ubi Sci

Sp Wv

Es NL

Ubiquitous Science

WESTERN RESERVE
PUBLIC MEDIA

http://www.WesternReservePublicMedia.org

Table of Contents

Ubiquitous Science

Overview

Canadian artist Jean-Pierre Gauthier created an interactive display of kinetic art at the Akron Art Museum. This art display and the science involved in creating it is the focus of this science multimedia package.

So what is kinetic art? It 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. Jean-Pierre Gauthier is a kinetic artist. He uses motion sensors to track the movements that people make. Their motion triggers his artwork to either move or make sounds or patterns.

Ubiquitous Science contains four modules. Each module deals with Benchmark B from the physical science content standards in grade 8. Benchmark B states, "In simple cases, describe the motion of objects and conceptually describe the effects of forces on an object."

Science Videos

There are four short videos that are available on the Western Reserve Public Media Web site (**http://www.WesternReservePublicMedia.org/ubiscience**), on iTunes and on D3A2.

1. Speed, Velocity and Weightlessness
2. Waves
3. The Electromagnetic Spectrum
4. Newton's Laws

Professional Development Videos

There is a professional development video to go with each instructional video. The goal and concepts covered as well as the overview of the video and the lessons that go along with it are previewed. These are available at **http://www.WesternReservePublicMedia.org/ubiscience**.

Credits

Project Coordinator
Maria Mastromatteo, Western Reserve Public Media

Teacher Guide

Teacher Design Team
Cathy Page Adler, Ravenna City School District

Zach Griffith, LaBrae Local School District

Gene Lynn, Copley-Fairlawn City School District

Bunny Perrin, Norton City School District

Teacher Guide Layout and Design
Paula Kritz, Western Reserve Public Media

Video

Produced by Western Reserve Public Media (WNEO/WEAO, Youngstown/Akron, Ohio)

Executive Producer
Maria Mastromatteo, Western Reserve Public Media

Producer
Duilio Mariola, Western Reserve Public Media

Videographer
Duilio Mariola, Western Reserve Public Media

Video Script
Larry Chance, Chance Productions

Professional Development Script
Cathy Page Adler, Ravenna City School District

Web

Layout and Design
Paula Kritz, Western Reserve Public Media

Funding

Funded by the Ohio Legislature through the eTech Ohio Commission

Ohio | eTech Ohio

Teacher Guide

A teacher guide is provided for each module and contains the following items:

- Introductory material
- A formative assessment
- A set of standards-based lesson plans with student handouts and resource materials
- A summative assessment
- A vocabulary list

The guide is available at **http://www.westernreservepublicmedia.org/ubiscience** and at D3A2.

Speed, Velocity and Weightlessness

WESTERNRESERVE
PUBLIC MEDIA

Speed, Velocity and Weightlessness

Distance and displacement are two quantities that may seem to mean the same thing, but they have distinctly different definitions and meanings.

- **Distance** refers to how much ground an object has covered during its motion. It has a numeric value.
- **Displacement** refers to how far out of place an object is. It is the object's overall change in position described with a numeric value and a direction.

Just as distance and displacement have distinctly different meanings (despite their similarities), so do speed and velocity.

- **Speed** is how fast something is moving or how much distance is covered in a certain amount of time. There are two types of speed: **instantaneous speed**, which is an object's speed at any given movement and **average speed**, which is the average of all instantaneous speeds. To calculate speed, you divide the total distance by the time: **s = d/t**.
- **Velocity** is the same as speed but it has a direction associated with it. Speed has no specific direction.

It is possible to have a negative velocity. This means that the object is going backward. It is not possible to have a negative speed because there is no specific direction.

Vectors are units with a direction associated with them.

Free fall is objects falling unaffected by air resistance. On Earth, we can't fall without air resistance. When things fall, they constantly accelerate until they reach **terminal velocity**, or the velocity at which the upward force of air resistance equals the downward force of gravity. Once you reach this velocity, you will no longer accelerate but will just fall at the same rate.

The formula for determining the distance something will fall is $d = \frac{1}{2} a t^2$, where "d" is the displacement it falls, "a" is acceleration, which on Earth is 9.8 m/s^2, and "t" is time. Everything accelerates at the same rate if we can neglect air resistance. Things that affect air resistance include the shape of an object (the more surface area means more air resistance.), the velocity (the faster you go, the more air resistance.) and the "thickness" of the air (there is less air resistance the higher you go up in the atmosphere.).

Weightlessness on the International Space Station has to do with the frame of reference. If everything is falling at the same rate, it appears as though an object is floating with no gravity. If you put a penny on your knee and go on an amusement park ride such as the Demon Drop at Cedar Point, the penny will "float" in front of you, at least from your frame of reference. It actually is falling at the same rate that you are. If you think about being in the space station, everything is falling with you, so you can't tell that you are falling.

Reaction Time Meter

Overview

Following a discussion about free fall, students will make a reaction timer that uses free fall to test reaction time. They will then test their own reaction time and compare it with the results of other students in the class. They will end with questions on how this relates to free fall.

Standards Addressed

Grade 8, Physical Science

06-08 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.

Y2003.CSC.S03.G06-08.BB.L08.I02 / Forces and Motion

02. Explain that motion describes the change in the position of an object (characterized by a speed and direction) as time changes.

Y2003.CSC.S03.G06-08.BB.L08.I03 / Forces and Motion

03. Explain that an unbalanced force acting on an object changes that object's speed and/or direction.

Materials

- Strips of thick paper (construction paper, poster board, card stock) per group, cut to make approximately 2 cm by 30 cm strips
- Rulers
- Calculators

Procedure — Free Fall Formative Assessment

1. Have the students complete the Free Fall Formative Assessment handout.
2. Set up the PowerPoint file titled speed_freefall.ppt found at **http://www.WesternReservePublicMedia.org/ubiscience**.
3. Review and discuss all questions from the assessment as you work through the PowerPoint presentation.

Formative Assessment Answers

1. *c. Both will hit at the same time. The mass of the ball does not affect the rate at which it falls.*

2. *c. Both will hit at the same time. The volume of the spheres does not affect the rate at which they fall.*

3. *c. The shape of the parachute causes more air resistance, or friction, which slows the rate at which he can fall.*

4. *a. It will continually drop at the same rate.*

5. *a. Everything on the space station is falling, so in comparison it seems as though everything is floating. The space station is held near the Earth by gravity. It is not far enough away to experience zero gravity.*

Procedure — Reaction Time Meter Activity

1. Divide students into groups of two.

2. Give each group a Reaction Time Meter Activity worksheet, paper strip and ruler.

3. Read through the introduction with the class and help them fill out the chart. Depending on the level of your students or time constraints, you may want to give your class the completed chart for them to fill in.

Displacement (cm)	Time (s)	Displacement (cm)	Time (s)	Displacement (cm)	Time (s)
1.225	0.05	7.056	0.12	17.689	0.19
1.764	0.06	8.281	0.13	19.6	0.2
2.401	0.07	9.604	0.14	21.609	0.21
3.136	0.08	11.025	0.15	23.716	0.22
3.969	0.09	12.544	0.16	25.921	0.23
4.9	0.1	14.161	0.17	28.224	0.24
5.929	0.11	15.876	0.18	30.625	0.25

4. After students have filled in their charts, help them create their reaction time meter by measuring out all the distances they have just calculated on their strip of paper. Make certain that all measurements are made from the bottom line, not from the last line measured.

5. Help students use their reaction time meter once they have completed making it. One student holds a hand over the edge of a desk with his or her thumb and forefinger an inch apart. The other student holds the reaction time meter so that his or her thumb is over the "0s" line.

6. Without warning, the first student drops the reaction time meter, while the other student attempts to catch it. By looking at where they caught it, they can see how long it took. They must have a partner for this so that the second student doesn't know when it will be dropped. You place you hand over the edge of a desk so you don't drop your hand lower when trying to catch it.

7. Help the students take an average of their times.

8. Help the students with the questions at the end of the worksheet.

Enrichment

This can be done using the dominant hand followed by the weaker hand. Find the average of each. Gather the data from the whole class using the ordered pair (right hand, left hand). Make a scatter plot of class data. Make sure that that there is a title for the graph, that the axes have equal intervals and that each axis is labeled. If there are left-handed students in the class, these points will appear as outliers on the graph. This is an excellent way to get across the concept that outliers are points that need to be examined and explained, not deleted.

Summative Assessment Answers

1. *Gravity.*
2. *Unbalanced, because is causes a change in motion.*
3. *The lines get further apart. The card is in constant acceleration and each second, it falls faster than the previous second.*
4. *a. The card is moving downward.*
   b. The card is not moving; the hand is moving upward.

Rubric for Lab

CATEGORY	4	3	2	1
Construction — Care Taken	Great care was taken in the construction process so that the structure is neat, attractive and correct.	Construction was careful and accurate for the most part, but one or two details could have been refined for a more attractive product.	Construction accurately followed the plans, but three or four details could have been refined for a more attractive product.	Construction appears careless or haphazard. Many details needed refinement for a strong or attractive product.
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.
Function	Structure functions extraordinarily well, holding up under atypical stresses.	Structure functions well, holding up under typical stresses.	Structure functions somewhat well, but deteriorates under typical stresses.	Fatal flaws in function with complete failure under typical stresses.
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.

Name______________________________

Free Fall
Formative Assessment

1. If a 6 kg cannon ball and a 200 g softball of equal volumes are dropped from the same height off a roof, which will hit the ground first?

   a. The cannon ball.

   b. The softball.

   c. Both will hit at the same time.

   d. Cannot be determined.

2. If a 900 mL softball and a 200 mL hardball of equal masses are dropped from the same height off a roof, which will hit the ground first?

   a. The softball.

   b. The hardball.

   c. Both will hit at the same time.

   d. Cannot be determined.

3. Which statement best describes why a man wearing a parachute falls more slowly than a man not wearing a parachute?

   a. The parachute provides lift by Bernoulli's principle.

   b. When the parachute is released, the reaction force lifts the person.

   c. The shape of the parachute causes more air resistance, or friction, which slows the rate at which he can fall.

4. When falling down on Earth, you eventually reach a state of terminal velocity. This is the velocity where the upward force of air resistance balances out the downward force of gravity on an object. What will happen to the object once this velocity is reached?

    a. It will continually drop at the same rate.

    b. It will continually fall more quickly.

    c. It will continually fall more slowly.

    d. It will stop falling.

5. Which statement best describes why things are weightless on the International Space Station?

    a. Everything on the space station is falling, so in comparison it seems like everything is floating.

    b. There is no gravity in outer space.

    c. It is too far away from the Earth to experience gravity.

    d. Things have no mass in outer space.

Name____

Reaction Time Meter Activity

How quick are your reflexes? How long does it take for you to see something and then react to it?

We are going to use the principles of free fall to figure this out. We know that all objects on planet Earth accelerate at 9.8 m/s^2, if we can ignore air resistance. Now, of course, air resistance does exist, but if we have an aerodynamic shape and a low velocity, then the air resistance won't noticeably change the speed. We can test reaction time using a strip of heavier paper.

The equation to determine how far something will fall in a given amount of time is displacement = ½ acceleration $(\text{time})^2$, or
$d = \frac{1}{2} a t^2$.

If the strip of paper falls x .05 seconds:
$d = \frac{1}{2} (9.8) \times .05^2$
=.01225 m

Multiply the displacement in meters by 100 to put it in centimeters.

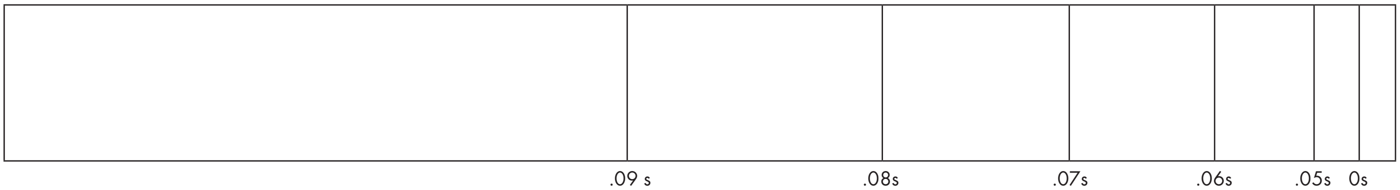
.01225 x 100 = 1.225 cm

We need to first fill in a chart for this.

Displacement (cm)	Time (s)	Displacement (cm)	Time (s)	Displacement (cm)	Time (s)
1.225 cm	0.05		0.12		0.19
	0.06		0.13		0.2
	0.07		0.14		0.21
	0.08		0.15		0.22
	0.09		0.16		0.23
	0.1		0.17		0.24
	0.11		0.18		0.25

Now that we have all the distances, we need we can make our reaction timer out of the strip of card stock.

(This is not to scale. See p. 18 for an accurate model.)



Procedure

Follow these steps to correctly mark your strip of card stock:

1. At the very bottom, make a line across the narrow end and mark it 0s.
2. Measure 1.225 cm above that line and make another line. Mark it .05s.
3. Measure the displacement you calculated in the chart above for .06s from the 0s line, and mark this line as .06s.
4. Repeat this for every other time that you calculated above until it is longer than your sheet of paper. It will look similar to the drawing above, except it will have lines for many more seconds and they will be closer together.

We now have a reaction timer.

To use a reaction timer, work with a partner as follows:

1. Place your hand over the edge of a desk with your thumb and index finger 5 cm apart.
2. Your partner will hold the reaction timer so that the zero-second line is at the bottom and the other lines are above it.
3. Line the zero-second line up with your thumb. Your partner drops the timer without warning. You catch it. Look where you caught it to see how long your reaction time was.

Test your reaction time five different times and record the results below.

Trial	Reaction times
1	
2	
3	
4	
5	

Take the average of your times (add them up and divide by five) and record it below:

Average reaction time ______________________________

Reaction Timer

.23s

.22s

.21s

.20s

.19s

.18s

.17s

.16s

.15s

.14s

.13s

.12s

.11s

.10s

.09s

.08s

.07s

.06s

.05s

0s

Name____

Free Fall
Summative Assessment

1. What force causes the reaction timer to fall?

2. Is this force balanced or unbalanced? How can you tell?

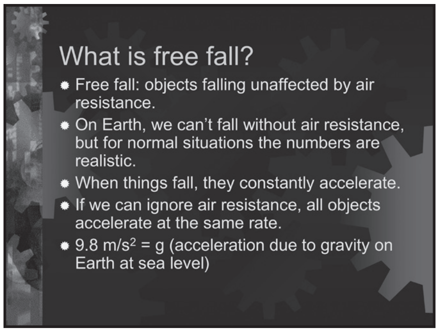
3. What happens to the space between the lines as the time increases? Why?

4. Tom Thumb, a very small man who is the size of a thumb, sits on a student's thumb as the student tries to catch a reaction timer.

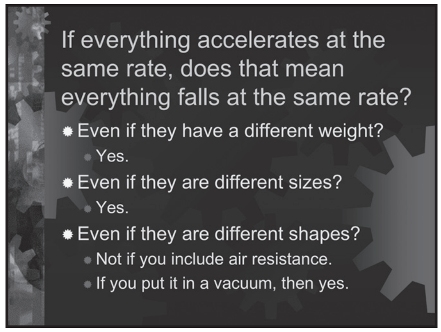
    a. From the frame of reference of sitting on the thumb, describe the motion.

    b. Now Tom jumps off just as the reaction timer is released. Describe the motion from this frame of reference.

