6. Piezo Ignition

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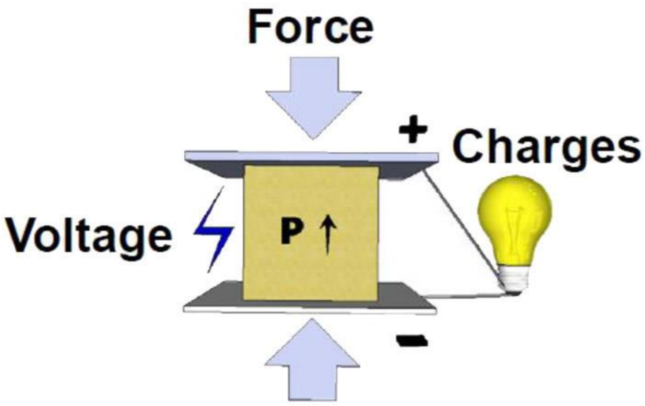


Problem To Be Investigated

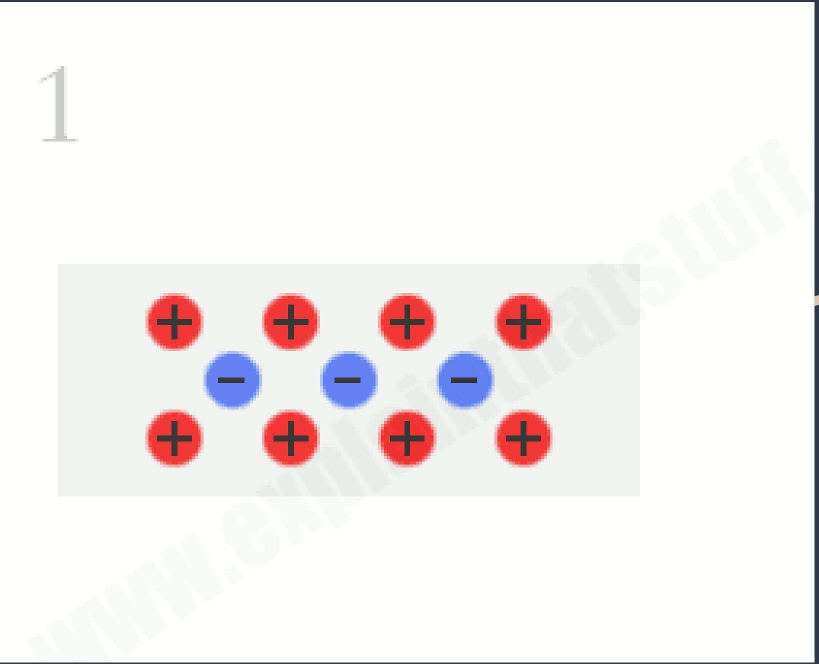
A common lighter uses *piezoelectric crystals*.

Investigate the quantitative parameters describing the response of such crystals to pressure.

Definition

- ***What is piezoelectricity?***
    - Piezoelectricity (also called the piezoelectric effect) is the appearance of an electrical potential (a voltage, in other words) across the sides of a crystal when you subject it to mechanical stress (by squeezing it).
    - In practice, the crystal becomes a kind of tiny battery with a positive charge on one face and a negative charge on the opposite face; current flows if we connect the two faces together to make a circuit. In the reverse piezoelectric effect, a crystal becomes mechanically stressed (deformed in shape) when a voltage is applied across its opposite faces.

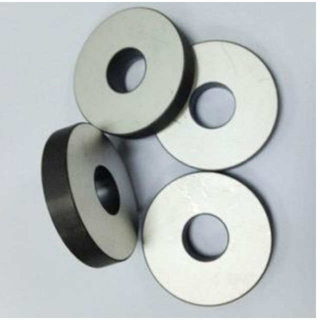
Definition

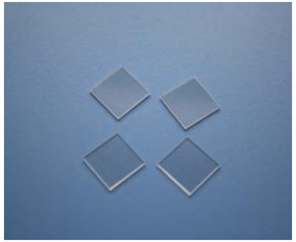


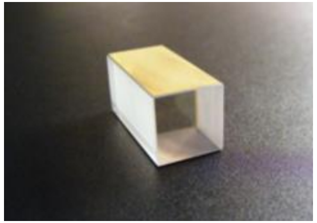
- **How piezoelectricity works**
  - Normally, the charges in a piezoelectric crystal are exactly balanced, even if they're not symmetrically arranged.
  - The electric dipole moments—vector lines separating opposite charges—exactly cancel one another out.
  - If you squeeze the crystal, you deform that structure and force the charges out of balance.
  - This effect carries through the whole structure so now the effects of the charges (their dipole moments) no longer cancel one another out, which leads to net positive and negative charges appearing on opposite crystal faces.

