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Activity 2: Piezo-Electric Popper

Introduction:
In this Activity you will be using a piezoelectric device to generate electrical energy. Some crystals demonstrate piezoelectric behavior, which means that when pressure is applied, a charge separation is induced, and they release electrons. There are many uses of piezoelectric behavior including quartz watches, barbecue lighters, and microphones.

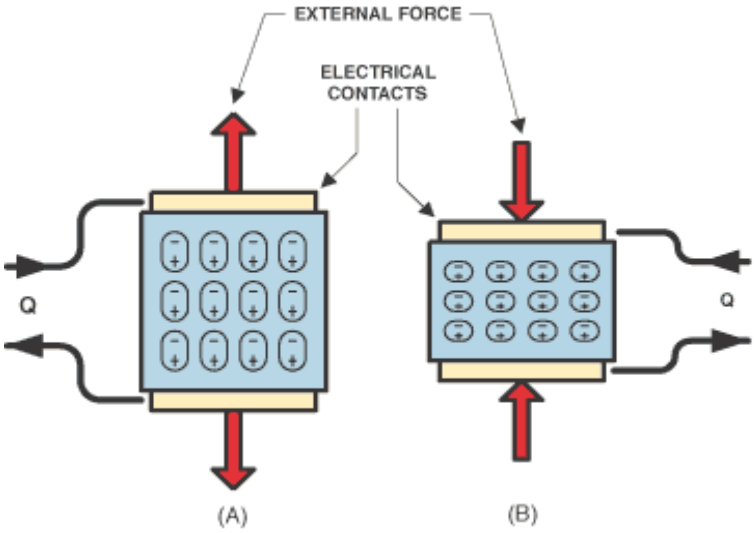

Fig. 1 Some crystal structures have a charge separation when the crystal undergoes tension (A) or compression (B). This charge separation can generate electrons to flow and convert mechanical energy into electric energy. In a gas lighter, when you depress the switch, a piezoelectric crystal is squeezed, generating a high enough voltage to generate a spark. This spark will ignite a combustible fluid and produce a flame.
(Image from http://archives.sensorsmag.com/articles/0203/33/main.shtml)

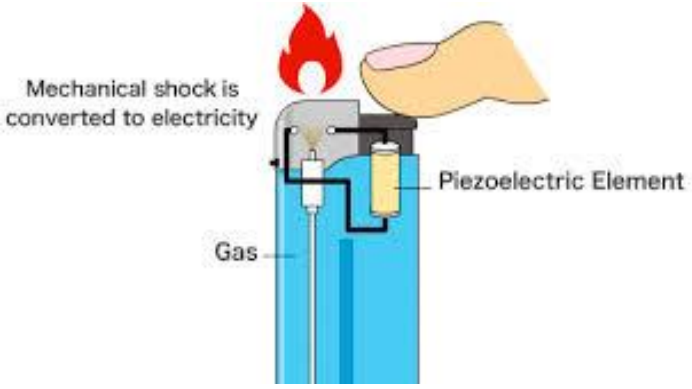

Fig. 2 A gas lighter uses piezoelectricity to produce a spark. (Image from global.kyocera.com)

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Activity 2-1: Firing the Popper

Objectives: Initiate a transformation of mechanical energy to electrical energy and back again

Virginia SOLs: PS.1a, PS.2f, PS.5a, PS.5c, PS.6a, PS.6b, PS.6c, PS.11a, 3.1j, 3.3b, 4.1a, 4.2d, 4.3c, 4.3d, 5.1b, 6.1c, 6.2a, 6.2e
Suitable for students in grades 6-12

Materials

- piezo popper
- rubbing alcohol (From Home)
- safety goggles (From Home)
- eye dropper or disposable pipet (From Home)

Introduction

The "piezo-popper" works similarly to a barbecue lighter. A small hammer inside the popper strikes a quartz crystal and generates a large voltage spark. How does the igniter work? The igniter is a piezoelectric generator. The word *piezo* comes from the Greek word for *press*. A piezoelectric substance is something that makes electricity when you press on it. The igniter holds this ceramic element in a plastic case, with a steel hammer attached to a spring and a catch. As you push down the plunger, the spring is compressed until it hits the catch, which releases the spring, pushing the hammer quickly down on the ceramic. The electricity runs through the wires to the spark gap, which it jumps across, igniting the fuel-air mixture. The spark occurs inside a canister with a removable top. As the name implies, the cannister can pop off from the top.