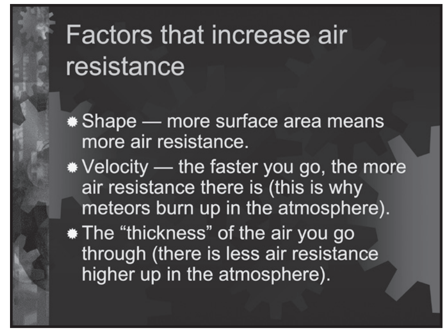
Free Fall PowerPoint Presentation



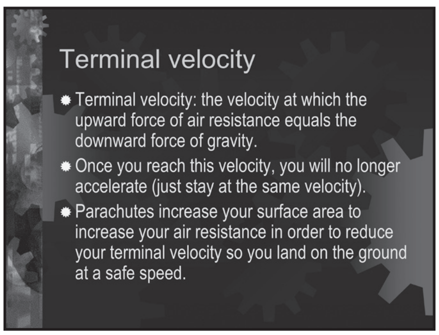
Slide 1



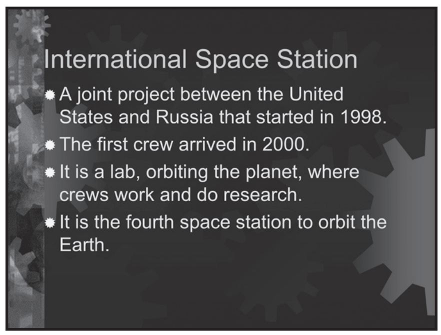
Slide 2



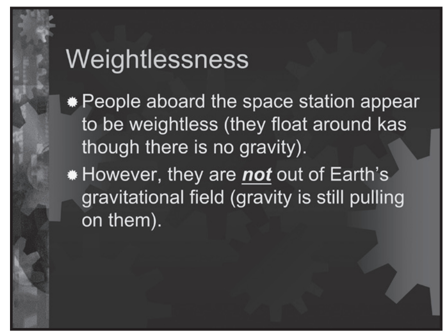
Slide 3



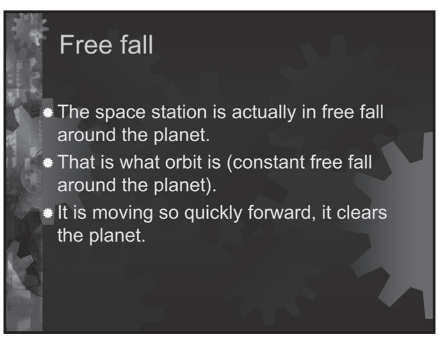
Slide 4



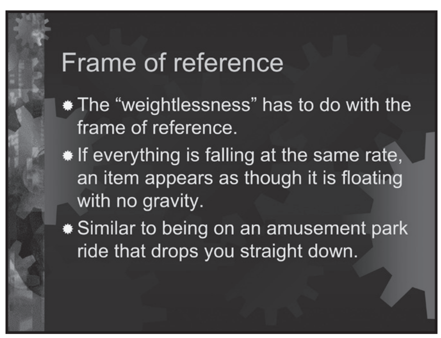
Slide 5



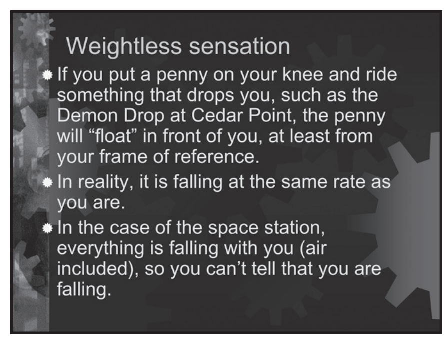
Slide 6



Slide 7



Slide 8



Slide 9

What's My Velocity?

Overview

The students will first discuss velocity and speed in class. Afterward, they will work in groups to walk a course and determine their own walking velocity. They will then compare it to other students' velocity in the class. They will end with questions on how this relates to the lesson.

Standards Addressed

Grade 8, Physical Science

06-08 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.

Y2003.CSC.S03.G06-08.BB.L08.I02 / Forces and Motion

02. Explain that motion describes the change in the position of an object (characterized by a speed and direction) as time changes.

Y2003.CSC.S03.G06-08.BB.L08.I03 / Forces and Motion

03. Explain that an unbalanced force acting on an object changes that object's speed and/or direction.

Materials

- Masking tape
- PowerPoint file titled speed_velocity.ppt
- Stopwatches
- Calculators

Procedure

1. Prepare the room beforehand by measuring out a 10-meter course and marking it with tape.
2. Have the students take the formative assessment.
3. Show the PowerPoint file.
4. Review and discuss all questions from the formative assessment in the PowerPoint as they are given.

5. Divide the class into groups of two.
6. Hand out to each group the What's My Velocity? worksheet and a stopwatch.
7. Review the worksheet instructions with the students and demonstrate how to walk the course, pointing out the starting and ending points.
8. Have one student walk while the other times him or her.
9. Make sure students are walking at the same pace all three times.
10. Help students with all calculations as needed.
11. Answers for the lab will vary based upon student times.

Formative Assessment Answers

1. *d. 5 m/s. Average speed is determined by taking distance traveled divided by time.*
2. *b. It is moving backward.*
3. *b. Turn.*
4. *a. 16 m. The distance is the sum of all distances walked.*
5. *c. 8 m N. The displacement is 12 meters north minus 4 meters south.*

Evaluation

The Velocity and Speed Summative Assessment will be used for evaluation purposes.

Rubric for Lab

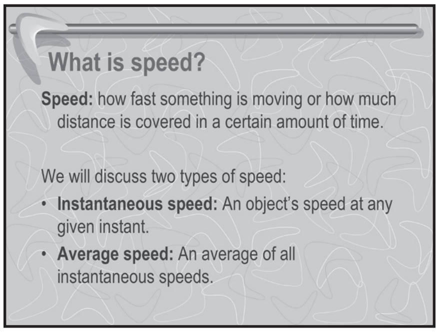
Building a Structure: What's My Velocity Lab

CATEGORY	4	3	2	1
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.
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully, or not taken in a reliable manner.

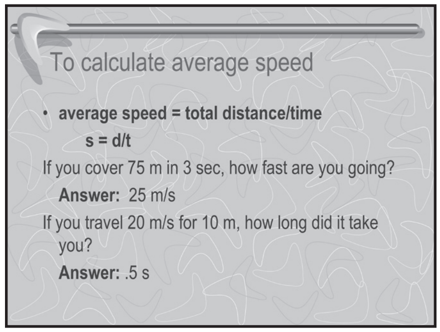
Answers for Velocity and Speed Summative Assessment

1. *a. Rate of motion.*
   b. Speed in a certain direction.
   c. How far something has moved.
   d. Distance in a certain direction.
2. *Speed = distance / time. Velocity = displacement / time.*
3. *Distance = 15m + 6 m + 4 m + 3 m = 28 m. Displacement = 15 m N - 6 m S + 4 m N - 3 m S = 10 m N.*

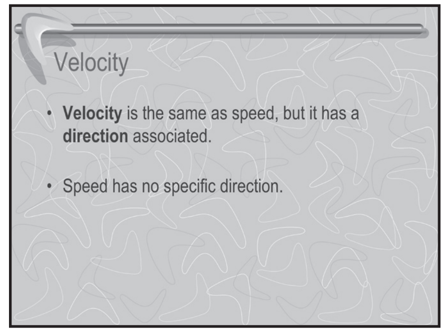
Velocity and Speed PowerPoint Presentation



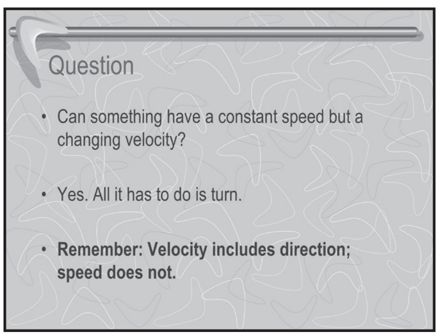
Slide 1



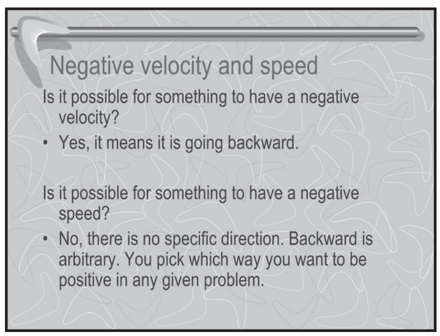
Slide 2



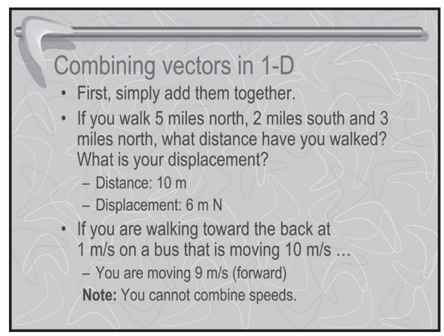
Slide 3



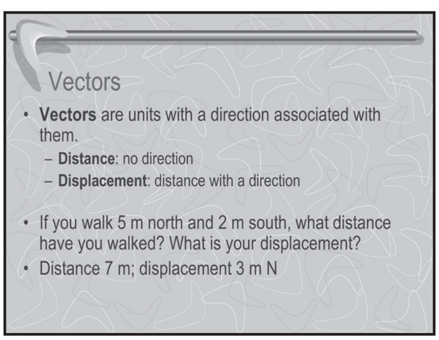
Slide 4



Slide 5



Slide 6



Slide 7

Name____

Velocity and Speed Formative Assessment

1. If an object moves 15 meters in three seconds, what is its average velocity?
   a. 18 m/s.
   b. 12 m/s.
   c. 45 m/s.
   d. 5 m/s.

2. What does it mean if something has a negative velocity?
   a. It is moving backward.
   b. It is not moving.
   c. It is speeding up.
   d. It is slowing down.

3. How can you change the velocity but not change the speed of an object?
   a. Speed up.
   b. Turn.
   c. Slow down.
   d. Stop.

4. If John walks 12 meters north and 4 meters south, what distance has he walked?
   a. 16 m.
   b. 12 m N.
   c. 8 m N.
   d. 3 m N.

5. If John walks 12 meters north and 4 meters south, what displacement has he walked?
   a. 16 m.
   b. 12 m N.
   c. 8 m N.
   d. 3 m N.

Name____

What's My Velocity?

Today we are going to determine rates of speed and velocity.

Procedure

1. Have a partner time your walk. He or she should stand at the finish line, tell you when to start walking and stop the stopwatch as you cross the end line.
2. Each person should walk three times at the same pace to make sure there wasn't a mistake with the stopwatch. It is important to try and walk at the same pace all three times.
3. If one time is far off from the others, redo the trial.
4. Fill the times in the chart.
5. Divide the distance of the course by your time for each trial and determine each individual velocity.
6. Take the average of all three velocities.

	Trial 1	Trial 2	Trial 3
Time for trip (seconds)			
Displacement for trip (meters)	10.0 m	10.0 m	10.0 m
Velocity of trip			

Average velocity: ________________

Round Trip

1. Have your partner time you as you walk. Walk from one end of the course to the other, turn around and walk back again. Time of trip: ________________
2. What was the distance that you walked? ________________
3. What was your displacement? ________________
4. What was your speed? ________________
5. What was your velocity? ________________

Name____

Velocity and Speed Summative Assessment

1. Define the following terms.

    a. Speed:

    b. Velocity:

    c. Distance:

    d. Displacement:

2. Give the formula for speed and velocity:

3. If you walk 15 miles north, six miles south, four miles north and three miles south, what is the total distance you walked and what is your displacement? If this trip took you 40 seconds, what is your speed and velocity? Label all quantities.

Speed, Velocity and Weightlessness Vocabulary

Average speed: An average of all instantaneous speeds.

Balanced forces: Two forces that are equal in size and opposite in direction. Balanced forces have a net force of zero.

Displacement: Distance in a given direction. If you walk 5 miles north and 2 miles south, your distance is 7 miles. Your displacement is 3 miles north.

Displacement: How far something will fall in a given amount of time. (displacement = ½ acceleration x $(\text{time})^2$ or $d = \frac{1}{2} at^2$)

Free fall: Objects falling that are unaffected by air resistance. If we ignore air resistance, all objects fall at the same rate. (Acceleration due to gravity of Earth at sea level is $g = 9.8\ m/s^2$.)

Instantaneous speed: An object's speed at any given instant.

Negative velocity: Means object is going backward.

Speed: How fast something is moving or how much distance is covered in a certain amount of time. (Average speed = total distance / time or s= d/t.)

Terminal velocity: The velocity at which the upward force of air resistance equals the downward force of gravity. Once you reach this velocity you will not longer accelerate.

Unbalanced forces: Two forces with different strengths working against each other.

Vector: Units with a direction associated with them.

Velocity: The same as speed, but it has a direction associated with it. Speed has no direction. (Velocity = displacement/time or v = d/t.)

Weightlessness: Has to do with the frame of reference. Because everything is falling at the same rate, it appears as though an item is floating with no gravity.

Waves

WESTERN RESERVE PUBLIC MEDIA

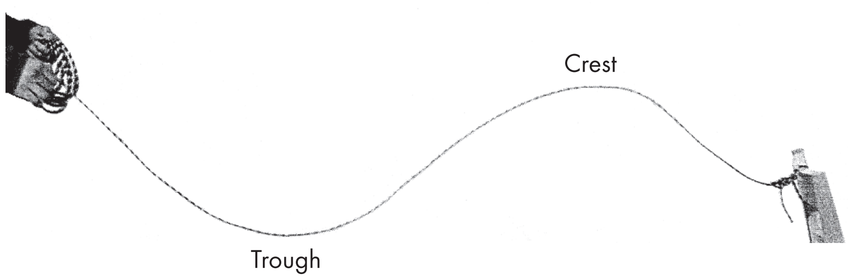
Waves and Speed

When you think of waves, you probably think of the ocean's 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.

Types of Waves

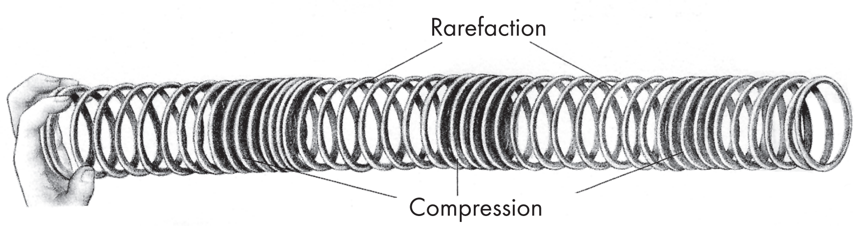
There are two types of waves as determined by the way the energy disturbs the molecules. One is called a **transverse wave**. If you tie one end of a rope to a chair, hold the other end and move it up and down, you create a transverse wave in the rope. The fibers that make up the rope move up and down.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

Waves spread away from the source in all directions.

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.

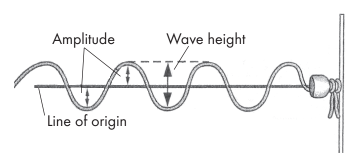
The wavelength of a transverse wave is the distance between two neighboring crests or between two troughs.

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.

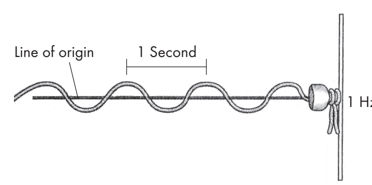
The wavelength of a longitudinal wave is the distance between two consecutive compressions or rarefactions.

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.

Overview

Students will see two examples of a transverse wave. They will become familiar with the terms crest, trough, period and amplitude.

Types of Waves

Standards Addressed

Science, Physical Science

Grade 8

6-8 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.

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

04. Demonstrate that waves transfer energy.

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

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).

Materials

- Ropes
- Slinky toys

Procedure

1. Distribute the formative assessment. (This assessment is for the entire module that covers the standards listed above.) Students will work on the assessment independently.

2. Have the students come to the front of the room and lock arms. 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. Have two students hold the ends of a long rope. The person on one end should create a wave by lifting one end. Students should watch what happens to the rope as the energy moves across it.

5. Ask a student to draw a picture of the rope on the board. Introduce this as a transverse wave.

6. Discuss the concepts of crest and trough (crest is highest point and trough is lowest point).

7. Have the students do the same thing, but lift it much higher or lower. Ask what happens to the height of the wave. (It gets larger as more energy is applied. This effect is called amplitude.)

8. Explain that a period is a repeating segment of time, such as a year or a class period. Ask the students if they can describe what a period of a wave might be. (The time it takes a wave to repeat itself.)

9. Use the Introduction to Waves PowerPoint presentation.

10. Instruct the students to record their observations on the Introduction to Waves student handout.

11. Invite them to share with the class what they know about different types of waves. Be sure to discuss different types of waves that are familiar to them, such as radiowaves, microwaves, ocean waves, sound waves, light waves and ultraviolet waves.

12. Divide the students into groups of two or three and give each group a Slinky.

13. Ask each group to draw a picture of what the Slinky looks like when an energy is applied to it.

14. Introduce the words compression or longitudinal waves and rarefaction.

15. Go over formative assessment questions 1 and 2.

Evaluation

Because this is an introductory lesson, it is important to make sure the students have a complete understanding before they continue. For that reason, it is important to go over the handout with the students after they have completed it. They could grade their own paper or exchange papers. There are five questions. Students could write the number they got correct over the total number.

Name____

An Introduction to Waves

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

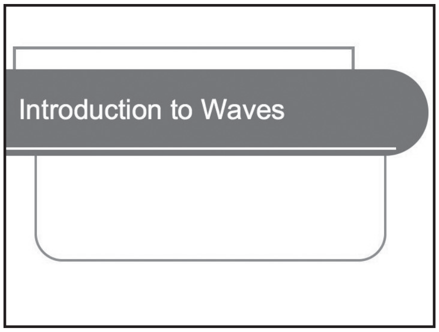
2. What did you observe when the teacher pushed and pulled the group forward and backward? What type of wave is this?

3. When you went back and forth faster, what did you observe about the rope with regard to the wave length and frequency?

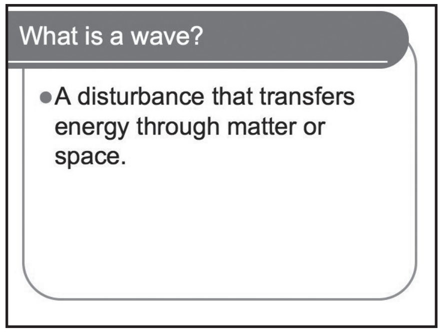
4. Draw a picture of this wave below. Label the trough, the crest and amplitude. (This is called a transverse wave.)

