provided and create both a parallel and a series circuit.

5. Students should draw their plans on the student handout.

6. After students have completed their circuits, as a class, discuss the following questions:

    a. How does the path of electricity flow differently in these two circuits?

    b. What happens if one light is removed in the series circuit? In the parallel circuit?

Evaluation

Student Handout

Activity 1: Eight points (two for each part)

Activity 2: Four points (two for each part)

Activity 3: Five points (one for each item that they selected and identified correctly)

Activity 4: Five points for diagram of serial circuit and 5 points for diagram of the parallel circuit

Total points: 27 points

You can use a percentage of the total to determine the grade.

Name(s) ____

Electricity

Activity 1: Physical Forces

What did you observe when you approached the balloon before and after you rubbed the comb?

What did you observe after you rubbed the second balloon and approached the first balloon?

Define **attraction**.

Define **repulsion**.

Activity 2: Static Electricity

What did you observe when you brought the comb near the cereal before and after you rubbed the comb?

What happened to the water? Why did this happen?

Activity 3: Insulators and Conductors

Name the items you tested and tell whether they are conductors or insulators.

1. ______________________________

Prediction ______________________

_____ Conductor _____ Insulator

2. ______________________________

Prediction ______________________

_____ Conductor _____ Insulator

3. ______________________________

Prediction ______________________

_____ Conductor _____ Insulator

4. ______________________________

Prediction ______________________

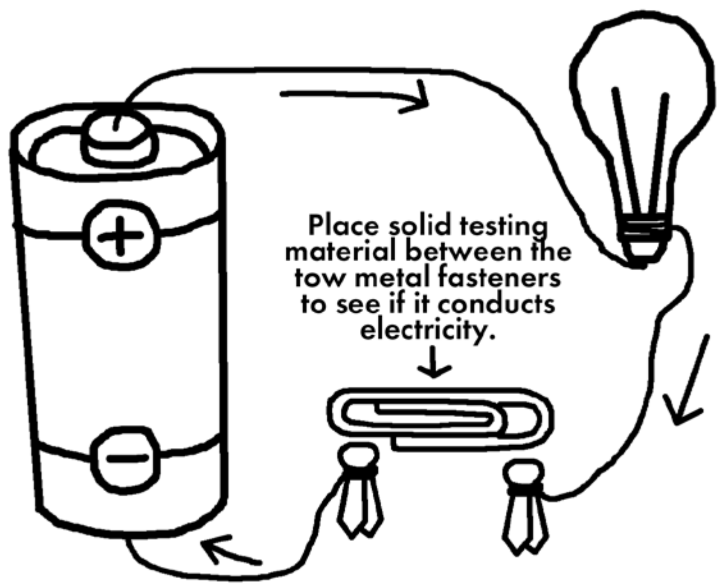
_____ Conductor _____ Insulator

5. ______________________________

Prediction ______________________

_____ Conductor _____ Insulator

Solid Conductor Testing Setup



Activity 4: Serial and Parallel Circuits

Make a diagram of your serial circuit.

Make a diagram of your parallel circuit.

Electricity Vocabulary

Alternating current (AC): Electrons in a wire that move first in one direction and then in the other. Your house uses AC, which allows the electrons to change direction about 120 times per second.

Amperes (amps): The number of electrons that pass a specific point in a circuit in one second indicates the amount of electric current. This is measure in by an **ammeter**.

Atom: The smallest particle of an element with all the properties of the element that can combine with other atoms to form a molecule. Contains protons, electrons and neutrons.

Attraction: The pull toward objects when positively and negatively charged object are brought together.

Circuit: A closed continuous path carrying an electric current.

Conduction: Occurs when electrons are transferred from one material to another by direct contact.

Conductors: Material that does conduct electricity well (gold, silver, copper, aluminum and mercury).

Direct current (DC): This type of current flows in one direction.

Dry cells: The electrodes are made of zinc and carbon and use a dry base such as ammonium chloride, an electrochemical cell.

Electric current: Electrons in a wire move or flow.

Electrical potential: "Electrical pressure" that moves the electrons between terminals in a circuit producing the current.

Electrochemical cell: Changes chemical energy into electric energy.

Electron: A subatomic particle with a negative charge located outside of an atom's nucleus.

Friction: Occurs when objects rub together and electrons move from the surface of one object to the surface of the other.

Induction: Occurs when the charges are rearranged without physical contact.

Insulators: A material such as wood, glass, plastic, ceramic, air or cotton that is a poor conductor.

Ohm's law: Defines the relationship among currency, voltage and resistance. The formula is ***I* = V/R** or **current = voltage divided by resistance**. The **ohm meter** measures the amount of resistance in a light bulb.

Neutron: A subatomic particle located in an atom's nucleus that has no electric charge and that has a mass similar to that of a proton.

Parallel circuit: A circuit in which the identical voltage is presented to all components.

Proton: A subatomic particle with a positive charge located in the nucleus of an atom.

Repulsion: The push away from each other when object with like charges are brought together.

Resistance: Electrons flow easily through copper wire to the filament. When they hit the filament they slow down due to **resistance** (the force opposing the movement) and convert the energy into light and heat. Good conductors have low resistance. Poor conductors, called **resistors**, have a high resistance.

Resistor: Uses electrical energy to do work.

