

Science of Energy
Idaho National
Laboratory

EROB-3E0201

Time Needed: The time needed to complete this entire “Science of Energy” unit will be about five - 45 minute periods. More or less time may be needed if students proceed more quickly than expected, or more slowly.

Unit Descriptor: This unit may be used as a whole, or in separate parts. Each day’s lesson can be assumed to be a stand-alone project.

Standards: These units will satisfy the following standards, in these select states.

Wyoming:	SC11.1.13, SC11.14
Washington:	1.1.4 Forms of Energy
Utah:	Objective Standard 4, Objective 1, 2, 3
South Dakota:	9-12.P.3.1
Oregon:	H.2P.3
Nebraska:	12.3.4 and 12.3.5
Idaho:	Standard 2, Goal 2.2, 2.3, 2.4
California:	Physics, Section 2, Paragraphs a-h

Objective: At the completion of lesson one, of this unit, a student should have an understanding of kinetic energy, potential energy, and how they are similar and how they are different.

Background Information: Energy is the ability to cause change. There are two broad categories of energy, one is potential and the other is kinetic.

Potential energy is the energy of position, or where “something” is at. It could be connected to another “thing”, like two atoms connected together to make a molecule. Potential energy could be some “thing” at the end of a stretched rubber band, or on a coiled spring, or held above the ground.

Kinetic energy is the energy of movement, or how something is moving. The “thing” that is moving could be a mass of substance, or a “field” of electromagnetic energy (photons), or the speed of a vibration of an atom within a larger molecule (like the oxygen *within* a molecule of water).

Energy can, and will, move between the categories, but energy cannot be made or destroyed. The very small exception to this is $E = mc^2$. This is Mr. Einstein’s idea that matter and energy are related and interchangeable.

Energy

Ability to Cause Change



FORMS OF ENERGY

All forms of energy fall under two categories

POTENTIAL

Potential energy is stored energy and the energy of position (gravitational).



CHEMICAL ENERGY

Chemical energy is the energy stored in the bonds of atoms and molecules. Biomass, petroleum, natural gas, propane and coal are examples of stored chemical energy.

NUCLEAR ENERGY

Nuclear energy is the energy stored in the nucleus of an atom. It is the energy that holds the nucleus together. The nucleus of a uranium atom is an example of nuclear energy.

STORED MECHANICAL ENERGY

Stored mechanical energy is energy stored in objects or substances by the application of a force. Compressed metal springs and stretched rubber bands are examples of stored mechanical energy.

GRAVITATIONAL ENERGY

Gravitational energy is the energy of place or position. Water held in a reservoir behind a hydropower dam is an example of potential gravitational energy. When the water in the reservoir is released to spin the turbines, it becomes motion energy.

KINETIC

Kinetic energy is motion. It is the motion of waves, electrons, atoms, molecules and substances.



RADIANT ENERGY

Radiant energy is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays and radio waves. Solar energy is an example of radiant energy.

THERMAL ENERGY

Thermal energy (or heat) is the internal energy in substances. It is the vibration and movement of atoms and molecules within substances. Geothermal energy is an example of thermal energy.

MOTION

The movement of objects or substances from one place to another is motion. Wind is an example of motion energy.

SOUND

Sound is the movement of energy through objects or substances in longitudinal (compression/rarefaction) waves.