5. Have one student hold each end of the Slinky. Pull one end. Draw a picture of what happens to the Slinky when one end is pulled. (This is called a compression or a longitudinal wave.) Label the points of compression and rarefaction.

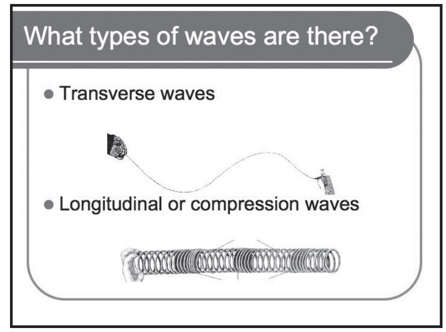
Waves PowerPoint Presentation



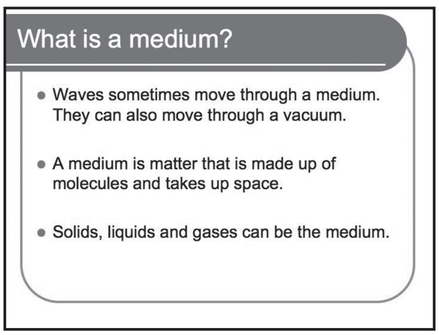
Slide 1



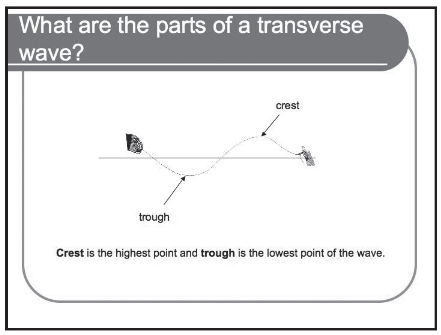
Slide 2



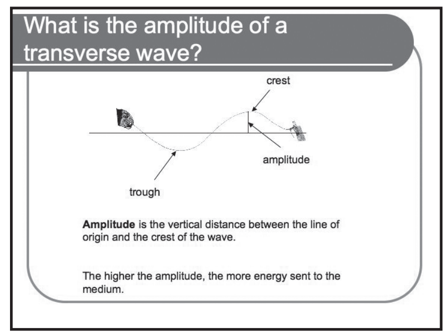
Slide 3



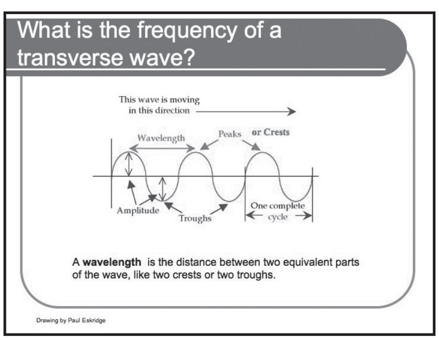
Slide 4



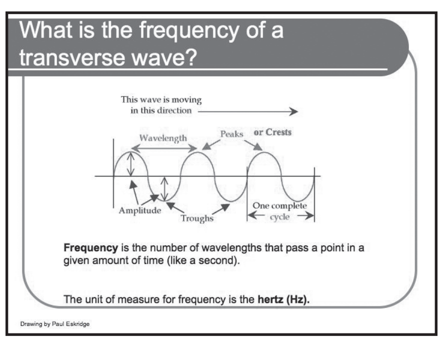
Slide 5



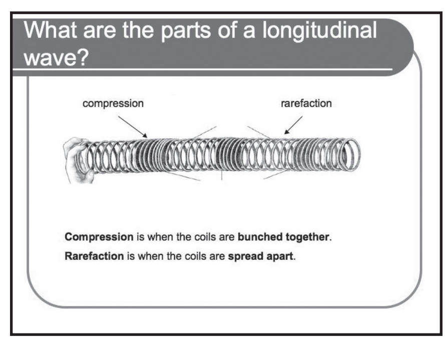
Slide 6



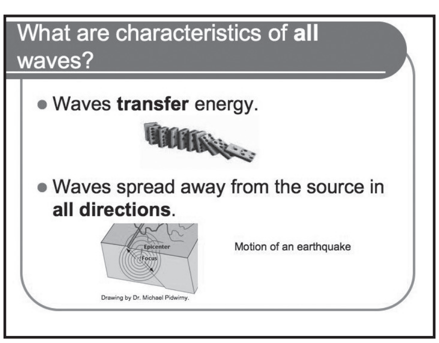
Slide 7



Slide 8



Slide 9



Slide 10

Ripples

Overview

Students will create waves using shallow water and pebbles. They will record what happens to the water and what happens to a cork placed in the water. They will then design their own experiment that explains wave characteristics related to energy transfer. They will create a graph and write an explanation of the graph and the conclusion they draw from it.

Standards Addressed

Science, Physical Science

Grade 8

6-8 Benchmark — *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.*

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

04. Demonstrate that waves transfer energy.

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

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).

Materials

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

Procedure

1. Review the types of waves from the first lesson.
2. Have the students work with a partner or a group of three.
3. Have each group of students fill a shallow pan with some water. Instruct them to drop a pebble into the water and write a sentence to tell what happened.
4. 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.

5. Have the groups increase the depth of the water and repeat the exercise. Instruct them to write a sentence to describe their results.

6. After these initials activities have been done, ask the students to design their own experiment that explains wave characteristics related to energy transfer. Remind students that the data they collect should be measureable and can include distance, time, diameter or mass.

7. Ask the students to create a graph that shows their data collection. They can do this by hand or by using Excel or Create-a-Graph at **http://nces.ed.gov/nceskids/createagraph/default.aspx**.

8. They then need to discuss whether their hypothesis is correct and what conclusions they draw from the experiment.

Evaluation

Rubric for Graph and Explanatory Paragraph

CATEGORY	10-9	8-6	5-3	2-1
Accuracy of Plot	All points are plotted correctly and are easy to see. A ruler is used to neatly connect the points or make the bars, if not using a computerized graphing program.	All points are plotted correctly and are easy to see.	All points are plotted correctly.	Points are not plotted correctly, or extra points were included.
Units	All units are described (in a key or with labels) and are appropriately sized for the data set.	Most units are described (in a key or with labels) and are appropriately sized for the data set.	All units are described (in a key or with labels) but are not appropriately sized for the data set.	Units are neither described nor appropriately sized for the data set.
Title	Title is creative and clearly relates to the problem being graphed (includes dependent and independent variable). It is printed at the top of the graph.	Title clearly relates to the problem being graphed (includes dependent and independent variable) and is printed at the top of the graph.	A title is present at the top of the graph.	A title is not present.
Labeling of X-axis	The x-axis has a clear, neat label that describes the units used for the independent variable (e.g, days, months, participants' names).	The x-axis has a clear label that describes the units used for the independent variable.	The x-axis has a label.	The x-axis is not labeled.
Labeling of Y-axis	The y-axis has a clear, neat label that describes the units and the dependent variable (e.g, percentage of dog food eaten; degree of satisfaction).	The y-axis has a clear label that describes the units and the dependent variable (e.g, percentage of dog food eaten; degree of satisfaction).	The y-axis has a label.	The y-axis is not labeled.

Evaluation of Explanation Paragraph

CATEGORY	10-9	8-6	5-3	2-1
Quality of Information	Information clearly relates to the main topic. It includes several supporting details and/or examples.	Information clearly relates to the main topic. It provides one or two supporting details and/or examples.	Information clearly relates to the main topic. No details and/or examples are given.	Information has little or nothing to do with the main topic.
Paragraph Construction	All paragraphs include introductory sentence, explanations or details and concluding sentence.	Most paragraphs include introductory sentence, explanations or details and concluding sentence.	Paragraphs include related information but are typically not constructed well.	Paragraphing structure is not clear and sentences are not typically related within the paragraphs.
Mechanics	There are no grammatical, spelling or punctuation errors.	There are almost no grammatical, spelling or punctuation errors.	There are a few grammatical spelling or punctuation errors.	There are many grammatical, spelling or punctuation errors.

Name____

Create Your Own Ripples

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

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

3. What happened to the cork when you dropped the pebble into the deeper water?

Your Experiment

A. Design an experiment that explains wave characteristics related to energy transfer. Remember that you need to collect measureable data. This data can include distance, time, diameter or mass. Write your experimental plan.

B. Write your hypothesis.

C. What is the independent variable in your experiment?

D. What is the dependent variable in your experiment?

E. Put your information into a table.

F. Create a graph of your findings.

G. Write a paragraph that tells if your hypothesis is correct and why or why not.

Energy Transformation

Overview

Students will try to show transfer of energy by using marbles. They will then try to predict what will happen when dominoes are placed in different positions. They will both diagram and write their results.

Standards Addressed

Science, Physical Science

Grade 8

6-8 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.

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

04. Demonstrate that waves transfer energy.

Materials

- Paper
- Marbles
- Dominoes, books or boxes

Procedure

1. Have the students work with a partner or in teams of three.
2. Instruct the groups to fold a piece of paper so that a groove is created.
3. Tell them to place four, five or six marbles in a groove so that they touch each other.
4. Have them 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.)
5. Have them roll two marbles against the others, then three, and so on. Instruct the students to write a sentence that tells what happened to the marbles.
6. Now have each group line up some dominoes, books or boxes and push the first one over. What happens with the transfer of energy? (When the first one is pushed, the kinetic energy transferred to it produced a disturbance. A portion of this kinetic energy is transferred each time it collides into the next object, causing a chain reaction.)
7. Ask students to tell how this is like a wave. (It transfers energy.) Ask how it is unlike a wave. (The objects do not return to their original position.)

Evaluation: Scoring Guide

4 All answers are correct

3 All answers correct, but no depth of answers

2 Some correct responses

1 No correct responses

Name____

Groovin'

Your Task

1. Fold a piece of paper so that a groove is created.

2. Place four, five or six marbles in a groove so that they touch each other.

3. Roll another marble against the end of the line of marbles. Diagram and explain what happened.

4. Roll two marbles against the others, then three marbles, and so on. Diagram and explain what happened to the marbles.

5. Now line up some dominoes (or books or boxes) and push the first one over. What happens with the transfer of energy? Make a drawing of how your group lined up the dominoes.

6. Now try a different arrangement. Make a drawing of this arrangement and write what happened.

7. How is this like a wave?

8. How it is unlike a wave?

Good Vibrations

Overview

Students will conduct hands-on activities to show that sound is caused by vibrations that move as waves. They will then look at how an earthquake moves away from its epicenter in all directions.

Standards Addressed

Science: Physical Science

Grade 8

6-8 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.

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

04. Demonstrate that waves transfer energy.

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

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).

Materials

- Slinky toys
- Mixing bowls less than 12 inches in diameter
- Aluminum foil
- Sugar
- Rice
- Compasses

Procedure

Part 1 *(This part has been covered in other lessons. If the students need additional practice on the concept of vibrations, it would be good to start here. If they understand the concepts, you can begin with Part 2.)*

1. Talk about the following three types of sound:
    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: Have the class 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.

3. Have one of the students squeeze together two or three coils and then quickly let them go. 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.

4. 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.)*

5. 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.

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

7. Tell them to clap their hands above the sugar and watch what happens. A tuning fork could also be used. *(The sugar jumps on the foil.)*

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

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

Part 2

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 satellite 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.

Enrichment: Earthquakes are very complex; this is just an introductory activity. Students can be put with partners or small groups and each group could take one question below and find an answer. They could then present the answers to the class. They could use the following site to find information: **http://earthquake.usgs.gov/learning/faq.php**. Another option would be to have them use a search engine and use "earthquake" as the search term.

1. What is an earthquake?

2. How is the intensity of an earthquake measured?

3. What is plate tectonics and what part do earthquakes play in it?

4. What causes an earthquake to happen?

5. What is an earthquake fault?

6. How do we know faults exist?

7. What are aftershocks?

8. Do tsunamis have any relation to earthquakes?

9. Can earthquakes be predicted?

10. Can animals sense an earthquake coming?

11. Do earthquakes cause volcanic eruptions?

12. Are there any fault lines in the United States?

Evaluation

Part 1 of this lesson is exploration. Part 2 deals with the concept that earthquake waves go out in all directions. The handout could be marked as correct or incorrect and a percentage of the total could be used.

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, volcanic activity, landslides, mine blasts and nuclear experiments.

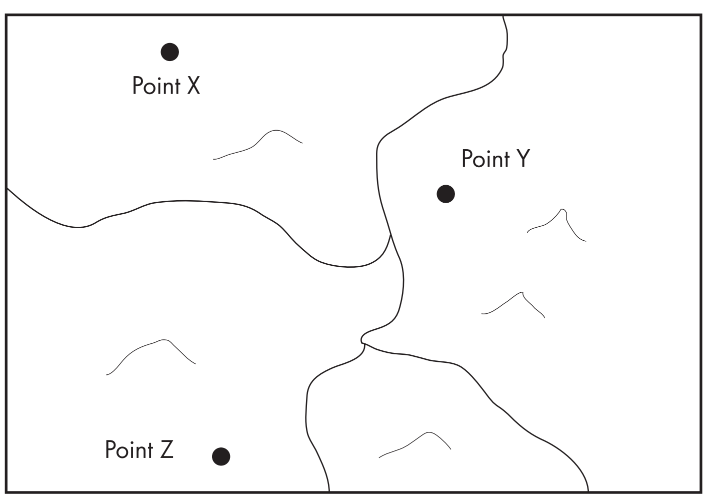
An earthquake's point of initial rupture is called its focus or hypocenter. The term **epicenter** means the point at ground level directly above this.

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.

Name____

Introduction to Waves: Formative Assessment

1. Draw a picture of a wave. Label the type of wave.

2. List some examples of the types of waves that you have heard about.

3. What does it mean when we say that waves transfer energy? Give an example.

4. What happens when you drop a stone in a pool of water? Draw and explain what this shows.

5. What happens to the earth when an earthquake occurs? What does this have to do with waves?

Name____

Introduction to Waves: Summative Assessment

1. Draw a transverse wave and label the crest, trough, amplitude and wavelength.

2. Draw a compression, or longitudinal, wave and label the compression, the rarefaction and the wavelength.

3. Name at least four types of waves.

    a.

    b.

    c.

    d.

4. What does it mean when we say that waves transfer energy? Give an example.

5. Draw and explain what happens when you drop a stone in a pool of water. What does this show?

6. What happens when an earthquake occurs? What does this have to do with waves?

Assessment Answers

Formative Assessment

1. Draw a picture of a wave. Label the type of wave. *(Students could draw either a transverse or a compression wave. See Introduction to Waves for examples.)*

2. List some examples of the types of waves that you have heard about. *(Could include transverse waves, compression waves, sound waves, light waves, microwaves, radiowaves, infrared waves, X-rays, ultraviolet rays, ocean waves and sound waves.)*

3. What does it mean when we say that waves transfer energy? *(This is the transfer of energy by moving it from one place to another.)*

4. What happens when you drop a stone in a pool of water? Draw and explain what this shows. *(Waves move in all directions. The magnitude of the wave is dependent upon the mass of the stone and the force with which it is dropped.)*

5. What happens to the earth when an earthquake occurs? *(An earthquake is a sudden release of energy and causes waves that travel through the earth.)*

Summative Assessment

This summative assessment should be given when students have completed the Waves module.

1. Draw a transverse wave and label the crest, trough, amplitude and wavelength. *(Students could draw either a transverse or a compression wave. See Introduction to Waves for examples.)*

2. Draw a compression, or longitudinal, wave and label the compression, rarefaction and wavelength. *(Students could draw either a transverse or a compression wave. See Introduction to Waves for examples.)*

3. Name at least four types of waves. *(Could include transverse waves, compression waves, sound waves, light waves, microwaves, radiowaves, infrared waves, X-rays, ultraviolet rays, ocean waves and sound waves.)*

4. What does it mean when we say that waves transfer energy? Give an example. *(The transfer of energy by moving it from one place to another. An example is an earthquake or the dropping of a stone in a pond.)*

5. Draw and explain what happens when you drop a stone in a pool of water. What does this show? *Waves move in all directions. The magnitude of the wave is dependent upon the mass of the stone and the force with which it was dropped.*

6. What happens when an earthquake occurs? What does this have to do with waves? *(An earthquake is the sudden release of energy and causes waves that travel through the earth.)*

Evaluation

Rubric for Evaluation

	20-16	15-11	10-6	5-0
Understanding	Shows complete understanding of the required scientific knowledge.	Shows nearly complete understanding of the required scientific knowledge.	Shows some understanding of the required scientific knowledge.	Shows limited or no understanding of the problem.
Communication	There is a clear, effective explanation.	There is a clear explanation. There is appropriate use of accurate scientific information.	There is an incomplete explanation. There is some use of appropriate scientific information.	There is no explanation or there is incorrect information. The explanation cannot be understood or is unrelated. There is no use or inappropriate use of scientific representations.

Scoring Guide

This could also be used if you want a holistic score for either assessment.

4 All answers are correct

3 All answers correct, but no depth of answers

2 Some correct responses

1 No correct responses

Evaluation

Could also be a percentage of the correct answers.

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.

Energy: The capacity of a physical system to perform work or the ability to make something happen.