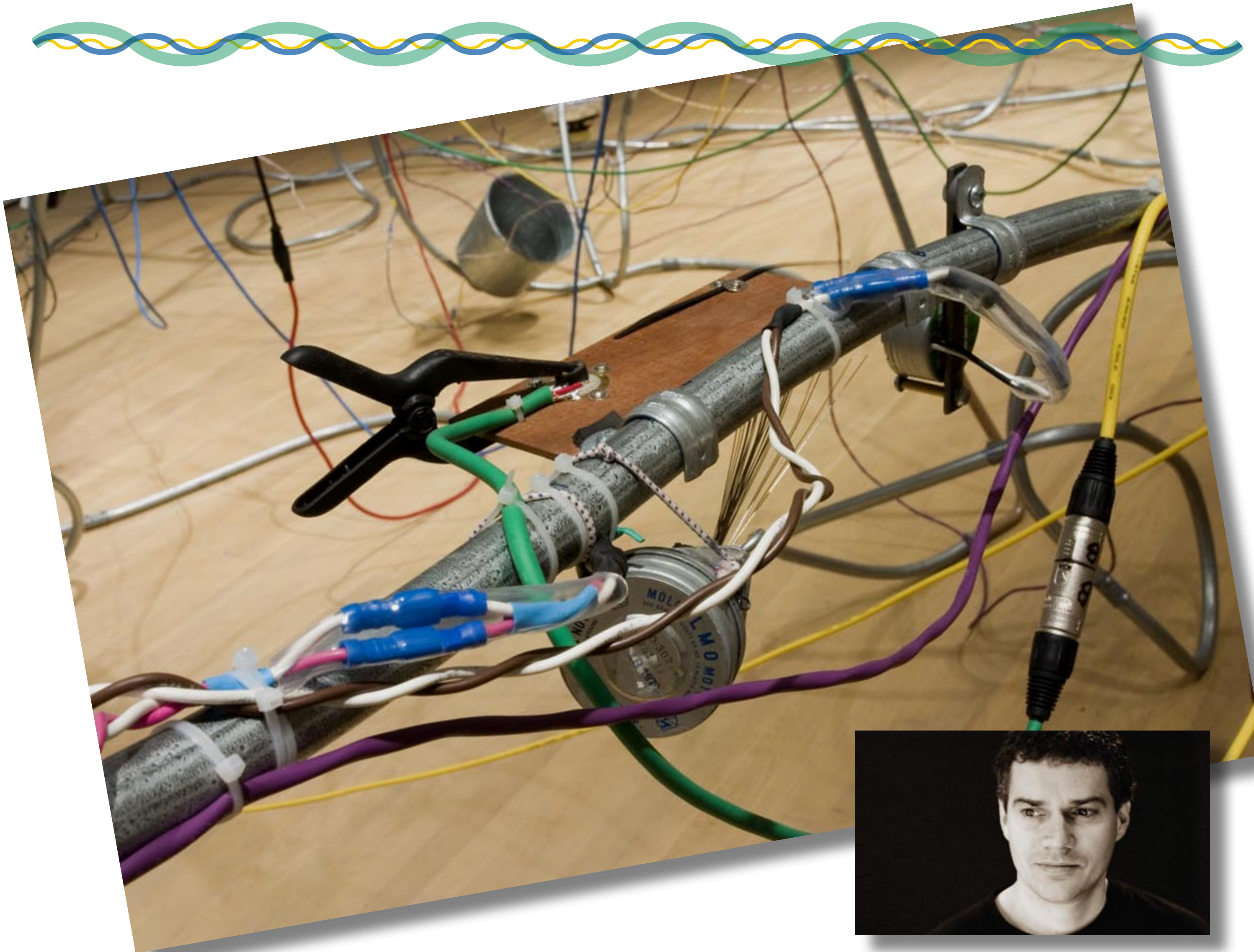
Series circuit: A circuit that connects a source, load, and conductors in a single loop. Any break in the circuit will stop the flow of current.

Static electricity: Electric charge that has accumulated on an object caused by friction, conduction or induction (electrons at rest).

Voltage: The positive terminal of a dry cell has high potential. The negative terminal has low potential. The difference between high and low potential is the **voltage** of the cell. Voltage is the amount of electric energy available to move charges and is measured by a **voltmeter**.

Wet cell: Contains lead and lead oxide plates called **electrodes**. (Remember, lead is a good conductor of electricity.) The plates are in a liquid conductor, sulfuric acid.

Sources: *Science State Standards*, **dictionary.com** and *Science Insights: Exploring Matter and Energy* by Scott Foresman, Addison-Wesley Publishing Co., Inc.



Jean-Pierre Gauthier: Machines at Play

Force and Motion

http://www.WesternReservePublicMedia.org/machinesatplay

May the "Force" Be With You!

Forces, Motion and Gravity

A **force** is a push or a pull. Forces are causing movement all around us: your bicycle rolling downhill, the ball hitting a tennis racket, riding in a car. Whenever an object speeds up or slows down or starts moving in a different direction, it is because a force has acted on it.

Forces and Gravity

Gravity is the natural force of attraction exerted by a celestial body, such as the planet Earth, upon objects at or near its surface, tending to draw them toward the center of the body. When something rolls off a table it falls to the floor due to the force of gravity pulling it down. Gravity can be measured using a spring scale. The spring stretches according to the amount of mass (weight) hung from it. The greater the force the more the spring will stretch. The unit for measuring force is a **newton**. One newton (N) is the amount of force needed to cause a one-kilogram mass to accelerate at a rate of one meter per second for each second of motion. This is about the same as the force of a small mouse sitting on a table exerts on the table. You would write a newton as **$1N = 1\ kg \times 1\ m / sec^2$**.

Friction

Exerting a force on something does not always make it move. This is because there is nearly always more than one force acting on an object. If you are trying to move a large concrete block, but it won't move, it's probably because of friction. **Friction** is the force created whenever two objects rub against one another. The heavy block is pressing strongly on the ground and creates strong friction. If the block were resting on ice, it would move more easily because ice is very smooth.

If you were to drop something from a great height, it would gradually move faster until the force of friction from the air, which acts upward, equals the downward force of gravity. This is called **terminal velocity**. Dense objects with little surface area fall for several seconds before reaching terminal velocity. Less dense objects with a lot of surface area reach terminal velocity much faster.

Newton's First Law of Motion

An object at rest will remain at rest and an object in motion will remain in motion unless acted upon by an outside force.

There are many forces around you. For example, when you sit in a chair, gravity pulls you toward the earth. Your body pushes outward with equal strength as the atmospheric pressure pushing in. The chair pushed up against the force of gravity to keep you from falling. The forces are balanced and you are **at rest**. You will remain at rest until some outside force moves it. You are at rest. You have **inertia**, or the tendency of an object to remain at rest or in motion until acted upon by an external force. You must exert some forces to get out of the chair.

The first law also tells us about objects in motion. If you are riding a bike and stop pedaling, the bike doesn't stop. It stays in motion in the same direction until it is acted on by air resistance or friction which causes it to stop.

Newton's Second Law of Motion

The force of an object is equal to its mass times its acceleration.