ELECTRICAL ENERGY

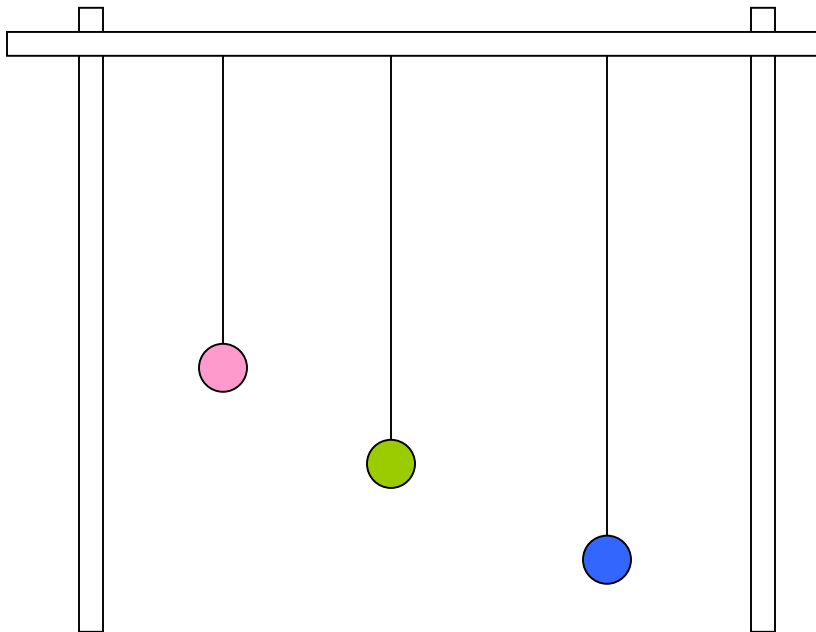
Electrical energy is the movement of electrons. Lightning and electricity are examples of electrical energy.

Materials Needed for Pendulum Lab

1. Fishing Line (string works, but 3 lb. fishing line works best)
2. Weights of various sizes (any size or weight will work, as long as mass is known)
3. Meter sticks or metric rulers
4. Stop watches
5. A bar from which a pendulum can easily swing

Procedures

1. In some way, and it will be different for individual cases, the string should be attached, or wound around, the suspension bar, so that the string length can be changed, and also measured.
2. Pull the bob back, measuring against the table, a known distance.
3. When released, time the swing of the pendulum for a number of cycles (back and forth is a single cycle).
4. Fill out the data sheet.
5. The **ONLY** thing that will matter is the length of the string. Students will understand this by the end of the lab. They should also understand that the amount of kinetic energy in the system is rising and falling in a manner exactly opposite that of the potential energy, such that the sum of the two does not change.



Name _____ Block ____ Pendulum Lab

Lab Justification

Pendulums swing with a very regular motion. This motion converts energy from gravitational potential energy to kinetic energy, and back again. This motion can be looked upon as a wave, or a cycle. We will examine this cycle, or wave, as part of the phenomenon of a pendulum.

Terms

Bob ~ this is the weight at the end of a pendulum

Cycle ~ a cycle the movement of a pendulum bob, such that the position of the bob is the same, and the direction of the bob is the same. Usually, this is from where the bob was replaced, to the top of the swinging motion on the opposite side, and back to the point of beginning. Displacement is zero.

Frequency ~ this is the number of cycles completed per second. This is cycles per sec.

String length ~ this is the distance from the pendulum support, to the center of the bob.

Distance pulled back ~ this is the distance, in meters, from the rest position of the bob, to the release point. This is measured against the table.

Procedure

There are three variables, but remember to only change one at a time.

Complete a control run of the pendulum. Everyone will do the same control run.

Everyone will use a string length of .33 meters, and a bob mass of .25-kg, pulled back .15 meters. Calculate the frequency.

Variables

You will need to complete six more runs. Change only one of the variables at a time, keeping the other two the same as the control run, but change the variable twice. Your teacher will show you an example.

Analysis

By examining your data, be able to prove to yourself which of the three variables, or combinations, will change how fast a pendulum swings. Answer the questions on the following pages. (5 points)

String Length	Bob Mass	Distance Pulled back	Cycles Counted	Seconds Counted	Frequency (cycle/sec)
.33m	.25-kg	.15 m	10 cycles		
	.25-kg	.15 m			
	.25-kg	.15 m			
.33m	.25-kg				
.33m	.25-kg				
.33m		.15m			
.33m		.15m			

According to your data, what is the factor that most influences the frequency of the swing of the pendulum? (1 point)

Explain why you think so. (1 point)

Describe the energy conversion in the pendulum's swing, between kinetic and potential energy. You need to show an understanding of the energy conversion, and may need to review your science text book. (2 points)

