4th Grade Physical Science Engineering Project

**Time:** 120 minutes

**Summary**

In this hands-on activity, student teams apply the engineering design process to create prototype toys with moving parts. They set up electric circuits using batteries, wire, and motors, and plan project materials to meet budget constraints.

**Engineering connection**

Modern toys often incorporate electronics, from motors to radio transmitters and receivers to electronic voice systems. Even without such technologically advanced components, toys are engineered with careful attention paid to their shapes and material composition. Due to the complex nature of the toy design and manufacturing industry, toy engineering often relies upon people with diverse engineering backgrounds who can work in multidisciplinary teams.

**Learning objectives**

After doing this activity, students should be able to:

* Apply the engineering design process to a design challenge.
* Create a plan for project material expenses based on a budget.
* Set up an electric circuit using batteries, wire, and a motor.

**Standards**

International Technology and Engineering Educators Association

* C. The engineering design process involves defining a problem, generating ideas, selecting a solution, testing the solution(s), making the item, evaluating it, and presenting the results.
* D. When designing an object, it is important to be creative and consider all ideas.

Next Generation Science Standards

Engineering Design

* 3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
* 3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
* 3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Physical science

* 4-PS3-4 Apply scientific ideas to design, test, and refine a devicethat converts energy from one form to another. [Crosscutting concept: Engineers improve existing technologies or develop new ones.]

**Materials**

Each group of three students needs:

* 10 Popsicle or wooden craft sticks
* 10 plastic drinking straws
* 1 pair of scissors
* 5 notecards
* 1 small electric motor (available online, such as the [1.5 to 3VDC hobby motor](http://www.radioshack.com/product/index.jsp?productId=2102822) at Radio Shack, model #273-223
* 2 wheel and axle sets (available online, such as at [Kidder](http://kidder.ca/))
* 2 sets of gears (available online, such as at [Science Kit](http://sciencekit.com/) (plastic gears IG0030524) or Kidder (ID=80-3570-00)
* 1 rubber band
* 3 paperclips
* 2 feet (.6 m) thin insulated wire
* 2 AA batteries
* 1 ruler
* 3 sheets of paper
* 1 set of markers
* 4 magnets
* masking tape
* toy money (such as Monopoly money)
* 1 copy of [Build-A-Toy Workshop Design worksheet](http://www.teachengineering.org/collection/cub_/activities/cub_electricity/cub_electricity_lesson05_activity3_design_worksheet.pdf)

**Introduction/Motivation**

Did you know that the job for some engineers is to design toys? Pretty cool, huh? Toy engineers get to apply their math and science skills making toys that work well and are also entertaining, inexpensive, and durable.

Even simple toys involve a lot of engineering. The engineers who design the darts for Nerf guns try out a lot of different designs, varying the darts’ shape, material, and mass before selecting a final design. These engineers also must balance out the darts’ performance with their manufacturing costs.

If engineering a dart takes that much time and testing, imagine all of the work that goes into designing a remote controlled car! Do you think you have what it takes to be a toy engineer? Even though it is a lot of work, I think you will find that it’s also fun and rewarding.

Today, we are going to take on an engineering challenge, and experience toy engineering firsthand!

**Challenge:**

Children of families who had to evacuate their homes because of a wildfires no longer have any toys. We need to engineer some new toys for them! You will be given various materials to work with and need to use your imagination plus math and science knowledge to design and build toys with moving parts. That means you need to apply your scientific knowledge of electrical circuits to your toy design. Think of toys you have seen that can move on their own.

All of those toys are built with electric circuits.

Remember, an electric circuit needs to include a closed loop that current can travel through, as well as a voltage or power source. What do you think could be used as a voltage source? *(Possible answers: Batteries, wall outlet.)* For your toys, you will use batteries.