You're in the car with your family and it stalls. Your dad says he thinks he can start it if you push it. You are exerting a force on the car. You're getting it moving pretty fast (acceleration) and your dad jumps in. The car slows considerably. This is because of the mass (weight) of what you are pushing. **Acceleration** is a change in velocity (speed) or the rate at which this change occurs. Newton's Second Law tells us that **force = mass times acceleration**. **It is also true that acceleration = force/mass**.

A rolling marble can be stopped more easily than a rolling bowling ball when both are traveling at the same velocity (speed). The **momentum** of an object is related to its mass and its velocity. The larger the mass or the larger the velocity (or both) causes greater momentum. Momentum is the product of the mass and the velocity of an object. **Momentum = mass times velocity**.

Newton's Third Law of Motion

For every action there is an equal and opposite reaction.

You can see Newton's Third Law in action if you blow up a balloon and then release it. Air shoots out of the neck of the balloon as it moves in the opposite direction. The force propelling the balloon is equal and opposite to the force of the air leaving the balloon.

Forces and the Laws of Motion

Overview

This lesson consists of a series of hands-on activities that deal with forces and the laws of motion. Students complete a student handout as they finish each of the tasks.

Standards Addressed

Science — Physical Science

Grade 3

3-5 Benchmark — C. *Describe the forces that directly affect objects and their motion.*

Y2003.CSC.S03.G03-05.BC.L03.I03 Forces and Motion

03. Identify contact/noncontact forces that affect motion of an object (e.g., gravity, magnetism and collision).

Y2003.CSC.S03.G03-05.BC.L03.I04 Forces and Motion

04. Predict the changes when an object experiences a force (e.g., a push or pull, weight and friction).

Grade 8

6-8 Benchmark — B. *In simple cases, describe the motion of objects and conceptually describe the effects of forces on an object.*

Y2003.CSC.S03.G06-08.BB.L08.I01 Forces and Motion

01. Describe how the change in the position (motion) of an object is always judged and described in comparison to a reference point.

Grade 9

9-10 Benchmark — D. *Explain the movement of objects by applying Newton's three laws of motion.*

Y2003.CSC.S03.G09-10.BD.L09.I21 Forces and Motion

21. Demonstrate that motion is a measurable quantity that depends on the observer's frame of reference and describe the object's motion in terms of position, velocity, acceleration and time.

Y2003.CSC.S03.G09-10.BD.L09.I22 Forces and Motion

22. Demonstrate that any object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced (net) force acts on it.

Y2003.CSC.S03.G09-10.BD.L09.I23 Forces and Motion

23. Explain the change in motion (acceleration) of an object. Demonstrate that the acceleration is proportional to the net force acting on the object and inversely proportional to the mass of the object. (F net =ma. Note that weight is the gravitational force on a mass.)

Y2003.CSC.S03.G09-10.BD.L09.I24 Forces and Motion

24. Demonstrate that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object.

Y2003.CSC.S03.G09-10.BD.L09.I25 Forces and Motion

25. Demonstrate the ways in which frictional forces constrain the motion of objects (e.g., a car traveling around a curve, a block on an inclined plane, a person running, an airplane in flight

Activity 1: Forces and Gravity

Materials

- Apples
- Spring scales
- Objects from the classroom (erasers, books, etc.)
- String or box

Procedure

1. Review with students the meaning of gravity. Ask them to give examples. Introduce the spring scale if students are unfamiliar with it. Ask them to look at the scale and see what the measurement unit is *(newtons)*. Ask if anyone knows what a newton is or what it means. If they don't know, have them look up the information either online or in their textbook. *(One newton (N) is the amount of force needed to cause a l kg mass to accelerate at a rate of 1 m per second for each second of motion. This is about the same as the force of a small mouse sitting on a table exerts on the table. This is expressed as* $\mathbf{1N = 1\ kg \times 1\ m / sec^2}$*)*. Once the students know the definition, ask if they understand it. You'll probably hear them say they don't so ask them to perform the following experiment.

2. Have the students work with a partner. One person will be the recorder and one will be the tester. They can alternate jobs during this activity.

3. Have each group select a spring scale, an object such as an apple and a student handout. They will either have to tie a string around the object to measure it on the scale or they can make a box of some sort to hold the object.

4. Ask them to use the spring scale to measure how many newtons their object is. *(Most regular-sized apples measure about one newton.)*

5. Then have them select five relatively small items in the room (at least small enough that the spring scale can measure them).

6. Have the students list five items on the student handout. Using the apple as a standard, one at a time, make an estimate as to the number of newtons and then measure with your spring scale.

7. Ask them to share the information they gathered. How accurate were they? Did they estimate high or low?

Enrichment

Have the students make a scatter plot with the estimate on one axis and the actual on the other. Neither of these is an independent variable, so either axis can be used for either variable. They can find out how accurate their estimates were by drawing an x=y line on the graph and then counting the number of spaces they are away from the line for each point. These are called residuals. Use this information to determine who the best estimator is in the class.

Activity 2: Newton's First Law

Materials

- Heavy cups or glasses
- Pennies
- Index cards
- Eggs – one raw and one hard-boiled per group

Procedure

1. Review Newton's First Law: An object at rest will remain at rest and an object in motion will remain in motion unless acted upon by an outside force.

2. Ask the students to tell what they think that means.

3. Working in pairs, students should now get a cup, penny and index card.

4. Instruct them to put the card on top of the glass and the penny on top of the card.

5. Have them flick the card away and see what happens to the penny. *(It should drop into the cup.)*

6. Discuss why this happens. *(Newton's First Law in action)*

7. Students should return the first set of materials and select one hard-boiled and one raw egg.

8. They should place the eggs on a counter or table top. Have them spin the hard-boiled egg, stop it for a moment and then release it. *(The egg remains at rest.)* Have them repeat the experiment with the uncooked egg. *(This time, the egg starts moving again when they release it.)*

9. Ask the students why this happens. (The uncooked egg continues to move inside the shell – there's that Newton's Law again.)

Activity 3: Newton's Second Law

Materials

- Meter sticks or pieces of wood or cardboard for the ramps
- Toy cars
- Tape
- Tape measures
- Graph paper (optional)
- Writing material

Procedure

1. Review Newton's Second Law: The force of an object is equal to its mass times its acceleration.

2. Divide the students into partners or groups of three and have them follow the instructions for Activity 3 on the Forces and Motion student handout.