Your principle walks in, and requests that you make a pendulum swing with a frequency of .25 cycles per second. How would explain to your principle how this would be done, or else explain why it could **not** be done. (1 point)

Examine the pendulum shown at the right. What will be the speed of the bob, at the lowest point of the pendulum? (2 extra points)

Bob has a mass of 2.5 kilogram

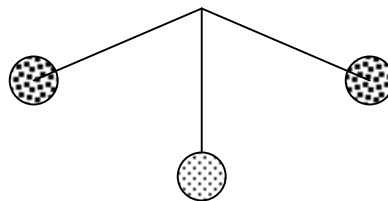
String length is 4 meters

Bob height at release point is 2.5 meters

GPE = mass • height

KE = $\frac{1}{2}(\text{mass}) \cdot \text{velocity}^2$

Law of conservation of energy says, "energy moved but not made or destroyed"



Materials Needed for Black and Silver Can Lab

1. Two regular soda cans, like one gets from a vending machine.
2. A can of silver spray paint
3. A can of dull black spray paint
4. Thermometers, or temperature probes
5. A bare lamp and an incandescent bulb, at least 60 watt. Compact Fluorescent Lights will **NOT** work well.
6. Graphing paper, straight edges and colored pencils

Pre-laboratory Preparations

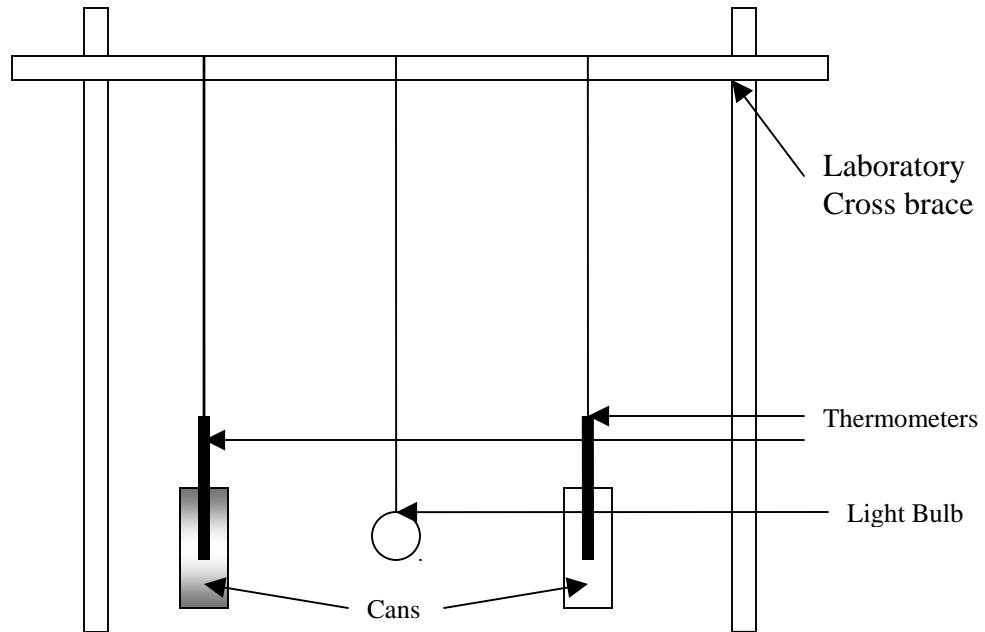
1. Decide on the number of groups you will have. Groups of two work well.
2. Accumulate two cans for each group
3. Paint $\frac{1}{2}$ of the cans a dull black
4. Paint the other $\frac{1}{2}$ of the cans silver
5. Make sure that each group has two (one will work, but it takes longer) thermometers.
6. Make an example graph, so that students can see what expectations you may have.

Safety Precautions

1. The bulb will get very hot, don't let students touch it.
2. Make sure there are no frayed wires or exposed electrical connections.
3. Make sure the paint on the cans is dry, and is not hazardous.