Material

- **Quartz crystal**
  - Both man-made and natural
- **PZT ceramics**
  - Man-made
  - Made by lead zirconate titanate
  - Can produce more voltage than quartz with the same amount of mechanical pressure.
- **Barium Titanate**
  - Man-made
  - Ceramic
  - Known for its long lasting durability
- **Lithium Niobate**
  - Man-made
  - Oxygen, lithium, and niobium
  - Ceramic material
  - Performs similar to barium titanate







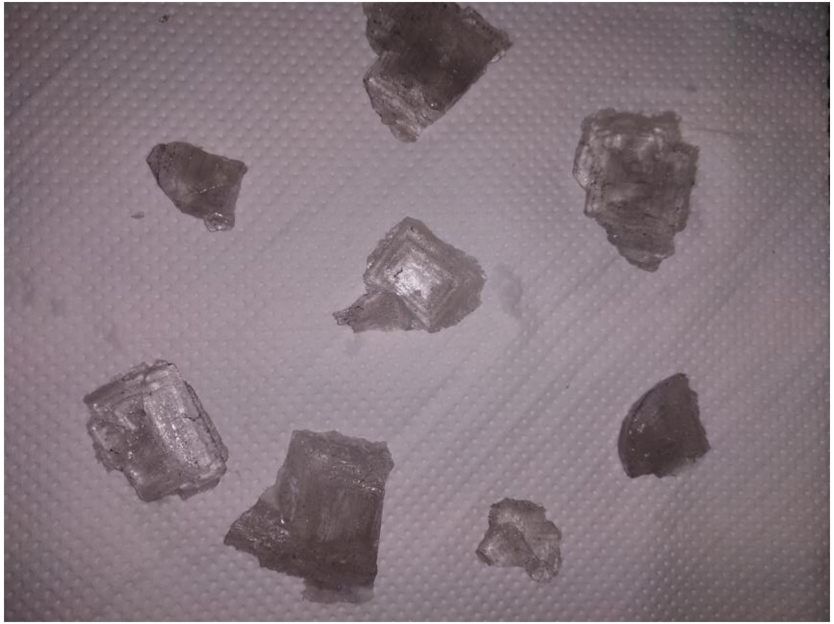
Hypotheses

- **Current**
  - The crystals will produce an alternating current, as the crystal generates a current when it's being compressed and a reverse current when it's being discompressed.
- **Size of the crystal**
  - The size of the crystal will affect the created voltage.
- **Force**
  - The produced voltage will be higher pro rata with the applied force.
- **Time that the force was applied for**
  - A crystal will generate the same voltage under the same mechanical stress no matter its duration.

Experiment

<u>Steps Of The Experiment:</u>

1. Collecting the ingredients needed
2. Making the crystals
3. Testing the crystals



Experiment

Step 1: Collecting The Ingredients

1. Potassium Bitartrate
2. Water
3. Sodium Carbonate

(1) Cream Of Tartar, bought
(2) Filtered Tap Water, room temperature
(3) Made by heating up Sodium Bicarbonate

Experiment

Step 2: Making The Crystals

1. Dissolve 44g of $KC_4H_5O_6$ in 100mL of water.
2. Keep adding pinches of Na_2CO_3 until bubbles no longer form and the solution is almost transparent (acid-base reaction, the carbonate turns into water & carbon dioxide which bubbles off).
3. Filter the solution.
4. Cover lightly and wait for the crystals to form before collecting them.