3. Discuss the following questions:

    a. How does increasing the mass (adding more washers) affect the force of objects in motion? (It changes the distance the vehicle rolls)

    b. What would happen if you added 15 washers?

    c. How does this relate to Newton's Second Law?

Enrichment

Students can graph their results. The number of washers is the independent variable and should go on the x-axis. The mean distance would go on the y-axis.

Activity 4: Newton's Third Law of Motion

Materials

- Masking tape
- Balloons
- Straws
- String

Procedure

1. Review Newton's Third Law: For every action there is an equal and opposite reaction.

2. Divide the students into groups of three and instruct them to build balloon rockets as directed in Activity 4: Newton's Third Law.

3. Have them record their data on the handout.

Evaluation

Each section of the student handout should be worth 25 points. A percent of the total will equal the grade. Bonus questions could be worth 10 points each.

Name(s) ____

Forces and Motion

Activity 1: Forces and Gravity

1. Define a newton:

2. Use the spring scale to measure five items of your choice from around the room.

Name of item	Estimated number of newtons	Actual number of newtons
1.		
2.		
3.		
4.		
5.		

Bonus: Make a scatter plot with the estimate on one axis and the actual on the other axis. Put in an $x = y$ line and write a statement about how good your predictions were.

Activity 2: Newton's First Law

1. What happened to the coin when you hit the card?

2. What did you observe when you stopped the hard boiled egg?

3. What did you observe when you stopped the uncooked egg?

4. Why do you think there was a difference?

5. How does this relate to Newton's First Law?

Activity 3: Newton's Second Law

Create a ramp using a board (or meter sticks) and some books. Put your car on the ramp and let it go. Measure the distance that the car travelled. Do this three times and record your results below. Now try it with five washers taped to the top. Then try it with 10 washers attached.

No. of Washers	Distance Trial 1 (cm)	Distance Trial 2 (cm)	Distance Trial 3 (cm)	Mean Distance (cm)
0				
5				
10				

1. How does increasing the mass affect the force of objects in motion? Remember, force = m x v2.

2. What would happen if you added 15 washers?

3. How does this relate to Newton's Second Law?

Activity 4: Newton's Third Law

Attach one end of a very long string to something solid. Measuring and marking the length of your string before you make your balloon rocket is a good idea.

Each group should collect the following materials to build a balloon rocket:

- Masking tape
- Balloon
- Straw (you determine the length)
- String

Put the straw on the open end of the string.

Blow up the balloon and attach the balloon to the straw. (Hint: If you attach the balloon to the straw at the end on which you blow, you'll get the longest distances.)

Record the circumference of the balloon at the largest part and the distance that the balloon travels down the string.

Hold the string level and shoot off five balloon rockets

Trials	Circumference of Balloon (cm)	Distance (cm)
1.		
2.		
3.		
4.		
5.		

1. Explain the factors that affect the speed and distance of your balloon.

2. How does this relate to Newton's Third Law?

Bonus: Make a scatter plot of your data. Put the circumference of your balloon on the x axis and the length the rocket went on the y axis. What does your graph show you? Can you make a prediction of the distance the balloon will travel based on the circumference?

Force Vocabulary

Acceleration: An increase or decrease in the speed of an object. **Acceleration = speed / time**.

Centripetal force or centrifugal force: A center-directed force that causes an object to follow a circular path. If you swing a weight (ball) on a string in a circular path, the string can be thought of as supplying a centripetal force causing the ball to rotate in a circular orbit. If the ball is swung fast enough, the string will break allowing the ball to fly off due to its centrifugal force.

Force: A push or a pull.

Friction: The force that resists movement whenever two objects rub against one another.

Gravity: The natural force of attraction exerted by a celestial body, such as the planet Earth, upon objects at or near its surface, tending to draw them toward the center of the body.

Inertia: The tendency of an object to remain at rest or in motion until acted upon by an external force.

Mass: The scientific measurement of the amount of matter that an object contains. The abbreviation is *m*. **Mass = weight / gravity (32 ft/sec^2)**.

Momentum: The product of the mass and the velocity of an object. **Momentum = mass times velocity**.

Newton: The unit for measuring force. One newton (N) is the amount of force needed to cause a l kg mass to accelerate at a rate of 1 m per second for each second of motion. This is about the same as the force of a small mouse sitting on a table exerts on the table. This is expressed as **1N = 1 kg x 1 m / sec^2**.