Laboratory Procedure

1. Examine the attached diagram or picture.
2. "Dangle" the thermometers into the cans, so that the red bulb is not touching the sides of the can. The thermometer(s), should be in about the same position in each of the cans.
3. Place the heating, incandescent bulb about equal distance from each of the cans. The cans can heat at the same time, or one after the other. It does not matter.
4. Take an initial reading (time=0), and then turn on the incandescent bulb. Take a reading each 30 second period, without removing the thermometers from the cans, for five minutes.
5. Complete your data chart, and compare it with your partners.
6. Transfer your data to a line graph, and complete your post lab questions.



Time	Black Can	Silver Can
Zero		
30 sec		
60 sec		
90 sec		
120 sec		
150 sec		
180 sec		
210 sec		
240 sec		
270 sec		
300 sec		

Electrolysis of Water, and Endothermic and Exothermic Reactions

Laboratory Experiment Justification

This lab will show students a conversion of energy from electromagnetic to chemical to thermal and sound. There will be an endothermic reaction and also an exothermic reaction.

Teacher Background

An endothermic reaction will absorb energy, hence the prefix “endo”. The reaction will be the combination of any number of particles. Usually an endothermic reaction will show a decrease in temperature, because temperature is often a good indicator of the level of energy in a substance.

An exothermic reaction will release energy, hence the prefix “exo”. The reaction will be the combination of any number of particles. Usually an exothermic reaction will show an increase in temperature.

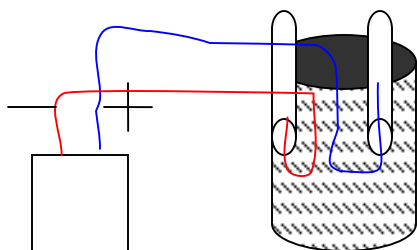
Electrolysis of water is when kinetic electrical energy is used to replace the potential energy of chemical bonds between the hydrogen and oxygen in water. A hydrogen atom is able to split away from the oxygen, and reforms with another hydrogen atom to make a hydrogen gas molecule. Oxygen is similarly separated from hydrogen in water, and combines with other free oxygen to make oxygen gas molecules.

Safety Concerns

1. Depending upon voltage used, electrical shock may be an issue
2. Glassware can break and be a sharp hazard
3. The chemical used are not extremely hazardous, but caution should still be used.
4. Matches will be used, so a fire extinguisher should be nearby.
5. When the hydrogen ignites, there will be a small “pop”. This should be of little concern, but in the rare case that a test tube does break, safety glasses and gloves should be worn.

Teacher Preparations

1. For each lab group you will need
 - a. Two test tubes
 - b. A large beaker or plastic bucket
 - c. Two insulated copper wires, about 16 gauge, stripped on both ends to expose about 1.5” of wire.
 - d. A power source. It must be direct current, and the higher the voltage, the more explicit the demonstration will be. **KEEP IN MIND THAT HIGH VOLTAGE IS DANGEROUS.** A four or five “D” size flashlight batteries, connected in series will work fine.
 - e. You will need NaCl, sodium chloride, table salt. This helps the electricity flow through the water.



Lab Procedure

This is a challenging laboratory experiment. Care should be taken so that no injuries or accidents happen. All of the safety contracts should be turned into your instructor.

1. Fill your large beaker about $\frac{3}{4}$ with water from the tap. Distilled water is not needed.
2. Fill one test tube with water from the tap, and cover it with your thumb. Turn it “upside down”, and place it in the water. No air should have gotten into the test tube.
3. Your partner will tape the test tube to the beaker. This is not as easy as it seems, because the test tube is on the inside of the beaker, and the tape is on the outside, but with care it can be done.
4. Repeat the process with the other test tube.
5. Bend the insulated wires so that the bare copper is inside the test tubes, near the bottom.
6. Have the wires **prepared** to connect to the wire source.
7. Dissolve about 10 mL of salt into the water. This will help the electricity flow. Stir the mixture *gently*, so the test tubes do not come loose.
8. Connect the wires to the power source. Begin answering your lab questions.
9. When the test tube is about $\frac{1}{2}$ full of gas, you are ready for the next step.
10. Remove the test tube and let the water flow out.
11. Keep your finger over the opening of the test tube, holding the test tube with a glove.
12. Take your test tube to the teacher, and get a match
13. Hold the test tube upside down, and place the match to the lip of the test tube. The test tube should give a sharp “pop”, and a bluish flame should be seen.

