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# Wild about learning

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# Hands-on Engineering

Elementary workshop


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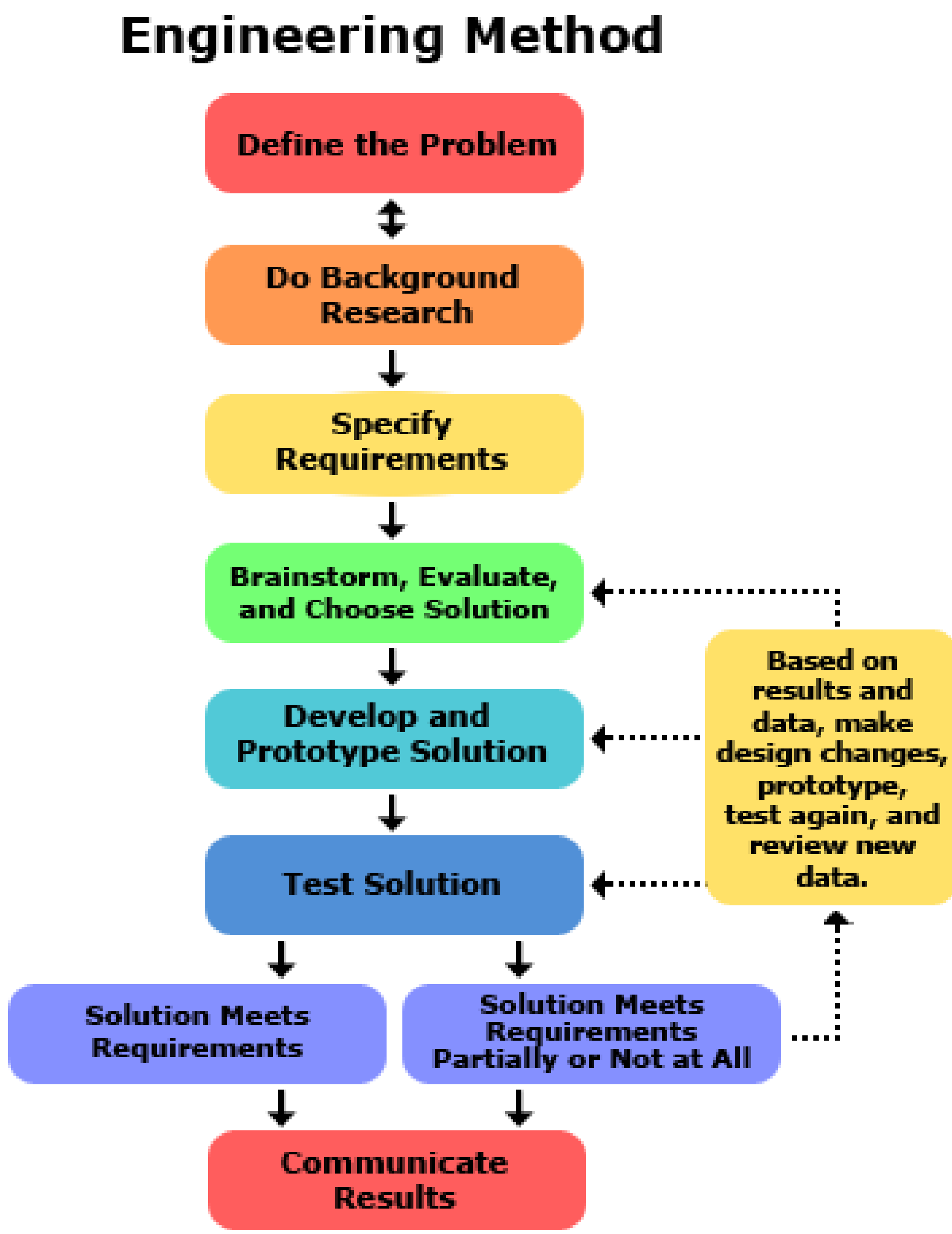
The engineering design process is a series of steps that engineers follow to come up with a solution to a problem. Many times the solution involves designing a product (like a machine or computer code) that meets certain criteria and/or accomplishes a certain task.