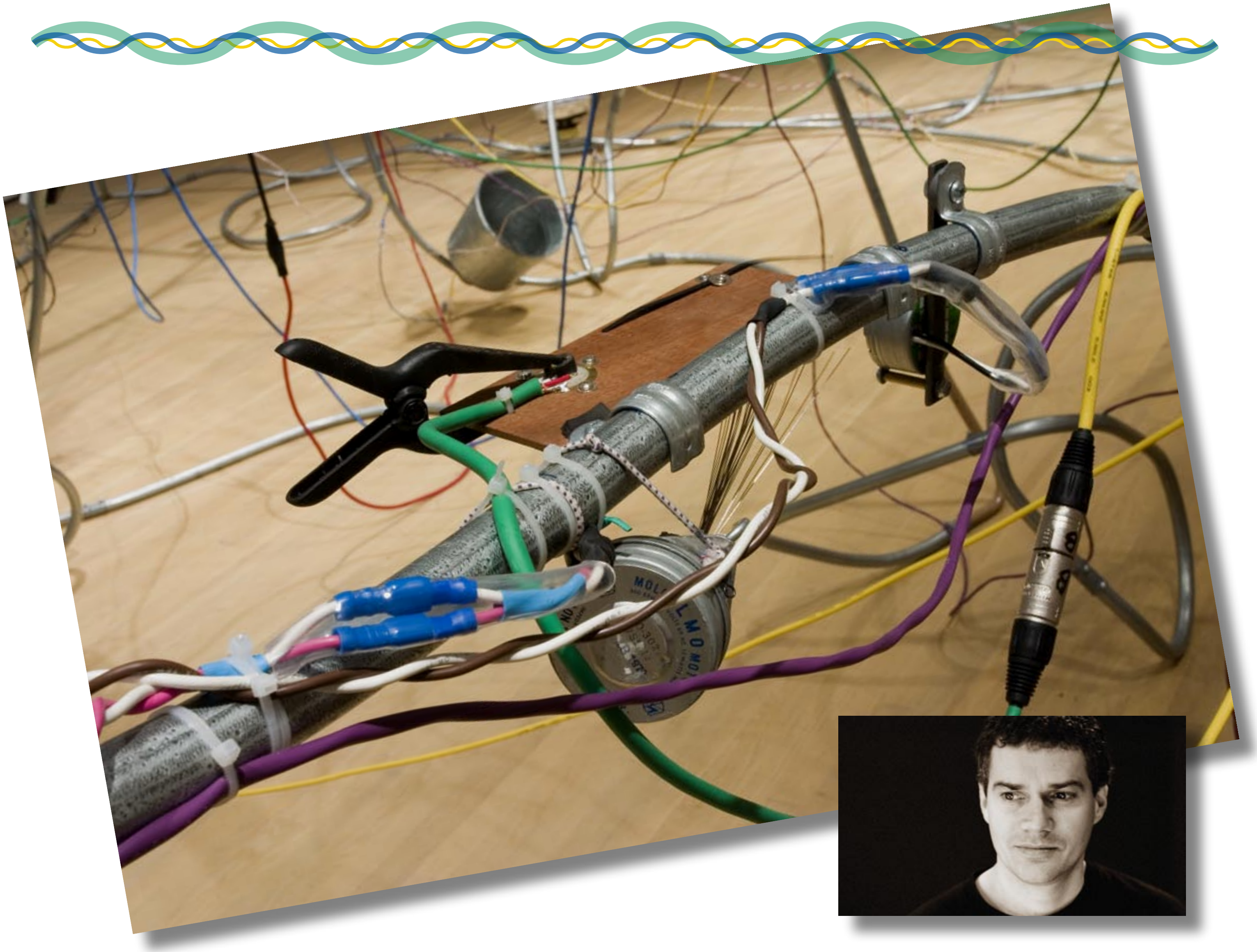
Newton's First Law of Motion: An object at rest will remain at rest and an object in motion will remain in motion unless acted upon by an outside force.

Newton's Second Law of Motion: The force of an object is equal to its mass times its acceleration. **Force = ½ times mass times volume squared**.

Newton's Third Law of Motion: For every action there is an equal and opposite reaction.

Terminal velocity: When the force of friction from the air, which acts upward, equals the downward force of gravity. Dense objects with little surface area fall for several seconds before reaching terminal velocity. Falling through air a feather would soon reach its terminal velocity while a piece of lead would accelerate for a longer time period. In a vacuum, both would fall at the same speed.

Sources: *Science State Standards*, **dictionary.com** and *Science Insights: Exploring Matter and Energy* by Scott Foresman, Addison-Wesley Publishing Co., Inc.



Jean-Pierre Gauthier: Machines at Play

Work and Machines

http://www.WesternReservePublicMedia.org/machinesatplay

Introduction to Work and Machines

Work

When you say you have work to do, does "work" always mean the same thing? Different people have many definitions of work. Science, however, has one standard definition for work. Two conditions must be met in order for work to be done on an object. The first is that the object moves. The second is that a force must act on the object in the direction the object moves.

You're out raking leaves. You pick up the rake and then pull back the leaves. Is this work? Part of it is. Picking up the rake does not act on the leaves (the objects). Pulling the leaves back is work. The object is moving and you are the force that is acting on the object. **Energy** is needed to rake the leaves or to do any kind of work. In fact, energy is defined as the ability to cause change or to do work.

What if you wanted to earn money raking leaves? What would you consider when calculating how much you want to charge? To figure the amount of work done, you use a formula: **work = force times distance** or **W=Fd**. The amount of work is sometimes measured on a **newton meter (Nm)**. This is also called a **joule (J)**. One joule equals the work done by a force of one newton that moves an object a distance of one meter. It would be my guess you're probably not going to use that formula to figure your wages.

How long it takes to move an object is not part of the equation for work. What if you and your friend are both raking yards of equal size? You are both using the same force, but you get finished 10 minutes before your friend. You used greater **power**. Power is the rate at which work is done. To calculate power you divide the amount of work done by the time it took to do the work: **power = work/time**.

Machines

A **machine** is a device that makes work easier by changing the direction or the size of the force needed to do the work. Did you ever wonder how the pyramids were built? In early Egypt cranes and heavy machinery were unavailable. The builders did use machines however. The force applied to a machine is the **effort force**. The force opposing the effort force is the **resistance force**. **Mechanical advantage (M.A.)** gives you a number that tells how many times the effort of the force is increased: **M.A. = resistance force/effort force**.

Types of Machines

Machines are everywhere. **Simple machines** do work with one movement. There are six types of simple machines: inclined plane, wedge, screw, lever, wheel-and-axle and pulley. Each changes the size or direction of a force applied to it.

- **Lever:** A board or bar that rests on a fulcrum, or turning point.
    - **Examples**: seesaw, hammer, crowbar
- **Inclined plane:** Flat surface that is higher on one end. You can use this machine to move an object to a lower of higher place making the work of moving things easier.
    - **Examples:** ramp, slanted road, slide, path up a hill
- **Wheel-and-axle:** An axle is a rod that goes through the wheel. This lets the wheel turn. It is easier to move things from place to place.
    - **Examples:** cars, roller skates, wagons, doorknobs, gears
- **Screw:** A simple machine made from another simple machine. It is actually an inclined plane that winds around a nail. Some screws are used to lower and raise things. Others are used to hold things together.
    - **Examples:** jar lids, light bulbs, stools, clamps, key ring
- **Wedge:** A simple machine used to push 2 objects apart. A wedge is made up of 2 inclined planes. These planes meet and form a sharp edge that can split things apart.
    - **Examples:** nail, fork, knife, axes
- **Pulley:** Made up of a wheel and rope. The rope fits on the groove of the wheel. One part of the rope is attached to the load. When you pull on one side of the pulley the wheel turns and the load will be moved. Pulleys will let you move loads up, down or sideways. Pulleys are good for moving objects to hard to reach places. It also makes the work of moving heavy loads a lot easier.
    - **Examples:** crane, flag poles, clotheslines

http://www.lessonplanspage.com/sciencemd6simplemachinesfullunit46.htm

Compound Machines

Compound machines are a system of two or more simple machines. The mechanical advantage is greater than with simple machines.