Gravitational Potential Energy and Rolling Ball Lab

Laboratory Justification

Students will be able to see the relationship between Gravitational Potential Energy and Kinetic Energy, and make a graphical representation of the relationship between the two. Students will be able to make predictions based on experimental data.

Teacher Background

Gravitational Potential Energy is the potential energy of an object that is reliant upon its location above the surface of the Earth. Three things are needed, and in simplistic terms they are; how big something is, how high it is, and how much gravity there is. The formula for Gravitational Potential Energy is $G.P.E. = \text{gravity (meters per second per second)} \times \text{height above surface (meters)} \times \text{mass (kilograms)}$.

Kinetic Energy is the energy of an object, which is reliant upon the mass and velocity of an object. Velocity and speed can usually be considered the same, because direction will generally not be changing. Velocity is actually speed with a directional component. The formula for Kinetic Energy is $K.E. = \frac{1}{2} \text{mass} \times \text{velocity}^2$.

Teacher Materials

Balls of various sizes. The maximum size should be about five centimeters (2 inches) in diameter. You will need at least one per group of two, but it is best to have a lot, so that students can have a choice.

Meter Sticks. Yard sticks would work, but science works with the metric system, so this should probably be the units of use. One meter stick per group works best.

Tape. You will need a roll of cheap, cheap masking tape, and the thinner the better.

Inclines. The inclines should be rounded and about 75 to 100 meters long. Thin gauge PVC piping can usually be found at a local home improvement center, and they will often cut it into one meter lengths, and in half for you.

Books. Usually students will have these in their backpacks.

Graph Paper. The students will make their own graphs, but I will suggest that the "x" axis be ramp "rise", and the "y" axis be how far the ball rolled.

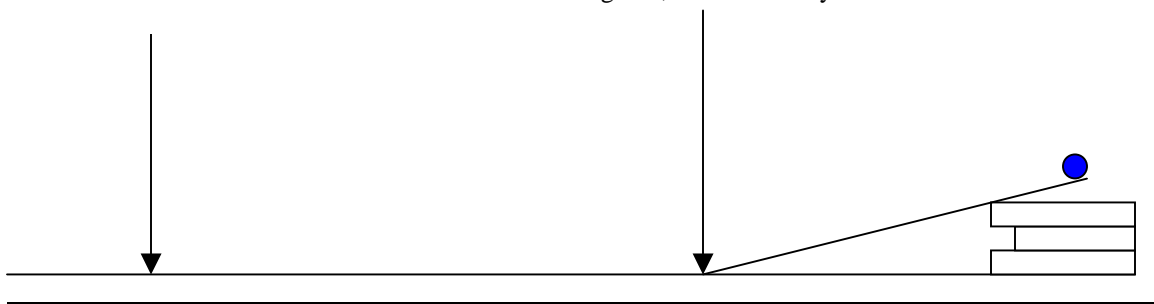
Procedure

1. Find an area that is large enough for your class to spread out, and if it is carpeted, that is even better.
2. Place a “starting line” down, made of masking tape.
3. Have students place the “end” of their ramp on the starting line, and raise the “start” of the ramp with a certain number of books.
4. Students should measure the “rise” of the ramp with the meter stick, and release the ball.
 - a. Students measure how far the ball rolled, and marks the point on their graph.
 - b. Students change the “rise” four more times, and complete the graph.
 - c. The graph can be used as an assessment, but its main use is to predict how high the ramp would have to be raised, to make the ball go a certain distance.
5. Place a “target tape” three or four meters away from the “starting line” and challenge the students to be able to roll the ball down the ramp, and have it end up on the “target tape”.
 - a. By using the graph as a reference, students should be able to predict how high they will have to raise the ramp, to make the ball roll a specific distance.
 - b. Do not be surprised when a team makes a ball land on a 2 cm piece of tape, from three meters away.
 - c. Do not be surprised when some students laugh, scream and dance with success.
 - d. Do try to give away a token of success.
6. An assessment could be the graph, if an assessment is wanted.