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.

Period: Time it takes for a wave to repeat itself.

Periodic motion: Motion that recurs over and over and the period of time required for each recurrence remains the same.

Pulse: To undergo a series of intermittent occurrences characterized by brief, sudden changes in a quantity.

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.

Transfer (wave): The process of transferring energy from one body to another.

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 or a disturbance in the medium.

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

The Electromagnetic Spectrum

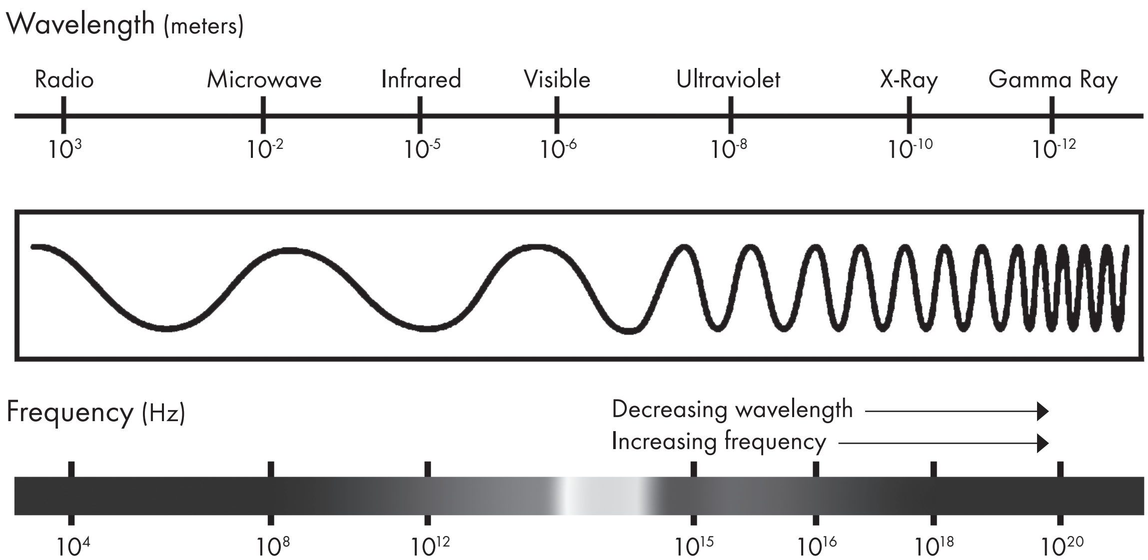
WESTERNRESERVE PUBLIC MEDIA

Introduction to the Electromagnetic Spectrum

What does the word *light* make you think of: the sun, a lamp, the many colors of the rainbow? Light is but a small part of a very broad family of mostly invisible waves. Electromagnetic waves form a continuous spectrum of wave energy ranging from very long radiowaves to very short gamma ray waves. Visible light represents only a very small portion of this spectrum.

You are surrounded by waves, both visible and invisible. Below is a diagram that shows a portion of this electromagnetic spectrum. Notice the small section that constitutes the small portion that is visible to the human eye. Note, however, that we can detect a portion of the infrared with our skin. The ultraviolet rays can easily give us a bad sunburn in the summer. Even if we don't feel light, we can feel its effects (as can be said for all shorter wavelengths — they damage living cells).

The Electromagnetic Spectrum



Electromagnetic waves are transverse waves composed of alternating electric and magnetic fields. They are created by accelerating charges or changing magnetic fields. Electromagnetic waves can travel through a vacuum and, unlike sound waves, they do not need a medium to travel through. All magnetic waves travel at the speed of light. The wavelength and the frequency of electromagnetic waves vary depending on the portion of the electromagnetic spectrum being investigated.

Wavelength is the distance between two equivalent parts of the wave (two troughs or two crests). The unit of measure is the meter and the symbol is lambda.

Frequency is the number of waves that pass a point in one second. When the wavelength is short, the frequency is high because more waves pass through a point in one second. The unit of measure for frequency is the hertz.

The electromagnetic spectrum shows increasing frequency and decreasing wavelength as you go from left to right. Radiowaves include AM , FM radio and shortwave radio. On the spectrum, television waves and radar waves come after radiowaves, but before microwaves. Infrared waves are just to the left of visible spectrum and can't be seen with the human eye. Next come the visible spectrum which contains all the colors of light seen by the human eye. To the right of the visible spectrum are the ultraviolet waves. Then come the X-rays, which are used to photograph dense material such as metal welds, bones and some kinds of animal tissues. Gamma rays have the shortest wavelength and the highest frequencies. Also note that the energy transmitted and the probability of damage to living tissue increase as you move to the right on the spectrum.

Common Uses

- **Radiowaves:** We are all familiar with AM and FM radio and shortwave. FM waves carry the picture portion of most television shows. The sound of most television shows is carried by AM waves.
- **Microwaves:** High-energy radiowaves are called microwaves. They are used in communications. They reflect off certain surfaces and are absorbed by others. These absorbed microwaves can be used for cooking.
- **Infrared waves:** Infrared waves are slightly longer than visible red light. They are used by certain types of cameras to show heat.
- **Visible spectrum:** Each color in the visible spectrum — red, orange, yellow, green, blue, indigo and violet — has a different frequency. Red, green and blue are primary colors that can be combined to create other colors.
- **Ultraviolet rays:** The main source of ultraviolet rays is sunlight. They can be used to destroy bacteria and viruses. They also can cause sunburn and skin cancer.
- **X-rays:** Most people have had experience getting pictures of their bones or teeth taken through the use of X-rays.
- **Gamma rays:** Radioactive material and nuclear reactions give off gamma rays. They damage living cells and are sometimes used to destroy cancer cells.

Properties of Solar Radiation: Reflection, Transmission and Absorption

Overview

Students will make a solar panel. They will use it as a radiation meter to distinguish how well various materials reflect or transmit solar radiation. Students will predict reflection and transmission properties for various materials and test their predictions using their sense of touch.

Standards Addressed

Grade 9, Physical Science

09-10 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.I18 / Nature of Energy

18. Demonstrate that electromagnetic radiation is a form of energy. Recognize that light acts as a wave. Show that visible light is a part of the electromagnetic spectrum (e.g., radiowaves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays).

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.

Materials

(one each per group of three or four students)

- 1-V, 400 mA mini–solar panel with alligator clip leads
- 45-degree mount for the solar panel
- Digital ammeter
- A flat black board such as a clipboard
- Masking tape (30 cm per group)
- If working without the sun, 150-watt incandescent bulb with lamp
- Squares of materials, approximately 10 x 20 cm
  - Mirror
  - Window glass
  - Frosted glass
  - Aluminum foil
  - Wood
  - Waxed paper
  - Clear plastic wrap
  - Cellophane: clear, yellow, red, blue, green
  - Construction paper: black, yellow, red, blue, green

Procedure

1. Have students complete the Formative Assessment.

2. Divide the students into groups of three or four and have one person in each group collect the materials needed to create a solar testing device.

3. Have each group prepare one 45-degree solar panel mount as described in the Transmission, Reflection and Absorption student handout.

4. Discuss the mathematical relationship between reflection, transmission and absorption. **Incident solar radiation** is the amount of **solar radiation** striking a surface per unit of time and area. Incident solar radiation (I) must equal reflected (R) plus transmitted (T) plus absorbed (A) radiation.

$$I = R + T + A$$

5. Demonstrate how to use an ammeter and a panel's conversion curve to obtain milliamps and then convert to watts per square meter (W/m^2). If time for the activity is limited, groups can run either the transmission or reflection lab (as described further in this plan) and then share their data prior to predicting the absorption capacities of the materials.

6. If weather conditions are unsuitable, or a proper sunlit space is not available for students to work with radiation directly obtained from the sun, a 150-watt incandescent lamp can serve as an alternative. Keep any lamp at least 120 cm away from the solar panel, or it might melt the protective cover.

7. Have the students work through the handout. This may require several class sessions.

8. Have the students complete the Summative Assessment. A percentage of the number correct could be used for evaluation.

Formative Assessment Answers

1. Radiowaves should have the lowest energy and gamma rays should have the highest.

2. Students can talk about how constant X-rays can be bad, sitting out in the sun can be harmful and small amounts of gamma radiation are deadly.

Lab Answers

Results will vary due to several variables, especially variations in light conditions and the positioning and holding of the solar cell.

The mirror and aluminum foil should show the highest levels of reflection. Window glass and clear plastic sheeting should show the highest level of transmission. The mirror, aluminum foil, copper sheeting, wood and construction paper should not transmit light energy.

Summative Assessment Answers

1. Reasoning for predictions will vary.

2. Thick and scratchy materials absorb more light.

3. The darker colors absorb more light.

4. Panels should be made all the same. Time during experiments should be about the same.

5. Light exterior and interior car colors in a sunny environment would reflect light. The opposite is true in a cold, sunny climate.

6. You would want the highest transmission so the light can pass through the cover and hit the solar panel. The description of the material should resemble window glass and clear plastic sheeting.

**adapted from Solar Ed for NY School Power*

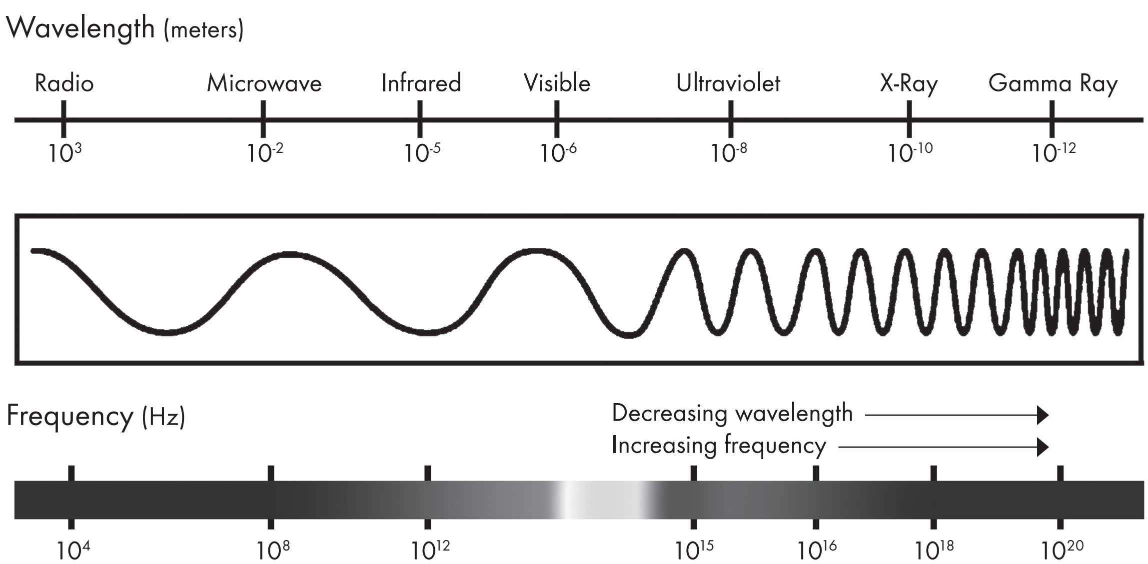
Name____________________

Electromagnetic Spectrum Formative Assessment

Demonstrate that electromagnetic radiation is a form of energy. Recognize that light acts as a wave. Show that visible light is a part of the electromagnetic spectrum (e.g., radiowaves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays).

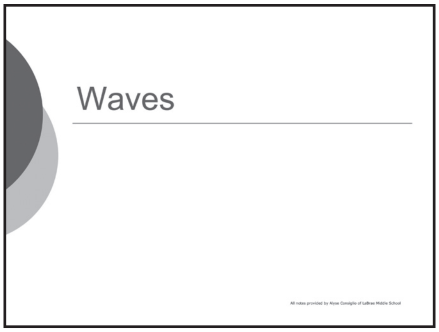
1. Using the diagram below, describe how much energy is in each type of electromagnetic wave, with one equaling the lowest amount of energy and 10 equaling the highest.