Learn About Work and Machines

Standards Addressed

Science — Physical Science

Grade 3

Y2003.CSC.S03.G03-05.BC.L03.I03 Forces and Motion

03. Identify contact/noncontact forces that affect motion of an object (e.g., gravity, magnetism and collision).

Y2003.CSC.S03.G03-05.BC.L03.I04 Forces and Motion

04. Predict the changes when an object experiences a force (e.g., a push or pull, weight and friction).

Overview

Students conduct a series of hands-on activities to acquaint themselves with using machines to make work easier.

Activity 1: Levers

Materials

- Boards
- Something to use as a fulcrum, such as a juice cans

Procedure

1. Give a brief review of simple machines.
2. Tell the students that it is their job to lift the teacher at least one foot off the ground.
3. Divide the students into groups of three or four or do this as a demonstration.
4. Have students use the provided materials to create a design that will lift the teacher.
5. Talk about the weight end and the force end of the lever.
6. Ask them to draw a diagram of their machine and write one or two sentences to explain how it worked.

Activity 2: Pulleys

Materials

- Jugs with handles
- Water
- Rope
- Masking tape
- Broom handles

Procedure

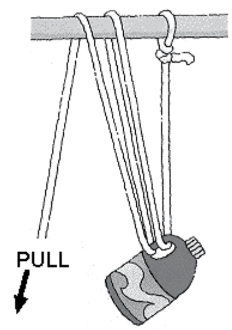
1. Have the students tape the ends of the broom handle down between two desk tops.

2. Divide the students into pairs or groups of three. Allow the students to experiment with ways to lift the jug using the rope and broom handle. Tell students they may not tie a knot in the rope.

3. Have student share their results.

4. The students should now tie the rope to the broom handle, loop the rope through the jug handle and lift by the free end of the rope with the weight in the middle (movable pulley). Loop the rope over the broom handle and pull down on the free end.

5. Have them loop the rope through the jug handle another time and then up and over the broom handle. They will have two loops over the broom and the original knot.



6. They can write a sentence about what they learned on the student handout.

Source: **http://www.grc.nasa.gov/www/k-12/summer_training/kaeavenuees/pulleys.html**

Activity 3: Inclined Planes

Materials

- Some type of filler: sand, rice, beans, etc.
- Plastic bags
- Tape measures

Procedure

1. Divide the students into pairs or groups of three.

2. Instruct them to stack four or five books and lean one of the books against the stack to make an inclined plane.
3. Each team should fill a plastic bag with one cup of rice, sand, beans, etc.
4. Have them cut a large rubber band and tie it to the neck of the sack.
5. Holding one end of the rubber band, they should lift the bag straight up to the top of the books.
6. Next have them measure the length of the stretched rubber strip.
7. Instruct the students to put the bag at the bottom of the inclined book.
8. Holding the end of the rubber strip, they should slowly pull the bag up the plane.
9. Have them measure the length of the stretched rubber strip when the bag is almost at the top.

Option

Students could get more accurate data if they used spring scales.

Source: **http://www.grc.nasa.gov/www/k12/summer_training/kaeavenuees/inclined_plane.html**

Activity 4: Wheel-and-Axles

Materials

- Skates
- Rubber bands
- Tape measures

Procedure

1. Divide the students into pairs or small groups.
2. Have each group collect a roller skate, a large rubber band and a tape measure.
3. Attach the rubber band to the roller skate.
4. Measure the length of the rubber band before you pull. Record your answer in centimeters.
5. Put the skate on its side and measure in centimeters the rubber band while the skate is being pulled and record your answer.

6. Put the skate on wheels and pull using the rubber band. Measure in centimeters the rubber band during the pull.

7. Have the students write one or two sentences about their results.

Option

Students could use a spring scale to get more accurate data.

Evaluation

Each section of the Work and Machines student handout can be worth 25 points to be distributed in any way the teacher likes. A percentage of this could be the grade. There are 12 questions. One point could be given for each question and this could be used as the criteria for evaluation.

Name(s)____

Work and Machines

Activity 1: Levers

1. What simple machine was used to lift the teacher?

2. Draw a diagram of how it was done and write one or two sentences of explanation.

Activity 2: Pulleys

1. Draw a diagram of the pulley your group made before you tied a knot.

2. Draw a diagram of the pulley your group made after you tied a knot.

3. Which one was more effective (required less force)?

Activity 3: Inclined Planes

1. What was the length in centimeters of the rubber band when you lifted the book straight up (or number of newtons, if you used a spring scale)?

2. What was the length in centimeters of the rubber band when you used the inclined plane (or number of newtons, if you used a spring scale)?

3. What conclusion can you draw from this data?

Activity 4: Wheel-and-Axles

1. What was the length in centimeters of the rubber band after you attached it to the skate?

2. What was the length in centimeters of the rubber band when the skate was on its side (or number of newtons if you used a spring scale)?

3. What was the length in centimeters of the rubber band when the skate was on wheels (or number of newtons, if you used a spring scale)?

4. What conclusion can you draw from this data?

Work and Machines Vocabulary

Amount of work done: To figure the amount of work done, use a formula: **work = force times distance** or **W=*Fd***.

Compound machines: A system of two or more simple machines. The mechanical advantage is greater than with simple machines.

Effort force: The force applied to a machine.

Energy: The ability to cause change or to do work.

Joule (J): A measure of the amount of work done. One joule equals the work done by a force of one newton that moves an object a distance of one meter.

Machine: A device that makes work easier by changing the direction or the size of the force needed to do the work.

Mechanical advantage (M.A.): Tells how many times the effort of the force is increased. **M.A. = resistance force/effort force**.

Power: The rate which work is done. To calculate power you divide the amount of work done by the time it took to do the work. **Power = work/time**.

Resistance force: The force opposing the effort force.

Simple machines: Do work with one movement. There are six types of simple machines: the inclined plane, wedge, screw, lever, wheel-and-axle and pulley. Each changes the size or direction of a force applied to it.