The steps of the engineering design process are to:

- **Define the Problem**
- **Do Background Research**
- **Specify Requirements**
- **Brainstorm Solutions**
- **Choose the Best Solution**
- **Do Development Work**
- **Build a Prototype**
- **Test and Redesign**




Engineers do not always follow the engineering design process steps in order, one after another. It is very common to design something, test it, find a problem, and then go back to an earlier step to make a modification or change to your design. This way of working is called iteration, and it is likely that your process will do the same!

**Define the Problem:** The engineering design process starts when you ask the following questions about problems that you observe:

**Do Background Research:** Learn from the experiences of others — this can help you find out about existing solutions to similar problems, and avoid mistakes that were made in the past. So, for an engineering design project, do background research in two major areas:

**Specify Requirements:** Design requirements state the important characteristics that your solution must meet to succeed. One of the best ways to identify the design requirements for your solution is to analyze the concrete example of a similar, existing product, noting each of its key features.

**Brainstorm Solutions:** There are always many good possibilities for solving design problems. If you focus on just one before looking at the alternatives, it is almost certain that you are overlooking a better solution. Good designers try to generate as many possible solutions as they can.

**Choose the Best Solution:** Look at whether each possible solution meets your design requirements. Some solutions probably meet more requirements than others. Reject solutions that do not meet the requirements.

**Develop the Solution:** Development involves the refinement and improvement of a solution, and it continues throughout the design process, often even after a product ships to customers.

**Build a Prototype:** A prototype is an operating version of a solution. Often it is made with different materials than the final version, and generally it is not as polished. Prototypes are a key step in the development of a final solution, allowing the designer to test how the solution will work.

**Test and Redesign:** The design process involves multiple iterations and redesigns of your final solution. You will likely test your solution, find new problems, make changes, and test new solutions before settling on a final design.

**Communicate Results:** To complete your project, communicate your results to others in a final report and/or a display board. Professional engineers always do the same, thoroughly documenting their solutions so that they can be manufactured and supported.

** Adapted from Science Buddies (http://www.sciencebuddies.org)*

# "Don't Blow Your Top" challenge

In this experiment, you will challenge your students to develop a method of increasing the speed in which the lid of a film canister will explode.

**Materials: (per group of students)**
One white film canister*
One effervescent tablet
Access to warm/cold water
Tray or other large plastic container (optional)
Timer/stopwatch
Safety glasses

* Canisters can be purchased from Educational Innovations ((http://www.teachersource.com/product/rocket-film-canisters/chemistry)

**Procedure:**

1) Choose which path is best for your students to complete this challenge. It would be best to have them design a solution first and to explain this design to the group/class before running the experiment.
2) All times collected from these experiments should be published for the class to observe along with the design ideas.
3) After communicating results, allow the students to choose the best design and rerun their experiment with an additional effervescent tablet.