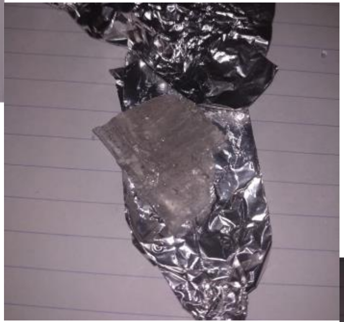
Experiment

Experiment

Step 3: Testing The Piezoelectric Crystals

Three crystals of different sizes were used to conduct the following experiments.

1



2

3

Experiment

3.1) Current

To test this parameter, mechanical stress was applied to all three crystals and their voltage was recorded both on the AC and the DC settings of a digital multimeter.

AC:

Crystal 1: 0A

Crystal 2: -0.008A to 0.006A

Crystal 3: -0.013A TO 0.015A

DC:

Crystal 1-3: 0A

Experiment

3.2) Size

To test this parameter, all three crystals' reactions under the same conditions were observed.

Crystal 1: 0V

Crystal 2: <0.012V

Crystal 3: <0.028V

Experiment

3.3) Applied Force

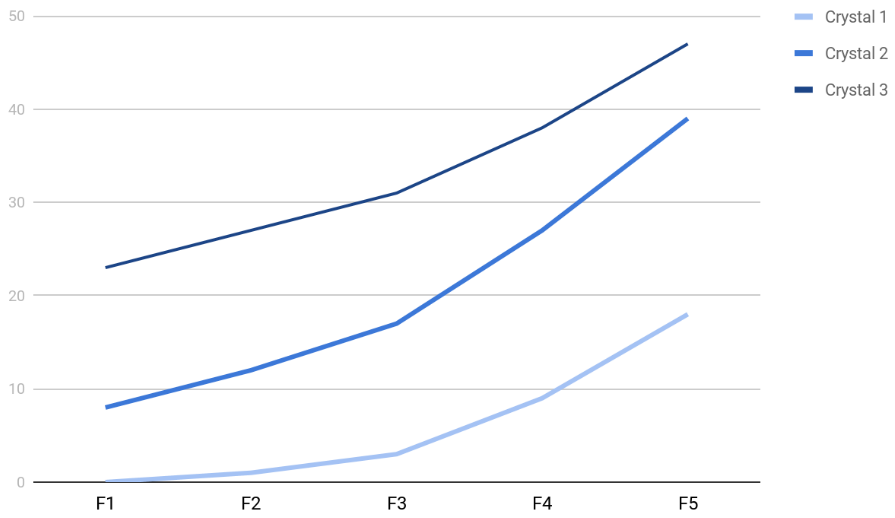
To test this parameter, the three crystals were all subjected to the same amount of force for 5 rounds. That amount increased in each round.

Maximum Voltage In Each Level (Ascending Order)

Crystal	0.000	0.001	0.003	0.009	0.018
	0.008	0.012	0.017	0.027	0.039
	0.023	0.027	0.031	0.038	0.049

Experiment

3.3) Applied Force



Experiment

3.4) Time Of Applied Force

To test this parameter, all three crystals were tested by applying the same force twice, one time being momentarily and the other being for an extended period of time (5s).

Time / Crystals	Momentarily	5s
Crystal 1	0.001V	0.002V
Crystal 2	0.009V	0.007V
Crystal 3	0.019V	0.02V

Conclusion

After conducting those experiment, the following conclusions can be drawn about Rochelle Salt crystals;

- The crystals produce an alternating current.
- The voltage of the crystal is proportional to its size.
- The higher the applied force, the higher the created voltage.
- The time a force is steadily applied for on the crystal does not significantly affect the produced voltage.

Appendix

- $2NaHCO_3 \rightarrow Na_2CO_3(s) + H_2O(g) + CO_2(g)$
- $2KC_4H_5O_6 + Na_2CO_3 \rightarrow 2KNaC_4H_4O_6 + H_2O + CO_2$
- An Arduino bracket was used to apply the same force to all crystals when needed.
- An Arduino humidity and temperature sensor was used to check the environmental conditions throughout the conduction of the experiment. Although neither of those parameters stayed exactly the same during the experiment, the changes in both were too slight to be considered significant to the experiment.
- Other possible errors include:
  - Malfunctioning/inaccuracy of the machinery used for the experiment.
  - Misusage of said mechanism.
  - Implications of other electromagnetic fields/radiation.

Sources

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Thank you for your attention.