- **Lever**: A board or bar that rests on a fulcrum, or turning point.
    - **Examples**: seesaw, hammer, crowbar
- **Inclined plane:** A flat surface that is higher on one end. You can use this machine to move an object to a lower or higher place making the work of moving things easier.
    - **Examples:** ramp, slanted road, slide, path up a hill
- **Wheel-and-Axle:** An axle is a rod that goes through the wheel. This lets the wheel turn. It is easier to move things from place to place.
    - **Examples:** cars, roller skates, wagons, doorknobs, gears

- **Screw:** A simple machine made from another simple machine. It is actually an inclined plane that winds around a nail. Some screws are used to lower and raise things. Others are used to hold things together.
    - **Examples:** jar lids, light bulbs, stools, clamps, key ring

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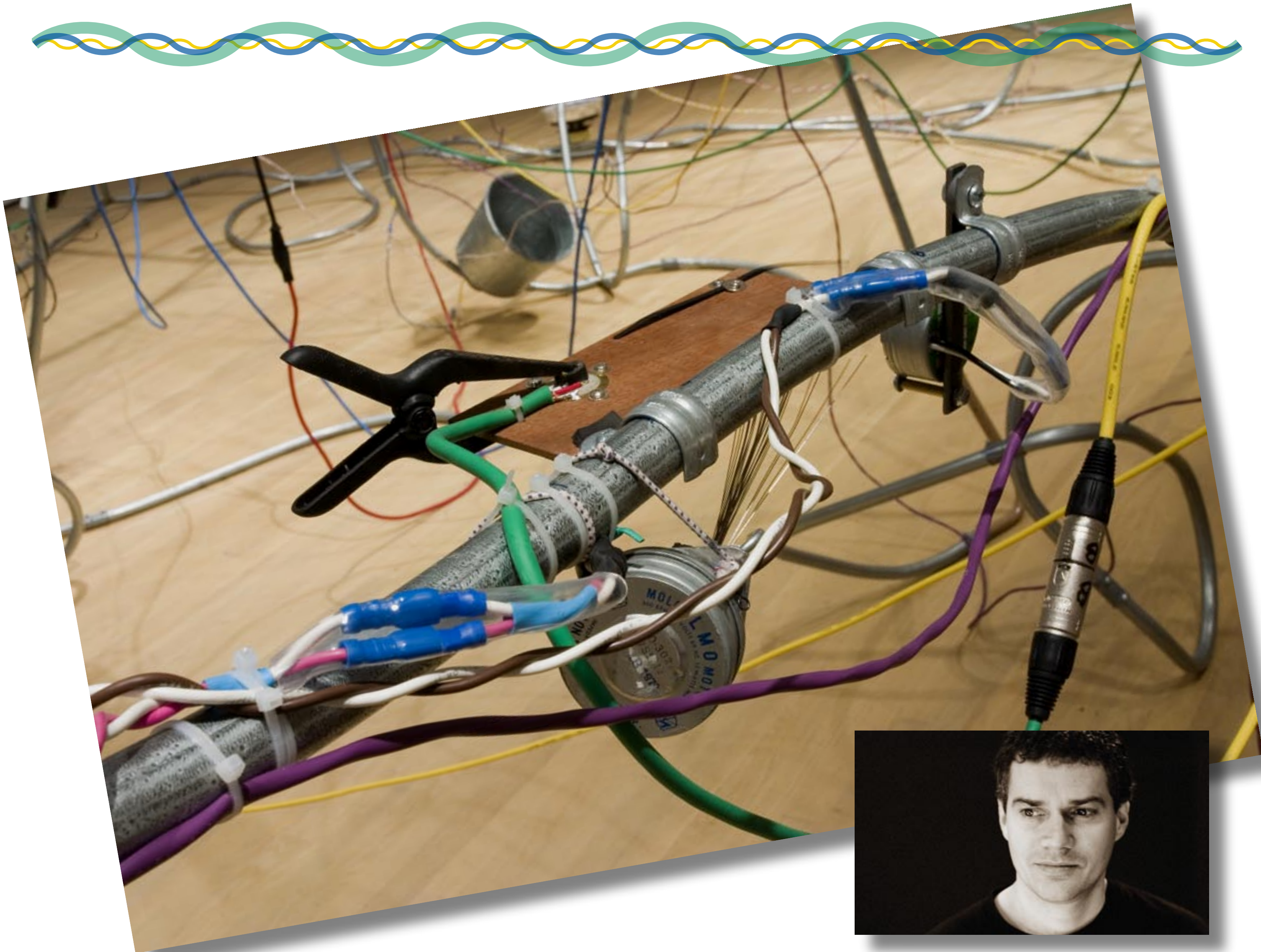
    - **Examples:** nail, fork, knife, axes

- **Pulley:** Made up of a wheel and rope. The rope fits on the groove of the wheel. One part of the rope is attached to the load. When you pull on one side of the pulley, the wheel turns and the load will be moved. Pulleys will let you move loads up, down or sideways. They are good for moving objects too hard to reach places. It also makes the work of moving heavy loads a lot easier.
    - **Examples:** crane, flag poles, clotheslines

Work: Two conditions must be met in order for work to be done on an object. The first is that the object moves. The second is that a force must act on the object in the direction the object moves.



Jean-Pierre Gauthier: Machines at Play

Project

http://www.WesternReservePublicMedia.org/machinesatplay

Machines at Play Project

Standards Addressed

Science — Scientific Way of Knowing

Grade 6

6-8 Benchmark C. *Give examples of how thinking scientifically is helpful in daily life.*

Y2003.CSC.S06.G06-08.BC.L06.I03 Science and Society

03. Identify ways scientific thinking is helpful in a variety of everyday settings.

Y2003.CSC.S06.G06-08.BC.L06.I04 Science and Society

04. Describe how the pursuit of scientific knowledge is beneficial for any career and for daily life.

Grade 7

6-8 Benchmark C. *Give examples of how thinking scientifically is helpful in daily life.*

Y2003.CSC.S06.G06-08.BC.L07.I03 Science and Society

03. Describe how the work of science requires a variety of human abilities and qualities that are helpful in daily life (e.g., reasoning, creativity, skepticism and openness).

Grade 8

6-8 Benchmark A. *Use skills of scientific inquiry processes (e.g., hypothesis, record keeping, description and explanation).*

Y2003.CSC.S06.G06-08.BA.L08.I01 Nature of Science

01. Identify the difference between description (e.g., observation and summary) and explanation (e.g., inference, prediction, significance and importance).