The Electromagnetic Spectrum

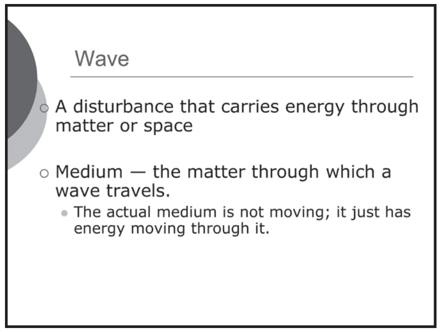


2. Using previous knowledge, describe how rays can be harmful to humans based on your energy diagram.

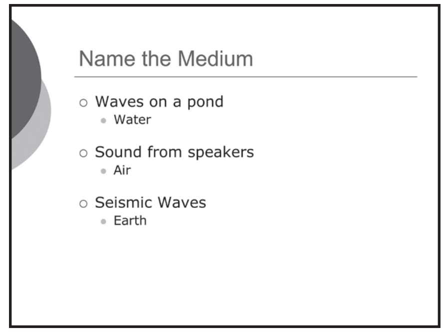
Waves PowerPoint Presentation



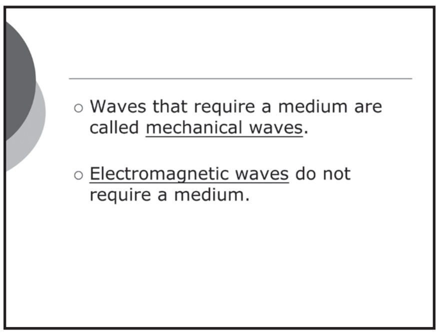
Slide 1



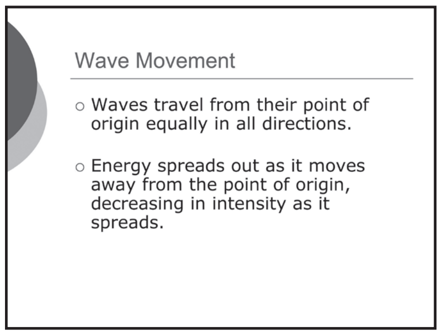
Slide 2



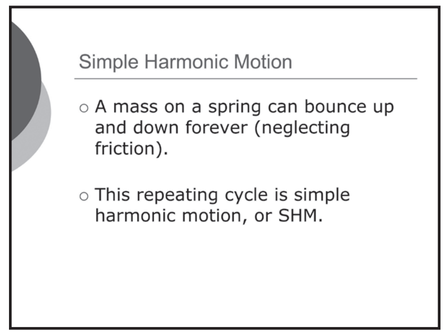
Slide 3



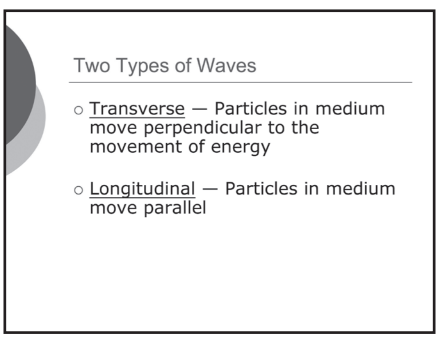
Slide 4



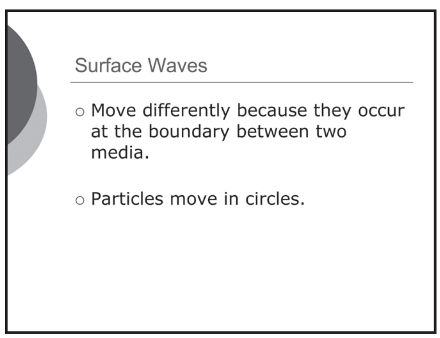
Slide 5



Slide 6

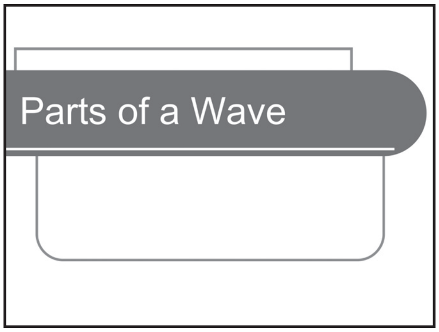


Slide 7

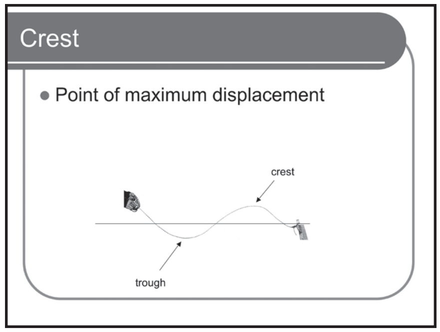


Slide 8

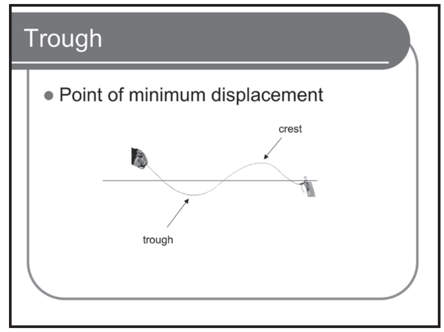
Parts of a Wave PowerPoint Presentation



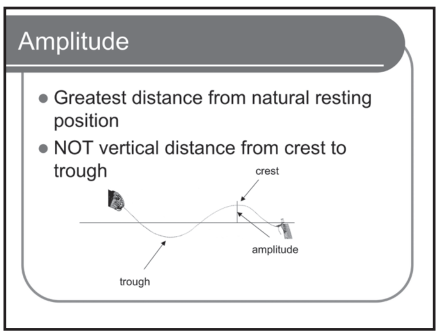
Slide 1



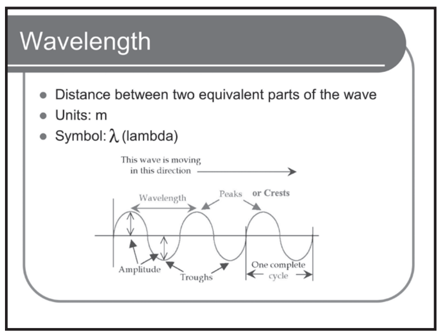
Slide 2



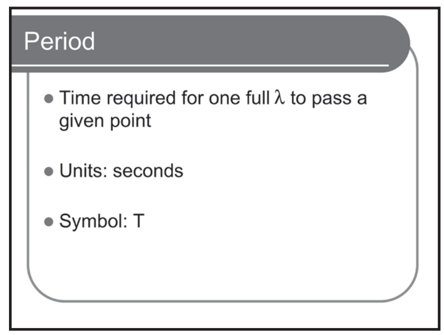
Slide 3



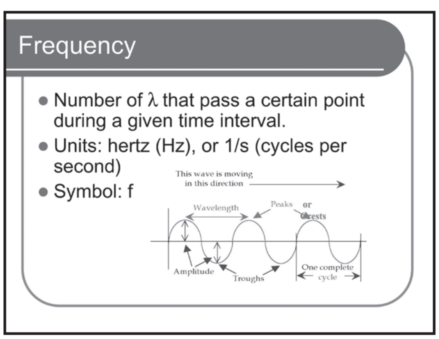
Slide 4



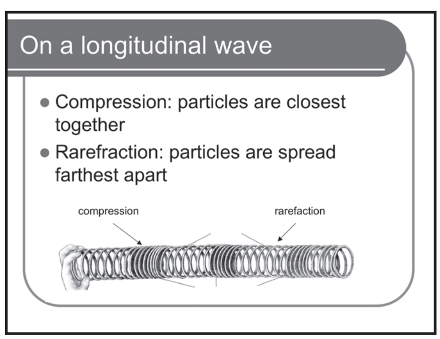
Slide 5



Slide 6

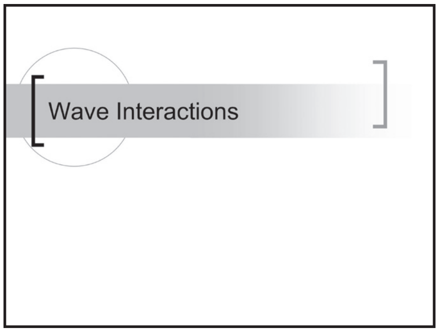


Slide 7

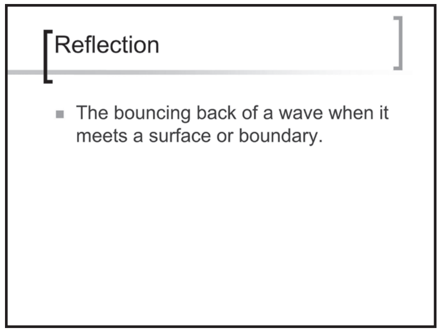


Slide 8

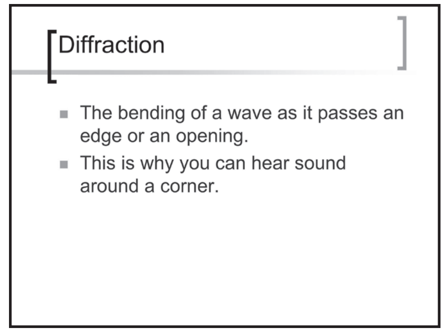
Wave Interactions PowerPoint Presentation



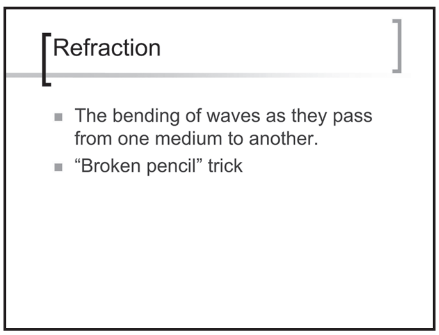
Slide 1



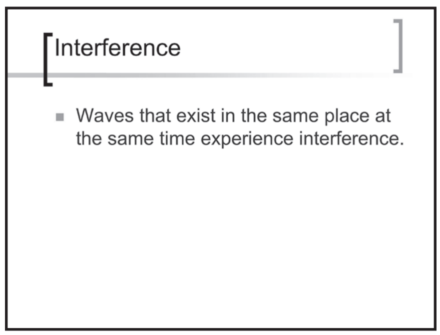
Slide 2



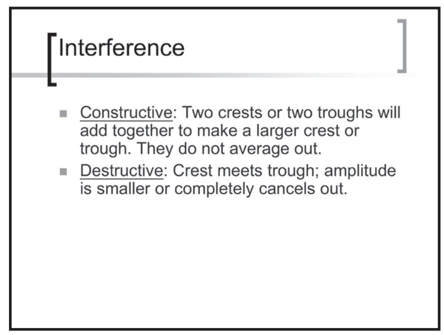
Slide 3



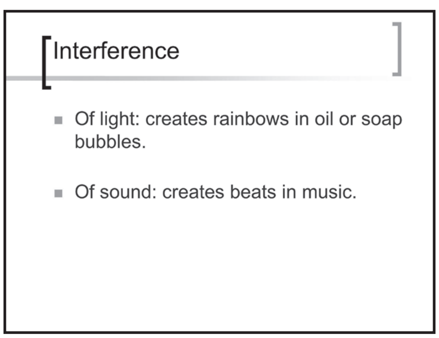
Slide 4



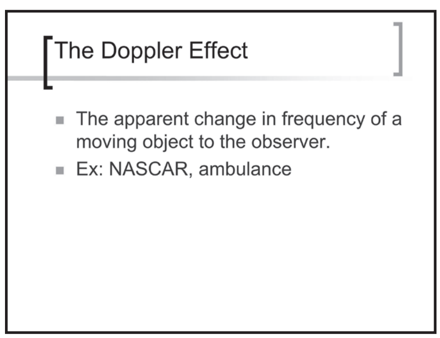
Slide 5



Slide 6



Slide 7



Slide 8

Nature of Light
PowerPoint Presentation

Nature of Light

Slide 1

Light

- Light can be modeled as a wave and a particle
- Transverse, electromagnetic wave
- Photons — particles of light

Slide 2

Speed of Light

- Vacuum — 3.00×10^8 m/s
- Water — 2.25×10^8 m/s
- Glass — 1.97×10^8 m/s
- Generally decreases as medium increases in density.

Slide 3

Intensity

- Intensity is referred to as brightness.
- Intensity decreases as distance from the origin increases. Why?
  - Photons spread out over wider area.

Slide 4

Lasers

- A device that controls the way energized atoms release photons.
- The word originates from the phrase light amplification by stimulated emission of radiation.

Slide 5

Properties of Lasers

- Monochromatic — one specific color
- Coherent — organized; moves in step with others
- Directional — tight beam; strong and concentrated

Slide 6

Modeling With Rays

- Rough surfaces reflect at all angles. This is called diffuse reflection.
- Smooth surfaces reflect light rays in one direction. This is called specular reflection.

Slide 7

Modeling with Light Rays

- The angle at which the ray strikes the surface is called the angle of incidence.
- The angle at which the light is reflected is called the angle of reflection.

Slide 8

Law of Reflection

- The angle of incidence is equal to the angle of reflection.
- Both are measured from a line perpendicular to the surface called the normal.

Slide 9

Nature of Light
PowerPoint Presentation (cont'd.)

Mirrors

- As light reflects off a mirror, some rays hit your eye and your brain interprets this as an image behind the mirror.

Slide 10

Flat Mirrors

- Show a virtual image, located behind the mirror at the same distance as the object is from the surface.
- Ex: Bathroom Mirror

Slide 11

Concave Mirrors

- Used to focus reflected light (magnification)
- Can create a real image in front of the mirror.
- Ex: reflecting telescopes

Slide 12

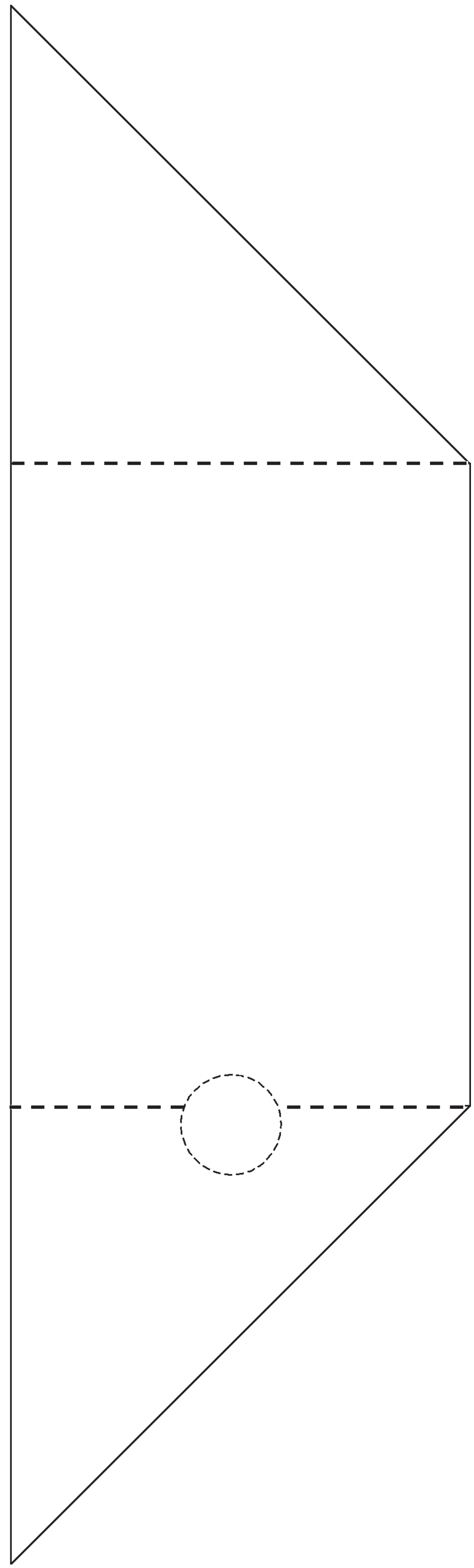
Convex Mirrors

- Used to gather more images.
- Ex: Mirror in corner of store or on side of car ("objects in the mirror are closer than they appear"). Let you see around a corner.

Slide 13

Template for Solar Panel 45-Degree Mount

Use this template to prepare a 45-degree solar panel mount for each team. Prepare each mount out of stiff cardboard. Each mount will be cut to the shape of the template. Cut out an opening for the solar panel wires as shown by the circle. Fold the wings of the mounts 90 degrees along the dashed lines. Use double-sided tape to hold the solar panel to the inside of the base.



Name____

Transmission, Reflection and Absorption

When solar energy strikes an object, three possibilities can occur:

- The energy may be transmitted through the object
- The object may reflect the solar energy
- The object may absorb it

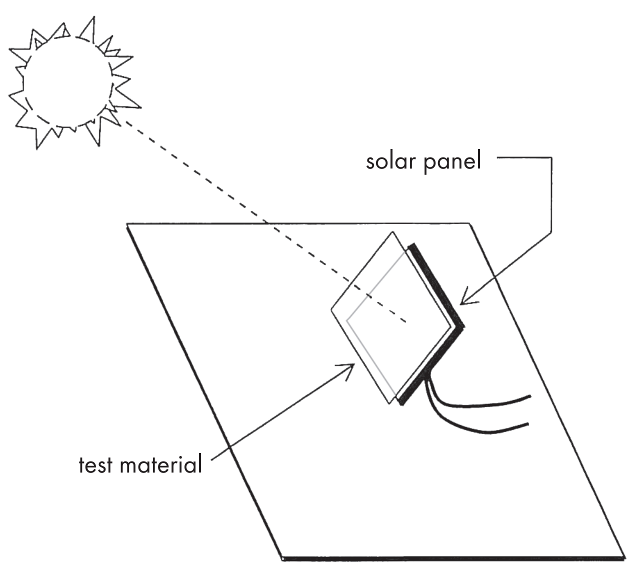
Most objects do all three, to a greater or lesser extent.

It is useful knowledge to understand how different materials transmit, reflect and absorb solar radiation. For instance, in the case of a solar cell, it is important to coat the surface with a material that is a poor reflector – we want as much light as possible to enter the cell. Accordingly, creating comfortable, well-lit homes, schools and offices requires an understanding of which building materials transmit, reflect and absorb solar radiation. After experiencing this lesson you may even begin to select the color and texture of new clothing purchases depending on the strength of sunlight during the seasons.

You are now going to distinguish how well various materials reflect or transmit solar radiation. From the data obtained, you will then predict how well each material absorbs solar radiation.

Transmission

1. Tape one edge of the solar panel to the flat, black board, as indicated in the picture below. Be careful not to cover any of the photovoltaic cells with tape. You should now be able to tilt the solar panel toward the sun.



2. Connect an ammeter to the solar panel leads. Position the board and tilt the solar panel so that the solar panel is perpendicular to the incoming light. You want the highest possible reading, so try moving it a few degrees in each direction. Prop the solar panel in this position with a heavy, bulky object such as a textbook and leave it this way for the rest of the transmission tests.

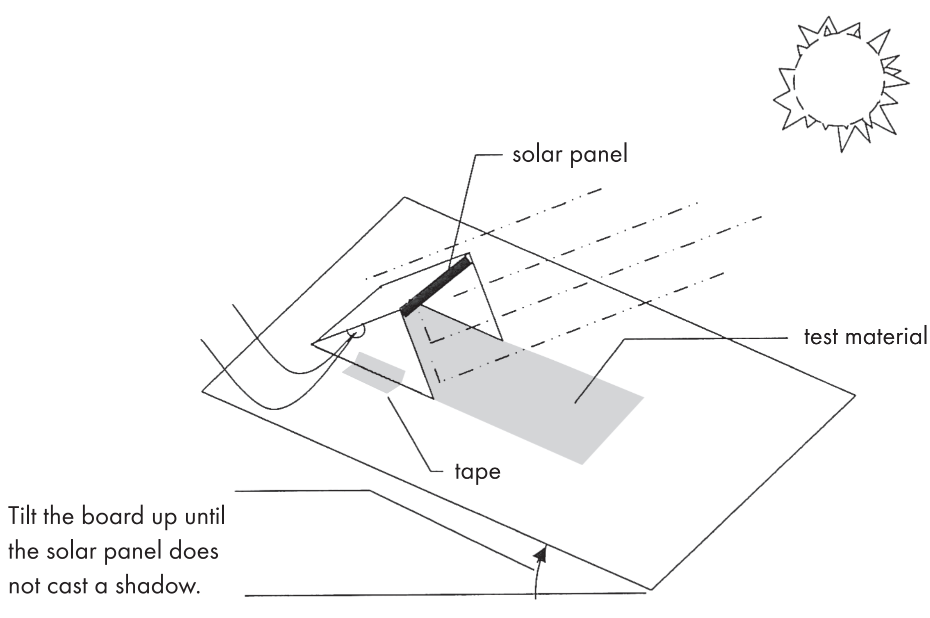
3. Cover the solar panel with each piece of material. For each material, record the ammeter reading in milliamps (mA) in the “as a transmitter” column of the Data Log sheet.

4. When you have finished testing all materials, use the ammeter readings and the solar panel’s calibration curve to calculate the intensity of light that was transmitted through each material. Record this as watts per square meter (W/m^2) in the “as a transmitter” column of the Data Log.

5. On the basis of your observations, rate each test material’s ability to transmit light using either excellent, good, fair, poor or no ability in the Data Log.

Reflection

1. Use double-sided tape on the back of the solar panel to secure it to the inside of the cardboard mount (the triangular wings wrap around the panel’s sides), with the wire leads fed through the hole. Use tape to secure the cardboard mount (with solar panel) to the board as shown in the diagram so the face of the solar panel is directed toward the board.



2. Place the mirror on the board in the test material location as shown in the diagram. Record the ammeter reading as “mA” under “as a reflector” in the Data Log. Remove the mirror and replace it in turn with each remaining test material. Make sure each test material is placed in the exact same position as the mirror. Record the ammeter reading for each test material in the Data Log.

3. For each material, use the ammeter reading and the solar panel's calibration curve to calculate the intensity of light that was reflected off the material. Record this as "W/m^2" under "as a reflector" in the Data Log.

4. On the basis of your observations, rate each test material's ability to transmit light using either excellent, good, fair, poor or no ability in the Data Log.