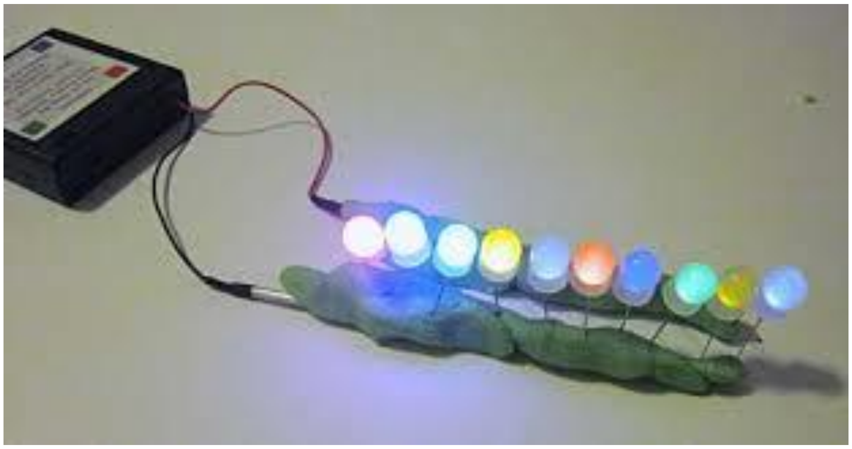
**Scientific Explanation:**
Effervescent tablets contain sodium bicarbonate ($NaHCO_3$), a base, and citric acid ($C_6H_8O_7$), an acid. (They also contain acetylsalicylic acid (aspirin) as a pain reliever, but it is not involved in making the fizz.) In the solid tablet the acid and base do not react, but when placed in water the sodium bicarbonate reacts with the citric acid in an acid-base neutralization reaction. One of the products is carbon dioxide gas, which causes the fizz.

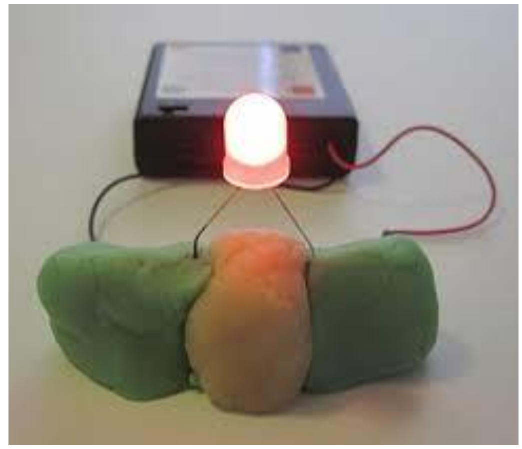
$$NaHCO_3(aq) + C_6H_8O_7(aq) \rightarrow NaC_6H_7O_7(aq) + H_2O(l) + CO_2(g)$$

**Hints:**
*Possible solutions include crushing the tablet into a powder or using warm water.*
Crushing the tablet into a powder increases the surface area of the powdered acids and bases that will react with each other in water. The increased surface area will allow for more of the tablet to react in a shorter amount of time. Warmer water will speed up the chemical reaction as the increased energy within the water will generate faster molecular movement within the solution. Both of these solutions will increase the gas production from the chemical reaction at an increased rate.

# Squishy Circuit challenge

In this experiment, you will challenge your students to develop a working circuit from insulating and conductive homemade dough.





**Materials:**

Conductive Dough
1 cup Water
1 1/2 cups Flour
1/4 cup Salt
3 Tbsp. Cream of Tartar) or 9 Tbsp. of Lemon Juice
1 Tbsp. Vegetable Oil
Food Coloring (optional)

Insulating Dough
1 1/2 cup Flour
1/2 cup Sugar
3 Tbsp. Vegetable Oil
1/2 cup Deionized (or Distilled) Water

And...

Several LEDs (RadioShack Catalog # 276-1622)
One (1) 9volt battery
Wires or alligator clips to connect battery to dough