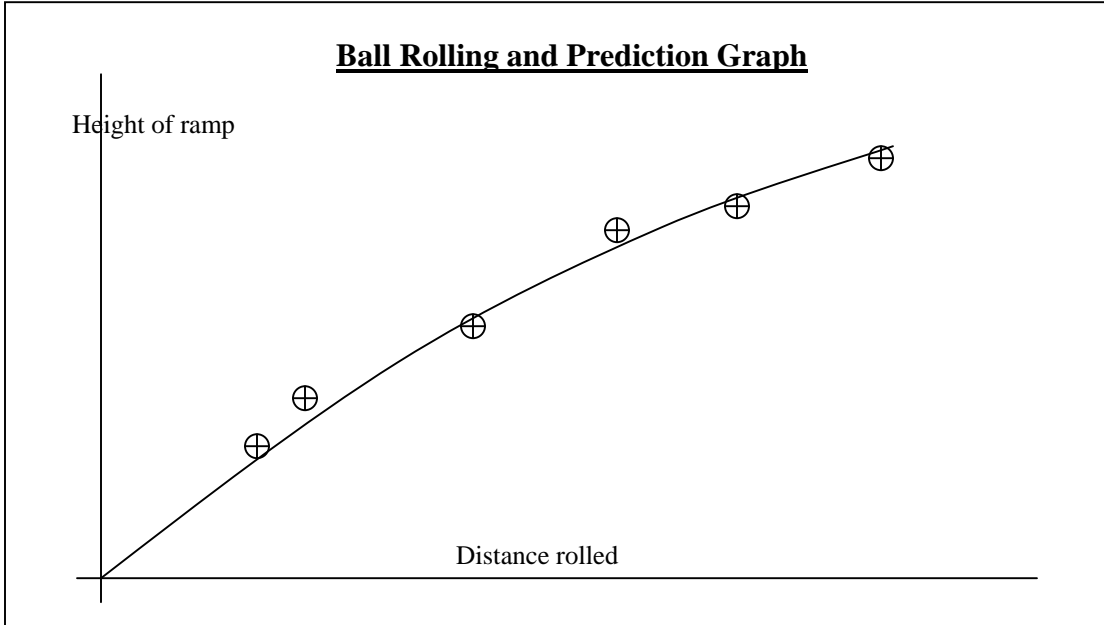
Finish line. Arbitrary placement, and whichever team gets closest, without any practice trials, wins.

They determine how high to release ball from, by data on their graph

Starting line, same for everyone



Example of a graph that a student might make



Stomp Rockets

Background: Stomp rockets are a simple way to show energy conversions, and it is most helpful if Newton's Laws of Motion have been introduced at a prior time.

Materials:

½" PVC, schedule 40 piping. It is really cheap, so buy four or five, 10 foot sections of it.

½" PVC elbow fittings. They are very, very cheap, so buy about 10 of them.

Paper. Various sizes, colors, textures and weights. This is a good time to clean out a waste drawer in the production room.

Tape. Rolls of duct tape for sure, but then get masking tape, transparency tape, and then any other kind you want.

Glue. White glue, hot glue, and any you might have lying around.