5. Predict which of the materials would become the warmest and which the coolest if left lying out in the sun. Use your sense of touch to test your predictions.

Enrichment: As an addition to this set of experiments, point your own mirror at a given solar panel. Determine if two, three, four or more mirrors — all focused on the same solar panel — make an appreciable increase in the ammeter reading.

Absorption

1. Review the data you collected and how you rated each material's ability to reflect and transmit light. For each test material, predict its ability to absorb light. Write excellent, good, fair, poor or no ability in the Data Log.

2. Predict which of the materials would become the warmest and which the coolest if left lying out in the sun. Use your sense of touch to test your prediction.

**adapted from Solar Ed for NY School Power*

Name____

Data Table

Material	As a Transmitter			As a Reflector			As an Absorber
	mA	W/m^2	Rating	mA	W/m^2	Rating	Rating
Mirror							
Window Glass							
Frosted Glass							
Aluminum Foil							
Wood							
Waxed Paper							
Clear Plastic Wrap							
Cellophane: Clear							
Yellow							
Red							
Blue							
Green							
Construction Paper: Black							
Yellow							
Red							
Blue							
Green							

Name______________________________

Evaluation
Transmission, Reflection and Absorption

1. What reasoning did you use to predict which materials would be the best or worst absorbers of light?

2. How did the texture of the material seem to affect its ability to reflect light? Absorb light?

3. How did the color of a material seem to affect its ability to transmit light? Absorb light?

4. What variables did you control to make sure that the material being tested was the only factor influencing the readings?

5. Using what you learned, what exterior and interior colors and materials would you want in a car if you lived in a hot, sunny climate? What colors and materials would you pick if you lived in a cold, sunny climate?

6. What properties of transmission, reflection and absorption of light would you look for in a material used to cover a solar electric panel? Describe how you would expect this material to appear (such as dull, shiny, dark, light-colored, etc.).

Summative Assessment

Demonstrate that electromagnetic radiation is a form of energy. Recognize that light acts as a wave. Show that visible light is a part of the electromagnetic spectrum (e.g., radiowaves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays).

Electromagnetic Spectrum Project

You will work in groups to complete a research paper and poster presentation on one category of electromagnetic waves.

My Electromagnetic Wave Topic: ______________________________

Part 1: Research Paper (50 points)

Content Points

1. Cover sheet with title, names, date
2. Range of frequency and wavelength (with correct units)
3. Various uses of this wave
4. Discovery of wave
5. Technology associated with wave
6. Harmful for humans? What can happen?

Format Points

Must be typed, double-spaced, 12-point font (Times New Roman or Arial only), 1-1 ½ " margins, left justified. No fancy folders; only staple once in top left corner.

Spelling and Grammar Points

Check for correct spelling and grammar! Everyone in group should proofread for errors.

Note: Plagiarism will not be accepted. Plagiarism is using any sentence directly from a source without paraphrasing or putting it into your own words. Plagiarized papers will receive a reduced grade or a zero, depending on the severity.

Part 2: Poster and Presentation (50 points)

1. Create a full-sized poster highlighting your research.
2. It must contain names and ranges (frequency and wavelength).
3. It must have pictures, drawings and/or illustrations of examples of waves, uses, technology, etc.
4. It must be informative, neat and pleasing to the eye.
5. Groups will be graded on the poster and presentation to class.
6. Group members may receive different grades, depending on their involvement in the presentation. Be sure to split up the presentation equally among group members.
7. The explanation of poster may be done "live" in class using a PowerPoint presentation, video, song, etc. The more creative you are, the higher your grade will be.

Evaluation

Transmission, Absorption and Reflection

CATEGORY	**4**	**3**	**2**	**1**
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.
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully OR not taken in a reliable manner.

The Physics of Music

Overview

Using a bubble mixture and wind instruments, students will show that when sound energy is transferred, the air does not move from the vibrating source along with the sound.

Standards Addressed

Physical Science

Grade 9

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.***

Nature of Energy / Y2003.CSC.S03.G09-10.BG.L09.I18

18. Demonstrate that electromagnetic radiation is a form of energy. Recognize that light acts as a wave. Show that visible light is a part of the electromagnetic spectrum (e.g., radiowaves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays).

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

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.

Materials

- Recorders, kazoos and flutaphones
- Containers
- Bubble solution: ½ cup (500 mL) liquid dishwater detergent, 4½ cups (4.5 L) water and 4 tablespoons (60 mL) glycerin

Procedure

1. Prior to class time, gently mix together the ingredients for the bubble solution. Foam may be skimmed from the top before use.
2. Divide the students into groups of two, three or four, depending on how many instruments you have.
3. Give one instrument and one container of bubble solution to each group.
4. Have the students dip the end of the instrument into the bubble solution and then blow a note into the instrument.

5. Instruct them to record their observations of the bubble that forms (i.e., how the bubble reacts to the sounds) and how it differs depending on which instrument they use.

Note: This exercise illustrates the principle that waves travel through a medium but the medium does not move. Students should know that the horn vibrates. This vibration is then transferred to the air.

Answers

1. The drawings should show that the air waves cause the bubble molecules to vibrate, but not move, from their original position.

2. Answers vary. Make sure the explanations and identifications are rational; for example, clocks, water waves, tuning forks and guitar strings.

Rubric for Lab

CATEGORY	**4**	**3**	**2**	**1**
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.
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully, or not taken in a reliable manner.

Adapted from *Teaching About Waves* by AAPT Bouffard/Lynes

Name____

Bubbles and Sound

- Place bubble mixture into a dish.
- Select or share three instruments to use in your experiment.
- Dip the end of the instrument into the bubble solution.
- Blow a note into the instrument and record observations of the glycerin bubble (i.e. how the bubble reacts to the sounds).
- Repeat for three different instruments and add your observations to the table below.

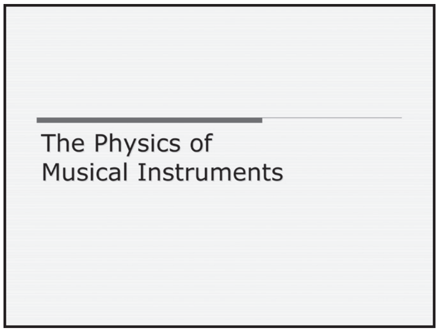
Instrument	Observation

Answer the following questions:

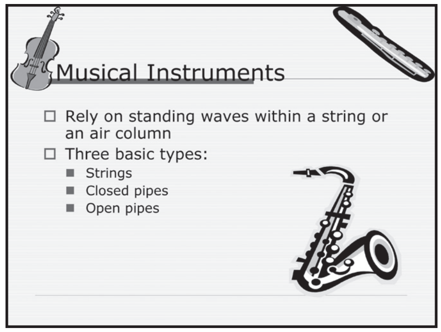
1. Draw pictures that show how the bubble looks before, during and after the sound wave reacts to the air molecules and the bubble.

2. Identify items that vibrate in everyday life and categorize them as either waves or objects that generate waves. Explain why they were placed in either category.

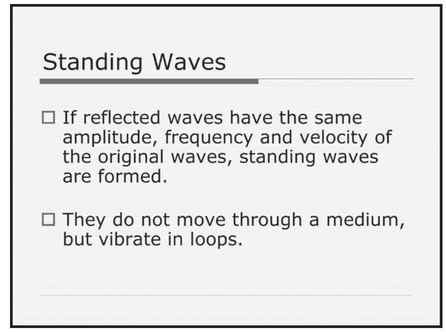
The Physics of Musical Instruments PowerPoint Presentation



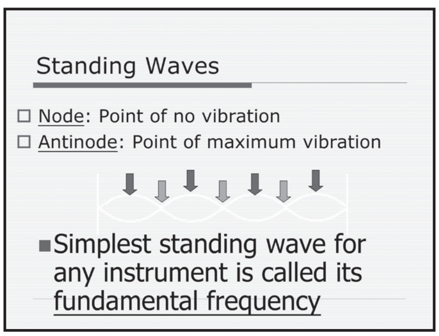
Slide 1



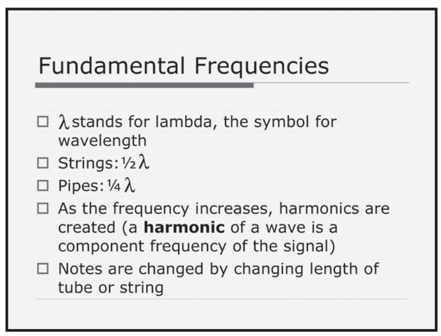
Slide 2



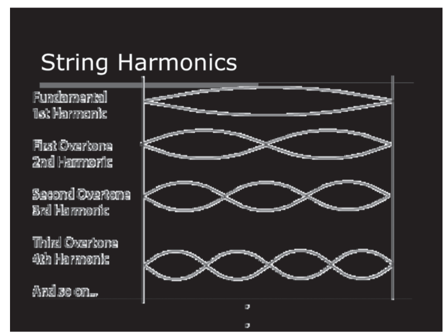
Slide 3



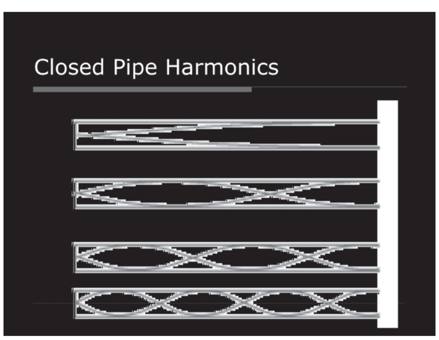
Slide 4



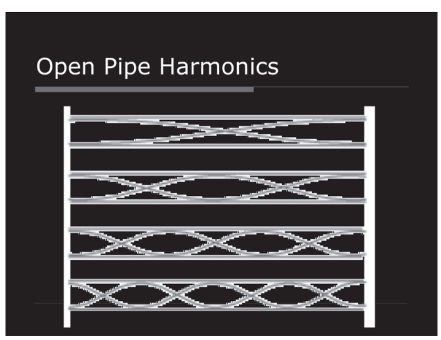
Slide 5



Slide 6



Slide 7



Slide 8

Wavelength and Frequency

Overview

Students will investigate standing waves using Slinkys and ropes. Students will learn that wavelength changes sound.

Standards Addressed

Grade 9, Physical Science

09-10 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.I18 / Nature of Energy

18. Demonstrate that electromagnetic radiation is a form of energy. Recognize that light acts as a wave. Show that visible light is a part of the electromagnetic spectrum (e.g., radiowaves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays).

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.

Part 1 Materials (one for each group):

- Slinkys
- Meter sticks
- Stopwatches

Procedure

1. Divide students into groups of two, three or four, depending on the quantity of materials that you have.
2. Have the students complete the student handout as instructed. They should see that as number of waves increases, the wavelength decreases.
3. Answers will vary depending on the length of the table. Have students exchange papers to check the math.

Answer for The Sound of Slinkys

1. The amplitude should be about the same.

2. Frequency is higher in shorter slinky because it takes less time to complete cycles.

Evaluation for Lab Procedures

CATEGORY	4	3	2	1
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.

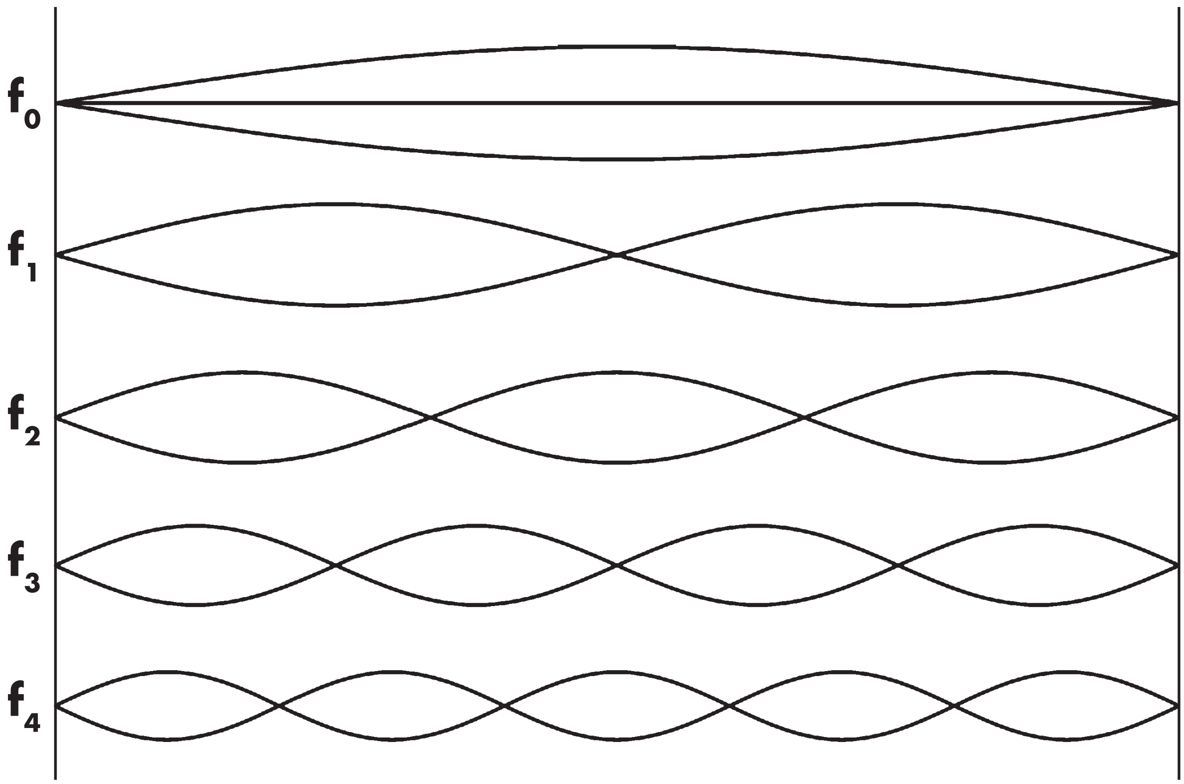
Name____

The Sound of Slinkys

1. Stretch a Slinky the length of a lab table and record its length. Record your answer as the shorter length in the table below.

2. Move the Slinky back and forth several times until you get a pattern similar to f_0. Once each pattern has been established, time five complete cycles. One cycle equals the movement from one side to the other and back. Record your answer in the "time for five periods" column of the table.

3. Increase the frequency until you get the other patterns, labeled f_1 through f_4. Time five cycles at each frequency and record them in the table.



Shorter Length __________				Longer Length __________			
	Time for Five Periods	Period	Frequency		Time for Five Periods	Period	Frequency
f_0				f_0			
f_1				f_1			
f_2				f_2			
f_3				f_3			
f_4				f_4			

4. Increase the length of the Slinky on the floor until it reaches the length of two lab tables. Repeat steps 1-3 above, recording the values in the right "longer length" section of the table.

5. Divide the times you measured by 5 to determine the mean length of one period, **T**. Now find the frequency by finding the reciprocal of the period **(f = 1/T)**.

Answer the following questions:

1. What stays the same for all the patterns when the length of the Slinky stays the same?

2. How do the frequencies of the longer Slinky compare to the frequencies of the shorter one? Can you suggest a reason or reasons why this might be so?

Adapted from *Teaching About Waves* by AAPT Bouffard/Lynes

Spectrum Terms

Electromagnetic waves: Waves that do not require a medium.

Law of reflection: The angle of incidence is equal to the angle of reflection. Both are measured from a line perpendicular to the surface called the normal.

Light

Photons: Particles of light.

Speed of light: Generally decreases as medium increases in density. Examples include the following:

Vacuum – 3.00 x 10^8 m/s

Water – 2.25 x 10^8 m/s

Glass – 1.97 x 10^8 m/s

Intensity: Brightness that decreases as distance from the origin increases because photons are spreading over a wider area.

Lasers: A divide that controls the way energized atoms release photons.

The word laser comes from the phrase light amplification by stimulated emission of radiation.

Monochromatic lasers: One specific color.

Coherent lasers: Organized. Colors move in step with each other.

Directional lasers: Tight beam, strong and concentrated.

Longitudinal waves: Particles in a medium move parallel.

Compression: When particles are closest together.

Rarefraction: When particles are spread farthest apart.

Mechanical waves: Waves that require a medium.

Medium: The matter through which a wave travels. The actual medium is not moving; it just has energy moving through it.

Parts of a wave:

Amplitude: Greatest distance from the natural resting position.

Crest: Point of maximum displacement.

Frequency: Number of hertz that pass a certain point in one second.

Hertz (HZ): Unit that measures speed of wave (cycles per second).

Period: Time required for one full wavelength to pass a given point. Symbol is T. Unit is in seconds.

Trough: Point of minimum displacement

Wavelength: Distance between two equivalent parts of the wave. Unit is meter and symbol is lambda λ.

Simple harmonic motion (SHM): The repeating cycle that allows a mass on a spring to bounce forever (neglecting friction).

Surface waves: Particles move in circles. They move differently because they occur at the boundary between two media.

Transverse wave: Particles in medium move perpendicular to the movement of energy.