Overview

Students have looked at waves, sound, electricity, forces and motion and work and machines. Now it's time to put it all to use to create "machines at play."

Procedure

1. Review with the students the information that has been covered during this unit. Perhaps the fact sheets that accompany this program could be distributed or made available to them. Review the experiments that were conducted. Try to clear up any content questions that the students might have.

2. Distribute the Machines at Play Project student handout and go over the expectations.

3. Break the students into groups of two to four students each.

4. Give each group a large envelope. Have one person in each group be in charge of the envelope. Instruct them to keep all of their material in that envelope.

5. Below are the directions that are on the student handout:

    a. With your team decide what you want to create. Examples include a catapult to shoot baskets or a rubber band powered car. Use your imagination. Think what might be fun to use or what might be a useful item. (This is the hardest part!)

    b. Construct a plan. Include what you intend to create and what materials you need to create it. Turn it in to your teacher for approval. Remember, you can use any of the things you have studied, so batteries, wires, simple machines, etc., are all available to be used. If possible, draw a diagram of what you will be creating. Be sure to name your machine.

It is a good thing at this point to make sure that the students are doing a project that is appropriate and realistic. Initial the envelope to show that you have approved their plans.

    c. You will have ___ class periods to make your machine at play.

You will need to determine how long you think your students will need to create the machine and to write the report. The entire project generally takes about a week. Sometimes the presentations take a sixth day.

    d. Once the machine is completed, draw a diagram of it.

    e. Label the forces needed to make the machine work. Label any simple machines that you used.

    f. Write a two- to three- paragraph explanation including the following information about your machine.

        i. Materials used

        ii. Forces required to operate the machine

        iii. Any simple machines that were involved

        iv. If you used sound or light, tell about the wave

        v. If you need a circuit, explain if it is serial or parallel and label the parts

        vi. Describe who did what on the project

You can once again set any parameters you would like on their report. You can request that it be word processed, that diagrams be a part of the report, for example.

g. Write a set of directions on how to use this "machine at play."

This is an additional step. Extra points can be given for this.

h. Present your machine to the class. Be prepared to answer questions about your "machine at play."

Once again, presentations can take whatever form that you prefer. It can be an "event" where there is a contest for the best machine or it can be a one- or two-minute activity per group.

Evaluation

Use the project rubric is on the student handout and the presentation rubric below.

Rubric for Presentation

CATEGORY	4	3	2	1
Content	Shows a full understanding of the topic.	Shows a good understanding of the topic.	Shows a good understanding of parts of the topic.	Does not seem to understand the topic very well.
Stays on Topic	Stays on topic 100 percent of the time.	Stays on topic 90 percent to 99 percent of the time.	Stays on topic 75 percent to 89 percent of the time.	It was hard to tell what the topic was.
Speaks Clearly	Speaks clearly and distinctly 100 percent of the time, and pronounces all words correctly.	Speaks clearly and distinctly 95 percent to 99 percent of the time, but mispronounces one word.	Speaks clearly and distinctly 85 percent to 94 percent of the time. Mispronounces one word.	Often mumbles or can not be understood; mispronounces more than one word.
Collaborates With Peers	Almost always listens to, shares with and supports the efforts of others in the group. Tries to keep people working well together.	Usually listens to, shares with and supports the efforts of others in the group. Does not cause "waves" in the group.	Often listens to, shares with and supports the efforts of others in the group but sometimes is not a good team member.	Rarely listens to, shares with or supports the efforts of others in the group. Often is not a good team member.

Machines at Play Project

You have looked at waves, sound, electricity, forces and motion and work and machines. Now it's time to put it all to use. You and your team are going to create a "machine at play."

Procedure

1. With your team, decide what you want to create. Examples include a catapult to shoot baskets or a rubber band powered car. Use your imagination. Think what might be fun to use or what might be a useful item. This is the hardest part!

2. Construct a plan. Include what you intend to create and what materials you need to create it and turn it in to the teacher for approval. Remember you can use any of the things we have studied so batteries, wires, simple machines, etc. are all available to be used. If possible draw a diagram of what you will be creating. Be sure to name your "machine at play."

3. You will have ___ class periods to make your machine at play.

4. Once the machine is completed, draw a diagram of it.

5. Label the forces needed to make the machine work. Label any simple machines that you used.

6. Write a two- to three-paragraph explanation including the following information about your machine.

    a. Materials used

    b. Forces required to operate the machine

    c. Any simple machines that were involved

    d. If you used sound or light, tell about the wave

    e. If you need a circuit, explain if it is serial or parallel and label the parts

    f. Describe who did what on the project

7. Write a set of directions on how to use this "machine at play."

8. Present your machine to the class. Be prepared to answer questions about your "machine at play."

Evaluation

Use the rubric below to help you know what is expected of you. You can get 250 points for the entire project.: 100 points for the "machine at work," 100 points for the reports and 50 points for your presentation.

CATEGORY	Great	Good	Satisfactory	Needs Help
Plan	Plan is neat with clear measurements and labeling for all components.	Plan is neat with clear measurements and labeling for most components.	Plan provides clear measurements and labeling for most components.	Plan does not show measurements clearly or is otherwise inadequately labeled.
Scientific Knowledge	Explanations by all group members indicate a clear and accurate understanding of scientific principles underlying the construction and modifications.	Explanations by all group members indicate a relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by most group members indicate relatively accurate understanding of scientific principles underlying the construction and modifications.	Explanations by several members of the group do not illustrate much understanding of scientific principles underlying the construction and modifications.
Construction Materials	Appropriate materials were selected and creatively modified in ways that made them even better.	Appropriate materials were selected and there was an attempt at creative modification to make them even better.	Appropriate materials were selected.	Inappropriate materials were selected and contributed to a product that performed poorly.
Modification/Testing	Clear evidence of troubleshooting, testing and refinements based on data or scientific principles.	Clear evidence of troubleshooting, testing and refinements.	Some evidence of troubleshooting, testing and refinements.	Little evidence of troubleshooting, testing or refinement.

"Machine at Work" machine ____________ points

Report ____________ points

Presentation ____________ points

Comments:

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A service of Western Reserve Public Media
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