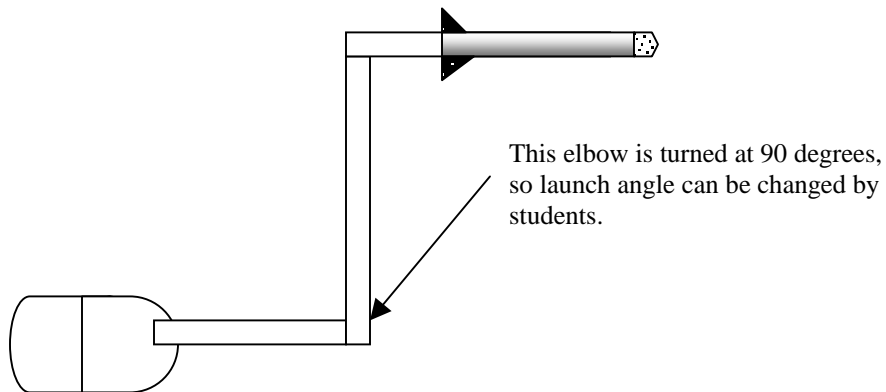
Drill, and a $\frac{7}{8}$ " drill bit.

Plastic drinking bottles. This part is critical. You are going to need at least 5 or 6, at a minimum.

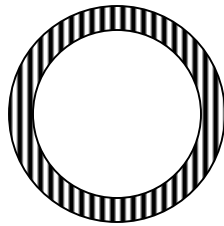
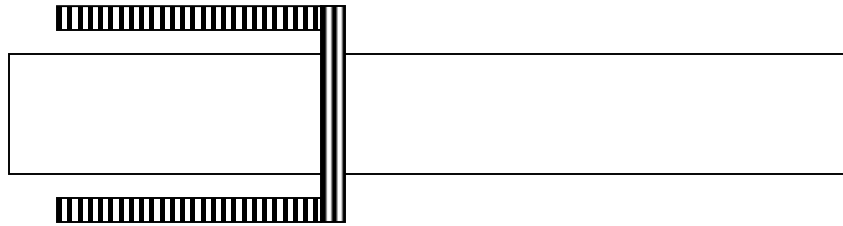
Scissors. One for each group.

Picture:

You may figure most



of this out just by looking at a picture.



The $\frac{1}{2}$ " pvc pipe is placed inside the $\frac{7}{8}$ " hole drilled in the cap. That way the soda bottle can be replaced, by simply unscrewing one, and screwing in the next.

How a Stomp Rocket Works Summary:

A student stomps on the drinking bottle, which changes the kinetic energy of his foot and leg into compressional potential energy in the air in the bottle. The air in the bottle flows through the $\frac{7}{8}$ " hole that has been drilled in the cap (and sealed with hot glue and duct tape). The energy wave of air (actually sound), moves through the tube to the rocket. In response to the energy in the air, the rocket accelerates. The rocket flies, but slows down, because its energy is transferred to the O_2 and N_2 molecules in the atmosphere. The accelerated molecules have more thermal energy because they are moving faster, so the air is heating up. In reality, one is heating the atmosphere by stomping on a rocket.

How the Students Learn

The students will be experimenting by trying different configurations of fins, nose cones, rocket lengths, paper materials, and even different types and sizes of soda bottles.

How to Build a Simple Stomp Rocket in Three Easy Steps

1. Take a piece of note book paper, and wrap it around a scrap piece of $\frac{1}{2}$ " PVC pipe. It should not be too loose, or too tight.
 2. Tape the seam of the paper (lengthwise), so that it does not unwrap
 3. Put tape over the top of the rocket, so it is not just a tube of paper.
- You are DONE. Granted, your rocket will not fly far or fast, but it is done.
4. Students can experiment with different lengths of rockets.
 5. Students can experiment with different types/numbers of fins
 6. Students can experiment with different types/shapes of cones
 7. Students can experiment with different launch angles.

Assessment

This project can be assessed in any number of ways, depending upon the skill level and ability of the students. The assessment could be based upon,

1. Teacher observation
2. Distance traveled
3. Time aloft
4. Creativity
5. Average speed to a target
6. Accuracy

The shape and configuration of a rocket will be determined by goal of the assessment.

Safety Notes

This project is a high interest activity for the students. It is not generally quiet, but it does generally hold the focus of students. There are sharp objects, and flying objects. The flying objects are only pieces of paper, but the instructor should still have certain ground rules for launching trial rockets.

Final Note

The writer of this particular project has had rockets fly in excess of 200 feet. A well made rocket is simply outstanding, and the student that made it will feel the same.