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

Wave interactions:

Interference: Waves that exist in the same place at the same time.

Constructive Interference: Two crests or two troughs will add together to make a larger crest, not average out.

Destructive interference: Crest meets trough and causes the amplitude to be smaller or completely cancel it out.

Diffraction: The bending of a wave as if passes an edge or an opening. This is why you can hear sound around a corner.

Doppler Effect: The apparent change in frequency of a moving object to the observer.

Reflection: The bouncing back of a wave when it meets the surface of boundary.

Refraction: The bending of waves as they pass from one medium to another.

Wave movement: Waves travel from their point of origin equally in all directions. Energy spreads out as it moves away from the origin, decreasing in intensity as it spreads.

Newton's Laws

WESTERNRESERVE
PUBLIC MEDIA

Introduction to Newton's Laws

Forces, Motion and Gravity

A force is a push or a pull. Forces are causing movement all around us: your bicycle rolling downhill, a 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 that a small mouse sitting on a table exerts on the table. You would write a newton as **1N = 1kg x 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 was 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 to the atmospheric pressure pushing in. The chair pushes 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 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 x 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 x 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.

Overview

Students will do a series of five experiments that should lead them to the understanding of Newton's Laws. They will deal with the concepts of force and acceleration. They will use the formula and find force, mass or acceleration.

Understanding Newton's Laws

Standard Addressed

Grade 9, Physical Science

09-10 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.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).

Materials

- Towel
- Basketball
- Stopwatch
- Record sheet (spreadsheet form, marked in one-minute intervals)

Procedure

Introduction to Newton's Laws, Part 1

1. Hand out the Forces, Motion and Gravity formative assessment and instruct the class to complete the handout.

Formative Assessment Answers

1. b. A push or a pull
2. d. A unit of measurement
3. a. The resistance of an object to any change in motion
4. c. The force that resists movement when two objects rub together
5. d. An increase or decrease in the speed of an object
6. a. Often thought of as weight
7. b. The tendency to draw an object toward the center of a body
8. c. Two forces that are equal in size and opposite in direction
9. 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 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. Rather, it stays in motion in the same direction until it is acted upon by air resistance or friction, which causes it to stop.
10. You are 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 are 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 equals mass times acceleration. It is also true that acceleration equals 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.
11. 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.

Introduction to Newton's Laws, Part 2

1. Before students come in, place a basketball on a towel on a table.

2. Remind them that observation is an important scientific skill.

3. Have students draw three columns on their paper and create a record sheet as shown below while you very dramatically discuss the object (basketball on towel) on the table. Begin the timed observations every 10 seconds for one minute.

Time	Object	Motion Noted
1		
2		
3		
4		

4. Collect record sheets and announce that no one recorded any motion. Ask students to brainstorm ideas about how their observations might be changed. (*Force must be added.*)

5. Use the History of Laws of Motion PowerPoint presentation and review how Newton's laws came into being.

6. Introduce a reference to Isaac Newton's first law and definition of inertia.

7. Ask a student to apply a force to the basketball to change its position relative to the group. Discuss how this can be done with a push or a pull. (*Definition of force.*)

8. Then ask students how the motion of the ball might be changed, once it has begun to move a specific direction. Note that the ball eventually stops.

9. Ask the students to move the ball in specific directions and distances. Identify **acceleration** (*an increase or decrease in the speed of an object)* and **velocity** *(how fast something is moving – includes a direction)* of the basketball. Note friction's role in the stopping of the motion of the ball.

10. End class with the reflection about the lack of inertia, and what life might be like.

Newton's First Law

Materials

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

Procedure

1. Introduce Newton's First Law using the information found in the History of Laws of Motion PowerPoint presentation.
2. Ask the students to tell what they think that means.
3. Help the students work through Part 1 of the Newton's First Law handout.
4. In the first trial, the penny should drop into the cup.
5. Discuss why this happens. *(Newton's first law in action.)*
6. Students should return the first set of materials and select one hard-boiled and one raw egg.
7. Have them spin the hardboiled egg, stop it for a moment and then release it. Discuss what happened. *(The egg remains at rest.)*
8. 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.)*
10. Have the students answer the questions in Part 2 of the handout.

Newton's Second Law

Materials

- Tennis ball
- Softball
- Basketball
- Bowling ball

Procedure

1. Introduce Newton's second law using the PowerPoint presentation. Point out key vocabulary words: mass, weight and volume. Also present the idea of newtons (N).
2. Ask students to present a fact about the mass of each of the displayed objects. Stress the difference between mass and weight. Ask which of Newton's laws is evident. *(Inertia)*.
3. Build on the concept of motion. Ask how we could change the positions of these objects in relation to us. *(Force)*. Have students predict which of the objects would require the greatest force. Explain why. *(Greater mass requires greater force.)*
4. Discuss acceleration and the velocity of the objects and remind them of the role that friction and gravity play. Show that the force needed to change the directions of each is directly affected by its mass.
5. Have students use varying amounts of force to move the different object different distances. Then, clearing a large floor area, have the students actually move the objects toward each other to change the direction. Have them predict which object will continue in a straighter line and which will be more affected by the greater mass.
6. After several attempts, the students should realize that the object with the greatest mass will be less affected.

7. Place two similar-sized students on either side of the textbook and ask them to exert a push (force) on the book to change its distance relative to the class. The book should not be moved greatly due to the equality of the forces exerted. Ask students to predict what would happen if you chose the smallest child in the class to exert force against the largest child. Students should accurately predict that the student with the greater mass would provide an unbalanced force and create motion in that direction.

8. Introduce the term unbalanced force. Have the students show evidence of motion when forces are not balanced.

9. Project onto a large screen the Gravity Launch activity from the Thinkfinity Web site, **http://www.sciencenetlinks.com/interactives/gravity.html**. After students have successfully accomplished one or two of the assigned tasks, have them analyze their success by discussing how the thrust and angle adjustment affected their mission.

10. Restate Newton's laws as they relate to motion and compare them to the satellites that orbit the earth. They continually falling toward Earth; however, because of Earth's curved nature, they simply travel around it, pulled into place by its gravity.

11. Relate the gravitational pull of an object to its mass. Ask students if they know the largest object in our solar system (sun), and why they think the planets seem to orbit the sun.

12. Introduce the formula F = ma (Force = mass x acceleration).

13. F_w = mg (Force = mass x gravity). Gravity is 9.8 m/s^2 at sea level on Earth. Remind students to always keep mass in kilograms.

14. Divide the students into groups and give them the Newton's Second Law handout.

Answers for Newton's Second Law handout

1.

Net Force N	Mass Kg	Acceleration m/s2 or m/s/s
10	2	5
20	2	10
20	4	5
10	2	5
10	1	10

2. An object in motion will remain in motion, so zero additional force is needed.

3. Maria is correct. Inertia depends upon mass, not speed.

4. His mass will increase and therefore his inertia will increase.

5. Acceleration = force/mass, so a = 80/40, which equals 2 N. 1 N = 1 kg x 1 m/s/s; therefore, 2 N would equal 2 m/s/s or 2 m/s^2.

Evaluation

Have students answer the following questions:

1. How does increasing the mass affect the force of objects in motion?

   The greater the mass the more force necessary to move it.

2. What would be the result of a car ramming head-on into a semi truck?

   The car would be damaged more severely than the truck. Why? *The truck has greater mass.*

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

   The law says that an object at rest will remain at rest and an object in motion will remain in motion unless acted upon by an outside force. The more mass, the more force required.

Newton's Third Law, Part 1

Materials

- Two rulers per number of lab partners
- A selection of coins, with at least six having the same value
- Masking tape
- Lab record sheet

Procedure

1. Review the Newton's Third Law PowerPoint presentation with the students.
2. Divide the students into groups of two or three.
3. Ask students to observe and hypothesize the observed reactions. Instruct them to use the tape to fasten the rulers parallel to each other on the tabletop.
4. Place five identical coins in line between the two rulers, making certain that each one touches the other in the middle of the ruler. Leave about an inch on each end. Students should then place another identical coin at the entrance to the gap between the rulers. They should carefully flick the coin toward the row of coins, making certain that it hits them in the center. *(The whole group of coins should move some, but the end coin should fly off away from the group.)*
5. Have the students repeat the process several times, and note the result on the lab sheet.
6. Have the students note what happens when two identical coins are flicked. (Two coins should be displaced from the group.) Then have students try this experiment with coins of differing weights and note the response. Have students hypothesize why this happens.
7. You may want to introduce a variable by having a student hold down one of the coins in the middle of the row and note that the end coin still flies off just as before.

Newton's Third Law, Part 2

Materials

- Masking tape
- Balloons
- Straws
- Scissors
- String
- Tape measures

Procedure

1. Divide the students into groups of three.
2. Have someone in each group collect masking tape, five balloons, a straw and a very long string (about room length).
3. Review the Newton's Third Law handout directions with the class.
4. Once the groups are finished, you can make a class graph. If this is done, you need to come to some common agreement as to how you will measure. *(This is really not good for prediction because there are many variables. You usually get a trend that the greater the circumference, the greater the distance; however, there tend to be outliers.)*

Evaluation

Rubric for Experiments

CATEGORY	4	3	2	1
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.
Data Collection	Data taken several times in a careful, reliable manner.	Data taken twice in a careful, reliable manner.	Data taken once in a careful, reliable manner.	Data not taken carefully OR not taken in a reliable manner.

Newton's Third Law: Action and Reaction

1. Distribute the Action and Reaction student handout. You can have students work alone on this activity or with a partner.

2. Explain to the students that the arrow on the picture shows the action and the action force is explained below the picture.

3. Their task is to draw an arrow that shows the reaction and write what the reaction is below the action statement.

4. After they have completed the handout, have the students share some of their examples.

Answers

a. Reaction force applies force on the head from the ball.

b. Reaction force applies force on the bug from the windshield.

c. Reaction force applies force on the bat from the ball.

d. Reaction force applies force on the finger from the nose.

e. Reaction force applies force from the flower on the hand.

f. Reaction force applies force on the athlete from the bar.

g. Reaction force applies force on the compressed air from the surface of the balloon.

h. Reaction force applies force on the earth from the person.

i. Reaction force applies force on the man from the wheelbarrow.

Enrichment: Tell the students this story and have them write or tell you why it is incorrect.

A donkey is supposed to pull a cart, but the donkey refuses. This donkey is not just being stubborn, he has a reason. He states that if he pulls the cart then the cart will pull back with an equal and opposite force. This will balance out all the forces and he can not make the cart move. Explain to the donkey why he is incorrect.

Evaluation

There are 13 possible points on this handout. A grade could be based on the percent correct.

Answer for Summative Assessment

1. b. balanced forces
2. a. changes the motion of the object
3. a. inertia
4. d. acceleration
5. c. momentum
6. false (should be equal and opposite to)
7. false (should be matter or inertia)
8. true as written
9. true as written
10. true as written
11. a. stay at rest or stay in motion
12. c. force
13. d. an equal and opposite reaction
14. b. Newton's third law of motion
15. c. acceleration
16. It would take 375 Newtons
17. It would take 120 Newtons
18. The mass of the object would be 100 kg
19. The mass of the object is 8 kg
20. Mass is how much matter makes up an object

Name______________________________

Formative Assessment

Choose the letter of the best answer.

1. Force is ______________.
   a. the resistance of an object to any change in motion
   b. a push or a pull
   c. the force that resists movement when two objects rub together
   d. a unit of measurement

2. A Newton is ______________.
   a. the resistance of an object to any change in motion
   b. a push or a pull
   c. the force that resists movement when two objects rub together
   d. a unit of measurement

3. Inertia is ______________.
   a. the resistance of an object to any change in motion
   b. a push or a pull
   c. the force that resists movement when two objects rub together
   d. a unit of measurement

4. Friction is ______________.
   a. the resistance of an object to any change in motion
   b. a push or a pull
   c. the force that resists movement when two objects rub together
   d. a unit of measurement

5. Acceleration is ______________.
   a. often thought of as weight
   b. the tendency to draw an object toward the center of a body
   c. two forces that are equal in size and opposite in direction
   d. an increase or decrease in the speed of an object

6. Mass is ______________.
   a. often thought of as weight
   b. the tendency to draw an object toward the center of a body
   c. two forces that are equal in size and opposite in direction
   d. an increase or decrease in the speed of an object

7. Gravity is ______________.
   a. often thought of as weight
   b. the tendency to draw an object toward the center of a body
   c. two forces that are equal in size and opposite in direction
   d. an increase or decrease in the speed of an object

8. Balanced forces are ______________.
   a. often thought of as weight
   b. the tendency to draw an object toward the center of a body
   c. two forces that are equal in size and opposite in direction
   d. an increase or decrease in the speed of an object

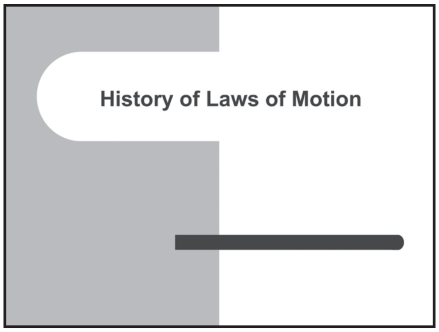
What do you think each of Newton's Laws mean? Explain them in your own words.

9. 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 source.

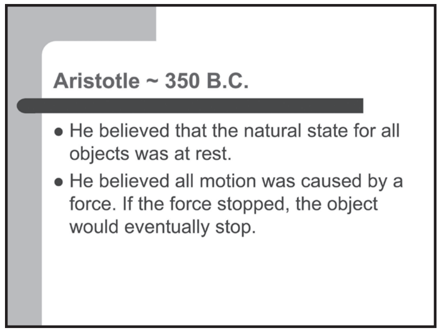
10. Second Law: The force of an object is equal to its mass times acceleration.

11. Third Law: For every action there is an equal and opposite reaction.

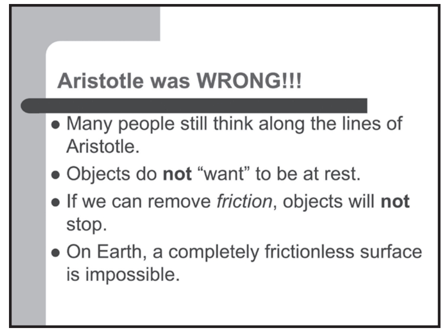
History of Laws of Motion PowerPoint Presentation



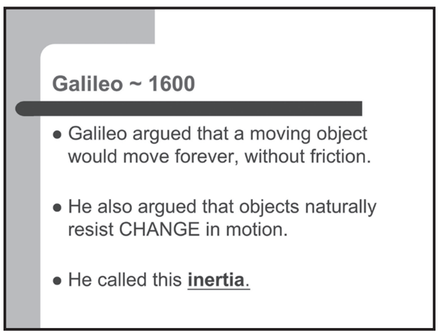
Slide 1



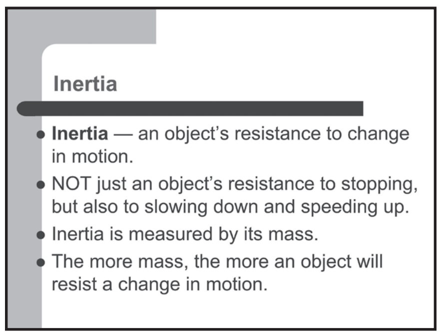
Slide 2



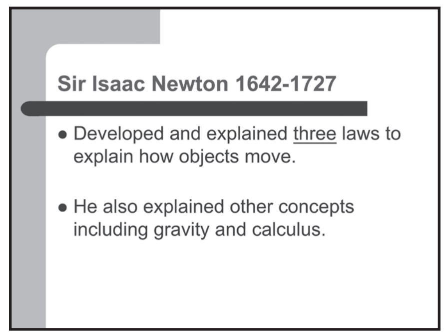
Slide 3



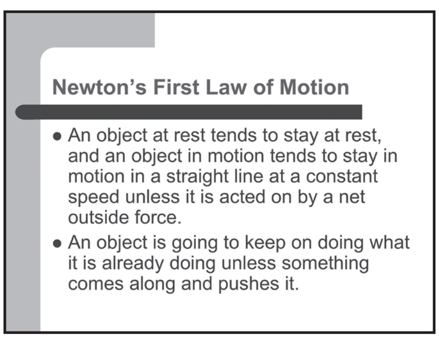
Slide 4



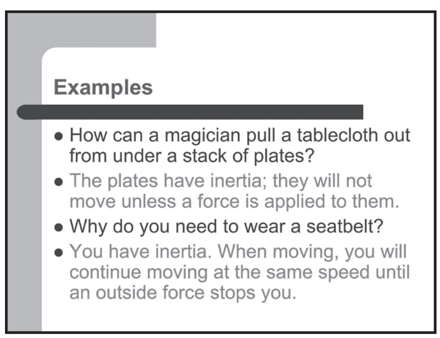
Slide 5



Slide 6



Slide 7



Slide 8

Name____

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.