**Procedure:**

Preparation: Conducting dough

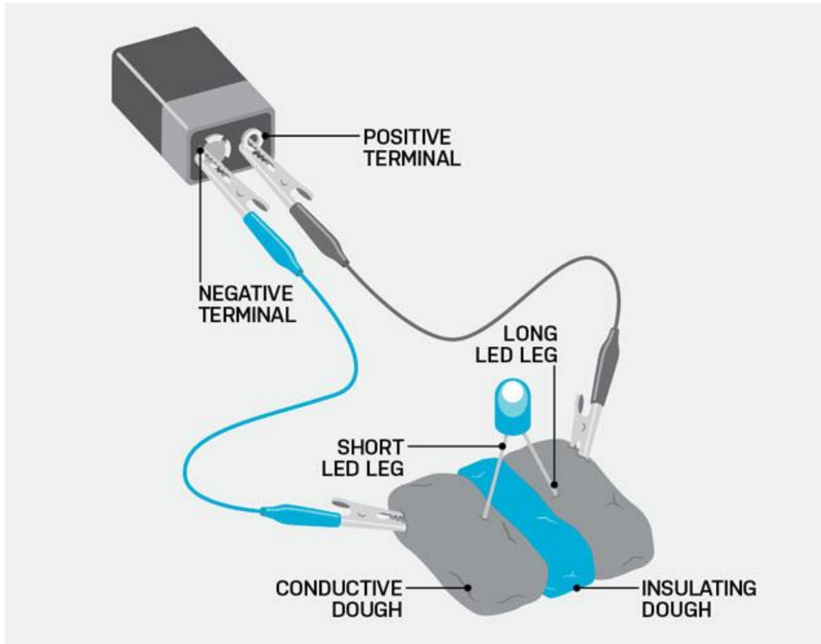
1) Mix water, 1cup of flour, salt, cream of tartar, vegetable oil, and food coloring in a medium sized pot.
2) Cook over medium heat and stir continuously.
3) The mixture will begin to boil and start to get chunky.
4) Keep stirring the mixture until it forms a ball in the center of the pot.
5) Once a ball forms, place the ball on a lightly floured surface.
6) WARNING: The dough will be very hot. I suggest flattening it out and letting it cool for a couple minutes before handling.
7) Slowly knead the remaining flour into the ball until you've reached a desired consistency.
8) Store in an airtight container or plastic bag. While in the bag, water from the dough will create condensation. This is normal. Just knead the dough after removing it from the bag, and it will be as good as new. If stored properly, the dough should keep for several weeks.

Preparation: Insulating dough

1) Mix solid ingredients and oil in a pot or large bowl, setting aside ½ cup flour to be used later.
2) Mix with this mixture a small amount of deionized water (about 1 Tbsp.) and stir.
3) Repeat this step until the mixture absorbs a majority of the water.
4) Once your mixture is at this consistency, knead the mixture into one "lump".
5) Knead more water into the dough until it has a sticky, dough-like texture.
6) Now, knead in flour to the dough, until a desired texture is reached.
7) Store in an airtight container or plastic bag. While in the bag, water from the dough will create condensation. This is normal. Just knead the dough after removing it from the bag, and it will be as good as new. If stored properly, the dough should keep for several weeks.

Activity:

1) Introduce that they are going to be scientists for the next few minutes, and they will be observing and experimenting with electrical circuits. Ask where they find electrical circuits in their everyday lives. Accept all reasonable answers, and summarize that electrical circuits are all electrical devices from computers (complex circuits) to lamps (simple circuits).




2) Identifying Components: The materials in front of them will be used to make some simple circuits. Ask them to identify the following components:

- Battery: The source of electrical energy. Connecting the positive and negative leads generates an electric current.
- Light Emitting Diode (LED): Emits light when an electric current run through the wires.
- Play dough: Connections between the battery and LED.

3) Building the first circuit: Ask them to make two balls (about $\frac{3}{4}$ in. diameter) of the colored dough. Each group should also get a battery and one LED. Ask them to make the LED light up using all 4 components, but that they should not directly connect the battery to the LED, since this might damage the LED. When they have been succeeded inquire as to what they've learned about when the LED turns on and when it doesn't. In particular, that (1) the LED only lights up when it's in a certain direction and (2) the two balls can't touch.

4) Plug one end of the battery into one ball and the other end of the battery the other. Then, plug the ends of the LED into separate balls, like a bridge. Ask how many of them worked (about half of them should work). Then ask

everyone to pull out his or her LED, flip it around, and reinsert into the dough. It should have flipped on or off.