Fig. 3 The piezo popper uses piezoelectricity. (Image from teachersource.com)
A closer view of the spark gap is shown in **Fig. 4**

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Fig. 4 Closer view of end of wire in canister

Types of air-fuel mixtures

While perfume (which is mostly alcohol) works well, the best fuels are hair spray and Binaca. Hair spray has alcohol in it also, but it also contains large amounts of propane, butane, and isobutane as propellants (gases under so much pressure that they are liquids in the can and turn to gas at the nozzle). These gases are excellent fuels. The Binaca is alcohol and isobutane and comes in a very convenient dispenser. It fits easily in a pocket and delivers just the right amount of fuel in a single push of its button. (The hair spray keeps spraying, so it is harder to get just the right amount). To create an explosion, you need a flammable gas, oxygen, and a source of heat to start things off. Solids like candle wax and liquids like alcohol only burn when they are heated enough to become gases. Then they need a little more heat to get them to break their chemical bonds so they can combine with the oxygen.

In our activity we will use alcohol, which when sprayed in a fine mist, produces a nice vapor, which will ignite with a small spark to start things burning. The small film canister can only hold a small amount of air and fuel mixture, so it is safe to fire off in the house. The plastic can is soft and light and can land on people without disturbing their hairdo. But it takes off rather quickly, and it is not recommended to have your head in the way during a launch.

The amount of air that is required to be mixed with the fuel will vary with which fuel is used. The ratio of air to fuel (called surprisingly enough, the 'fuel-air ratio') must be just right for some fuels. Other fuels (such as hydrogen) have a wide range of ratios that will explode.
Hydrogen will burn in air at concentrations ranging from 4% to 75% by volume. Methane (natural gas) burns at 5.3% to 15%. Propane burns at 2.1% to 9.5%. Isobutane burns at 1.8% to 8.4%. Hydrogen will explode in air at ratios of 13% to 59%. Methane explodes at a much

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narrower range between 6.3% and 14% (ratios are fuel to air). It is easy to see how too little fuel will result in no explosion. But the ratios we saw in the preceding paragraphs show that the problem is more likely to be too *much* fuel. If it won't go *Bang!*, try lifting it off the pad and putting it back. This will allow a little more air in, and you will probably get a bang out of the results.

As the fuel-air mixture burns, energy is released by the formation of chemical bonds between the oxygen in the air and the carbon and hydrogen in the fuel. This energy heats up the gasses that result from the burning. The resultant gases are water vapor (H_2O) and carbon dioxide (CO_2). Since they are hot, they expand. The expansion pushes on all sides of the can and its lid. The can and the lid separate quickly, and the can goes skyward.

Predictions

1. Cite an instance when you were able to see an electric spark.

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2. Do you think that you will be able to see a spark inside the "piezo-popper"? Why or why not?

_____
_____
_____

3. In the end of the activity, you will be combusting two drops of alcohol to launch the popper into the air. Predict how high the popper will rise.

_____
_____
_____

Observations

1. With the bottom of the film canister off, depress the trigger. Observe the spark carefully. If you can't see the spark, turns the lights off. Describe the spark.

_____

2. Put your goggles on.

3. Place the bottom of the canister onto the popper. Be certain that your popper is not aimed at anybody or at anything breakable. Depress the trigger. Record your observations, including how high/far the canister was launched.

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4. Using the dropper, place two drops of alcohol inside the canister and place the bottom onto the popper. Hold the canister in your hands for at least two minutes to vaporize the alcohol.

5. Go outside, or to a gymnasium, or other room with high ceilings. Be certain that your popper is not aimed at anybody or at anything breakable. Depress the trigger. Record your observations, including how high/far the canister was launched.

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Explanations

1. Describe how there was mechanical energy present before the spark of electrical energy was produced.

_____
_____
_____

2. We know that energy is conserved. What happened to the electrical energy from the spark in Step 1? Be specific.

_____
_____
_____

3. What happened to the electrical energy from the spark in Step 5? Be specific.

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