Part 1

1. Working with a partner, place a card on top of a cup and a penny on top of the card.
2. Flick the card away and record in line 1 below what happened to the penny.
3. Return the first set of materials and select one hard-boiled and one raw egg.
4. Spin the hard-boiled egg, stop it for a moment and then release it. Record in line 2 what happened.
5. Repeat the process with an uncooked egg. Record in line 3 what happened.

Time	Object	Motion Noted
1		
2		
3		

Part 2

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

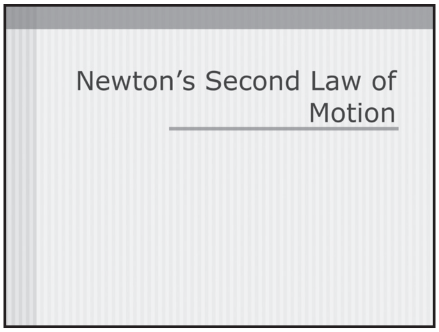
2. What did you observe when you stopped the hard-boiled egg?

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

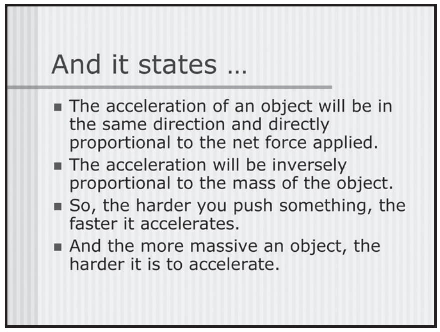
4. Why do you think there was a difference?

5. How does this relate to Newton's first law?

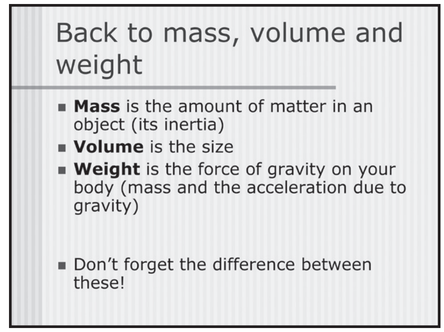
Newton's Second Law of Motion PowerPoint Presentation



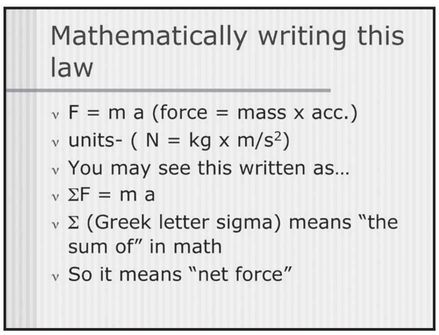
Slide 1



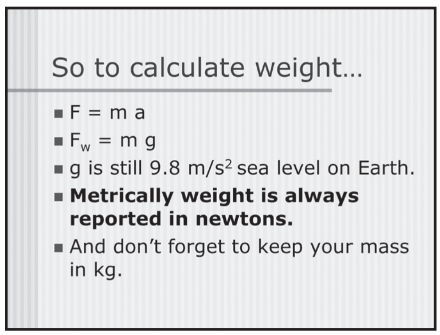
Slide 2



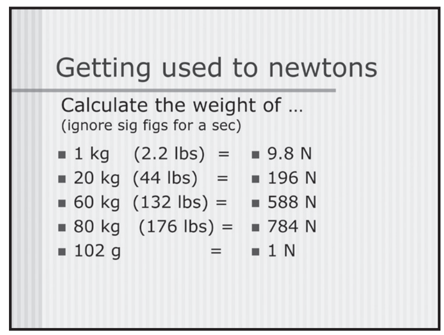
Slide 3



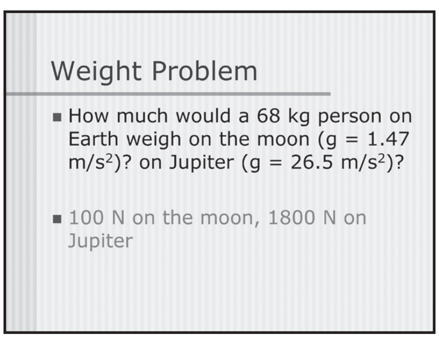
Slide 4



Slide 5



Slide 6



Slide 7

Name______________________________

Newton's Second Law

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

F = ma (Force = mass x acceleration)

Acceleration = Force/mass

Imagine that you are out with your friend and your car breaks down. You push it (force) and that causes the car to move. Your friend decides to help, so you have doubled the force so the car accelerates. If some of your other friends hop in the car, you have increased the mass and therefore the car slows down.

1. Compute the missing terms.

Net Force **N**	**Mass** **Kg**	**Acceleration** **m/s^2 or m/s/s**
10	2	
20	2	
20	4	
	2	5
10		10

2. A 10-kg object is moving horizontally with a speed of 4 m/s. How much net force is required to keep the object moving at this speed and in this direction?

3. Cafeteria time! Joe says if he flings his "Jello surprise" with greater speed, it will have greater inertia. Maria says he's not right. She says force depends upon mass, not speed. Who is right? Why?

4. Malcolm lays on the couch and watches the Browns. He eats nachos and drinks lots of pop. What effect will this have on his inertia? Why?

BONUS: A big dog has a mass of 40 kg. If the dog is pushed onto the ice with a force of 80 N, what is the acceleration?

Newton's Third Law of Motion PowerPoint Presentation

Newton's Third Law

Slide 1

And it states…

- **For every (action) force, there is an equal (reaction) force in the opposite direction on the object that applied the force by whatever the force was applied to.**
- In short: For every action there is an equal and opposite reaction.
- This has nothing to do with human nature or philosophy!

Slide 2

It means…

- If you punch someone in the face…
- It does not mean they will stand up and punch you back!!! (they could just sit there and cry, or run away!)
- It means their face hits your hand with the same force your hand hit their face!
- Which is why so many guys get broken hands in a fight!!

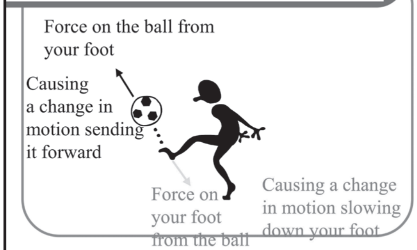
Slide 3

Major misconception

- The action and reaction force are NOT on the same object!
- Action is on the object the force is applied to.
- Reaction is on what applied the force.
- If you kick a ball …
  - **action force** on the ball from your foot
  - **reaction force** on your foot from the ball

Slide 4

Force Diagram



Slide 5

All Motion Depends On This Law

- How do you walk?
- You push on the ground backward; the ground pushes you forward.
- How do you swim?
- You push the water back; the water pushes you forward.

Slide 6

Motion in Outer Space

- It's a **vacuum** — there is nothing there. No air of any kind.
- If you want to move, you had better bring something with you to throw out the back!
- Spaceships bring oxygen and hydrogen, and ignite them in the back of their ships.
- This sends water vapor flying in the opposite direction and pushes them forward.
- They call it a burn on the movies (and in mission control)

Slide 7

Name____

Newton's Third Law

For every action there is an equal and opposite reaction.

Part 1

1. What happened to the coins in the center when you pushed one coin?

2. What happened to the coins in the center when you flipped one coin?

3. How does this relate to Newton's third law?

Part 2

1. Have someone in your group collect masking tape, five balloons, a straw, tape measures and a very long string (about room length).

2. 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.

3. Put the straw on the open end of the string.

4. 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.)

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

6. Hold the string level and shoot off five balloon rockets. You may want to practice once or twice.

Trials	Circumference in cm	Distance in cm
1		
2		
3		
4		
5		

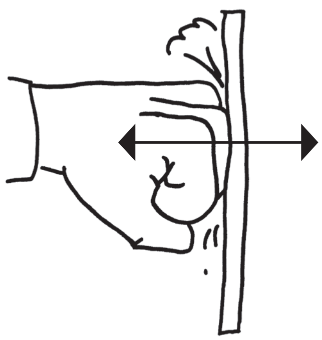
7. Make a graph that shows the results. The circumference is the independent variable therefore it should be on the x-axis and the distance on the y-axis. Can this be used to predict distance? Why or why not?

8. What forces are in action in this experiment?

Name____

Newton's Third Law
Action and Reaction

1. In the example below, the action-reaction pair is shown by the arrows (vectors), and the action-reaction is described in words. In (a) through (i), **draw the other arrow** (vector) and **state the reaction** to the given action. Make up your own examples in (j) and (k).



Action force applies force to wall from his hands.

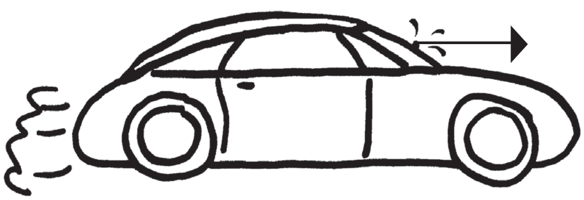
Reaction force applies force to hand from wall.

Action force applies force to ball from head.

a. ____

____

____

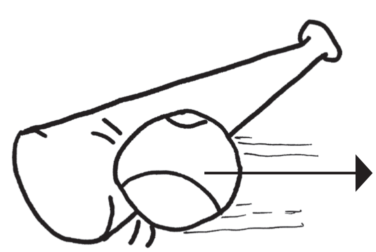


Action force applies force to windshield from the bug.

b. ____

____

____

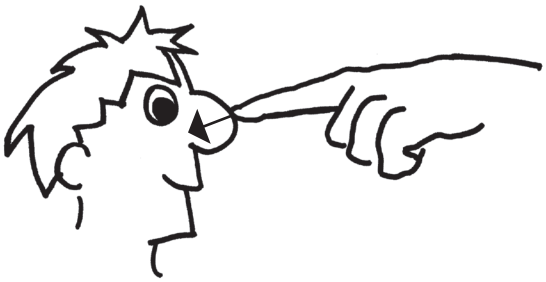


Action force applies force to the ball from the bat.

c. ____

____

____

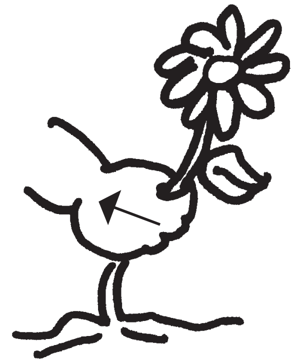


Action force applies force to the nose from the finger.

d. ____

____

____

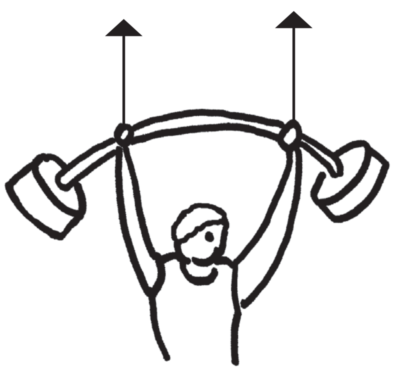


Action force applies force to the flower from the hand.

e. ____

____

____

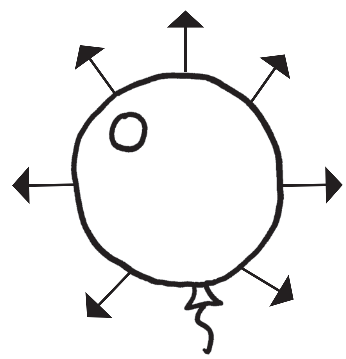


Action force applies force to the bar from the athlete.

f. ____

____

____

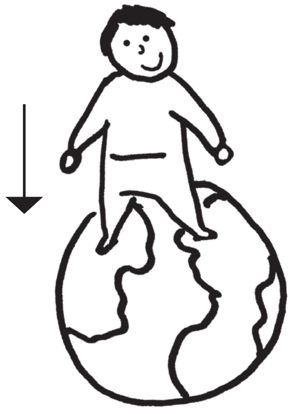


Action force applies a force on the surface of the balloon from the compressed air.

g. ____

____

____



***Gravity pulls a person downward*.**

Action force applies a force on a person from the earth.

k. ____

____

____

Man pushes wheelbarrow.

Action force applies force to wheelbarrow from a man

i. ____

____

____

(Make up your own.)

j. Action force ____

____

Reaction force ____

____

(Make up your own.)

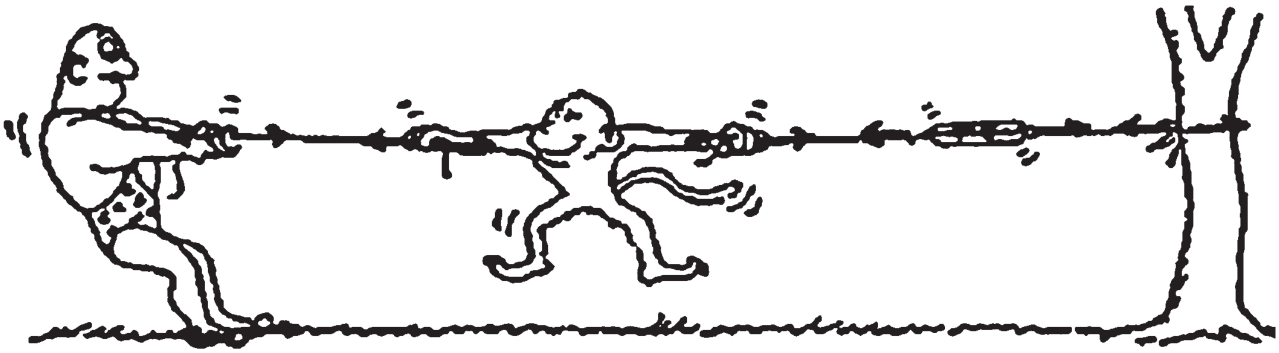
k. Action force ____

____

Reaction force ____

____

2. **Draw arrows** and **label** at least <u>six</u> pairs of action-reaction forces below.



3. A donkey is supposed to pull a cart, but the donkey refuses. This donkey is not just being stubborn; he has a reason. He states that if he pulls the cart then the cart will pull back with an equal and opposite force. This will balance out all the forces; therefore, he cannot move the cart. Explain to the donkey why he is incorrect.

Name____

Newton's Laws Summative Assessment

Circle the letter that represents the best answer.

1. When two equal forces act in opposite directions on an object, they are called ________________.
   a. friction forces
   b. balanced forces
   c. centripetal forces
   d. gravitational forces

2. When an unbalanced force acts on an object, the force ________________.
   a. changes the motion of the object
   b. is canceled by another force
   c. does not change the motion of the object
   d. dis equal to the weight of the object

3. The resistance of an object to any change in its motion is called ________________.
   a. inertia
   b. friction
   c. gravity
   d. weight

4. According to Newton's second law of motion, force is equal to mass times ________________.
   a. inertia
   b. weight
   c. direction
   d. acceleration

5. The product of an object's mass and its velocity is called the object's ________________.
   a. net force
   b. weight
   c. momentum
   d. gravitation

Answer true or false. If the statement is true, write "true as written." If it is false, change the underlined word or words and make the statement true.

6. According to Newton's third law of motion, whenever you exert a force on an object, the object exerts a force back on you that is <u>greater than</u> your force.

7. Mass is a measure of the amount of <u>force</u> an object has.

8. <u>Weight</u> is the measure of the force of gravity exerted on an object.

9. <u>Conservation</u> in science refers to the amount of some quantity before and after an event.

10. The force that causes a satellite to orbit Earth is <u>gravity</u>.

Circle the letter that represents the best answer.

11. Inertia is Newton's law that says that an object will ______________________.
    a. stay at rest or stay in motion
    b. resist all forces
    c. overpower all forces
    d. roll in space forever

12. A push or a pull is called a ______________________.
    a. motion
    b. Newton's Law
    c. force
    d. constant speed

13. For every action there will be a punishment ______________________.
    a. a punishment
    b. a reward
    c. a speed
    d. an equal and opposite reaction

14. Action and reaction forces are discussed in ______________________.
    a. math books
    b. Newton's third law of motion
    c. coffee shops
    d. Newton's first law of motion

15. The rate at which velocity changes is ______________________.
    a. never predictable
    b. affected by gravity
    c. acceleration
    d. hard to measure

Solve for the variables and answer the questions.

16. How much force would it take to accelerate a 75-kg object by 5 m/s^2?

17. How much force would it take to accelerate a 40-kg object by 3 m/s^2?

18. What is the mass of an object if it takes 25 N to accelerate the object 0.25 m/s^2?

19. What is the mass of an object that is hit with a force of 32 N and moves with an acceleration of 4 m/s^2?

20. If you travel to the moon and step on a scale, your weight will change from what is was on Earth, but your mass will stay the same. Please explain why this is true.

Newton’s Laws — Vocabulary

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

Balanced forces: Two forces that are equal in size and opposite in direction. Balanced forces have a net force of zero.

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 flyoff 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 equals mass times velocity**.

Newton: The unit for measuring force. One newton (N) is the amount of force needed to cause a 1-kg 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. 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 equals one-half 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.

Unbalanced forces: Two forces with different strengths working against each other.

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

WESTERN
RESERVE
PUBLIC MEDIA

Western Reserve Educational Services
A service of Western Reserve Public Media
1750 Campus Center Drive
Kent, OH 44240-5191
330-677-4549
http://www.WesternReservePublicMedia.org