**WARNING: Do not connect the battery to the LEDs directly, as they are not designed to withstand 9V for an extended period. Explain that an LED only works if the electricity is flowing in the correct direction.**

5) Electric Current: Reset their circuits to the 1 LED circuit. Explain that they've created a loop from the positive end of the battery through one dough ball, the LED, the other dough ball, and into the negative end. This allows an electrical current to flow.

6) Open vs. Closed Circuit: Reset their circuits. Ask them to pull off one of the leads. This breaks the pathway, preventing electricity from flowing. This is an open circuit. When the loop is complete, it's a closed circuit.

7) Short circuit: Reset their circuits. Ask them to make another dough ball and connect the two balls. This will turn off the light, because it creates shortcut for the electricity. This is a short circuit. The same thing happens when the two balls touch. This dough is conductive and allows electricity to flow through it.

8) Sandwich: Reset their circuits. Then what happens if you connect the two balls with a ball of the white (insulating) dough? It will not turn off because electricity cannot flow through this dough. This dough is insulating. Ask them to create/demonstrate a sandwich of two conducting balls with insulating dough in between and to create a circuit with an active light.

9) Parallel Circuit: Ask them to get another LED, and see if they can get two lights to turn on. This is a parallel circuit, because there are parallel paths for the electricity. If possible, draw the parallel circuit shown below.

10) Series Circuit: Ask them to create a larger sandwich by adding an insulator ball and a conductive ball. Can they turn on two LEDs using all three conducting balls? This is a series circuit, because there is one path going through both. What happens when they remove one of the LEDs? This breaks

the path creating an open circuit. If possible, draw the series circuit shown below.

11) <u>LED Sculpture</u>: Challenge them to come up now to create a CREATURE that uses three or more LEDs. Be creative.

Scientific Explanation:

This activity is an exploration of electrical circuits through play dough. In this instance, current electricity is created by the flow of electrons, carrying an electric charge, through a conductive material. (It can also be carried by ions.) A conductive material, such as metal, typically has many free electrons that are easily dislodged from their orbits. Materials that do not allow the flow of electricity are known as insulators.

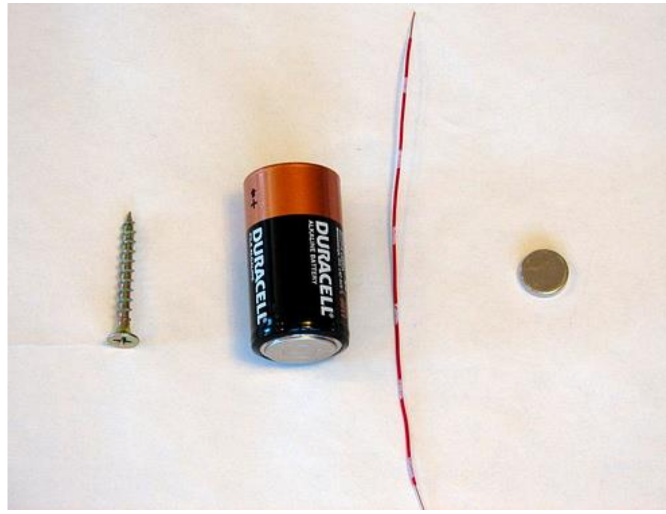
An electrical circuit is a closed looped pathway for the flow of electricity. Typically, it contains an energy source and a load, a component or set of components that uses electricity energy for work. Finally, wires are typically used to move the electricity from the battery through the load. Modern electrical circuits range in complexity from simple lamps, to complex computers. This activity explores various circuit arrangements to power one or more LEDs. In particular, it explores open vs. closed circuits, short circuits, and parallel vs. series circuits.

For our circuits, a battery will be the energy source and LEDs will be used for the load. The part of the wires will be played by play dough, which due to its high salt content and some acidity is conductive. Insulating dough is also available to buffer the conductive dough and allow for the creation of larger structures.

*Lesson adapted from the Center for Science and Engineering Partnerships (csep.cnsi.ucsb.edu)

## Simple motor challenge

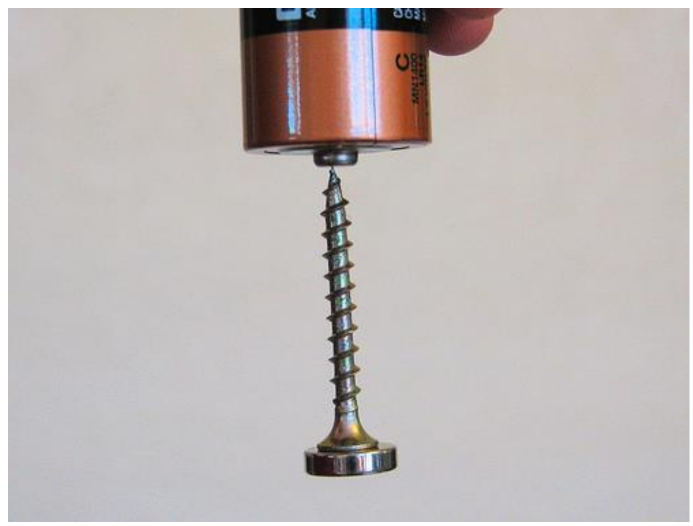
In this experiment, you will challenge your students to create a motor from four very simple items.




**Materials:**
one drywall screw
one 1.5 V alkaline battery
six inches of plain copper wire
one small neodymium magnet

**Procedure:**

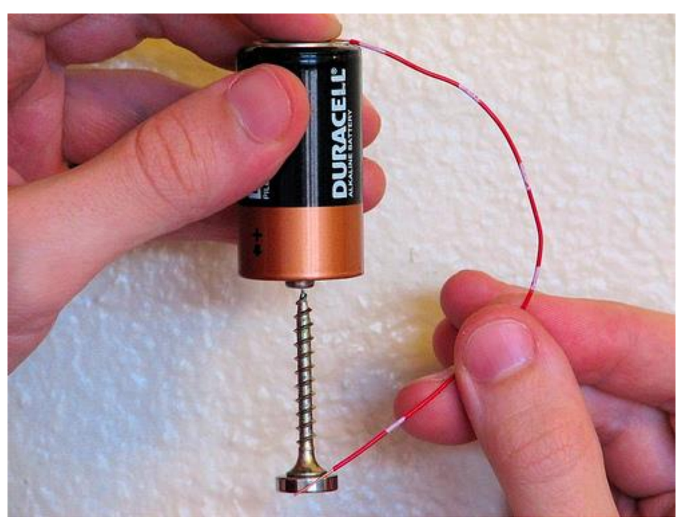
1) Set the screw on the magnet, bend the wire.
2) Attach the magnet to one end of the battery.



**Scientific Explanation:**

The easy explanation:

When you touch the wire to the side of the magnet you create an electric circuit. A current runs out of the battery, down the screw, through the magnet, the wire and finally to the other end of the battery. The force of the magnet and the electric current flowing through it cause a new force to act on the magnet. this new force drives the magnet to spin very fast! Congratulations! You have must made a homopolar motor!




The "not so" easy explanation:

When you touch the wire to the side of the magnet, you complete an electric circuit. Current flows out of the battery, down the screw, sideways through the magnet to the wire, and through the wire to the other end of the battery. The magnetic field from the magnet is oriented through its flat faces, so it is parallel to the magnet's axis of symmetry. Electric current flows through the magnet (on average) in the direction from the center of the magnet to the edge, so it flows in the radial direction, perpendicular to the magnet's axis of symmetry. If you took physics at some point, it's possible that you'll remember the effect that a magnetic field has on moving electric charges: they experience a force that is perpendicular to both their direction of movement and the magnetic field. Since the field is along the symmetry axis of the magnet and the charges are moving radially outward from that axis, the force is in the tangential direction, and so the magnet begins to spin.