You have also already learned about resistance. What is an example of a resistor that you have seen in past lessons and activities? (Answer: A light bulb.) Your toys will incorporate motors, which act as resistors. It is up to you to decide how to use that spinning motor as part of your toy. One last constraint for this engineering challenge: your toy must cost $80 or less to build. Let’s get started!

**Before the Activity**

* Gather materials and arrange them into a “store.” Consider posting the cost of each item on the board. Suggested material prices are provided on the design worksheet.
* Prepare to project the attached [Toy Engineering Presentation](http://www.teachengineering.org/collection/cub_/activities/cub_electricity/cub_electricity_lesson05_activity3_toy_presentation.pptx). (Click[HERE](http://www.teachengineering.org/collection/cub_/activities/cub_electricity/cub_electricity_lesson05_activity3_toy_presentation.pdf) for .pdf)
* Make copies of the attached [Build-a-Toy Workshop Design Worksheet](http://www.teachengineering.org/collection/cub_/activities/cub_electricity/cub_electricity_lesson05_activity3_design_worksheet.pdf), one per group.
* Divide the class into groups of three students each.

**Activity**



Examples of student-designed toy vehicles Copyright © 2009 William Surles, University of Colorado Boulder

1. Introduce students to their engineering design challenge with the Toy Engineering Presentation. Review basic information about electric circuits.

2. Review the following information with students:

Before you start working on your toy, it is important that we review the engineering design process so we can use it to accomplish this task. Who can list the engineering design process steps for me? (*Answer: Identify the Prpblem, imagine or brainstorm ideas, design, build, test, redesign and retest.)*

First, you need to outline the problem and your constraints. Next, brainstorm with your group and write down all ideas you can think of, no matter how crazy they sound. After you have written down your ideas, vote as a team and agree on one, best design to work on. Draw out a plan for how to make the idea you’ve created. Then, gather materials and begin building a prototype. Once your prototype is complete, test it to see if it works the way you planned. After you’ve tested it, apply what you learned to improve it.

Now that we’ve reviewed the engineering design process, let’s get started with the first step – Identifying the problem. For this activity, we are going to imagine that we all work for a toy company called Build-a-Toy Workshop. Build-a-Toy Workshop heard that some families in a town nearby lost their homes and all their belongings in a wildfire. These families evacuated with only their most important belongings and the children in these families no longer have any toys at all to play with. Build-a-Toy Workshop decided to put their engineers to work to create really special toys for these children. They want the toys to be fun and creative to make the children feel better after all they’ve been through. They also have given us the requirement that the toys must have moving parts, and must cost $80 or less. Since we are the engineers that work for Build-a-Toy Workshop, it is our job to design and build these toys!

3. Distribute a Build-a-Toy Workshop Design Worksheet, $80 of toy money, and several markers or other writing utensils to each group.

4. Direct students to begin working through the steps of the design process using their worksheets. Consider requiring that each section be signed off by theh teacher before the team can move on to the next step (this prevents groups from taking shortcuts and subsequently constructing sloppy toys).

5. After groups complete the “Build” section of their worksheets and know exactly what materials they need (as well as the total cost) they are ready to purchase materials from the “store.”

6. Give students time to build their toy prototypes. Toy construction may take a significant amount of time, especially if students have chosen a more complicated design (such as an electric car).

7. Once building is complete, encourage students to test their toys and see how well they function. Tell students to complete the “Test” portion of the worksheet, in which they detail two changes they feel are necessary to improve their designs.

8. Give students time to make changes to their designs. If they need additional materials, issue additional money to each of group for re-design expenses, or permit them to sell back materials they did not use.

9. When groups finish improving their toys, challenge them to develop a sales pitch or advertisement for their creations. Explain that they need to sell their idea to the Build-a-Toy Workshop management team to get the toys manufactured. Have students include explanations of their electrical circuits and how they used the motor in their toys.

**Troubleshooting Tips**

* Before the activity, build several different example toys using the activity materials to give students a head start and help them understand how the motors work.
* Students may automatically want to build toy cars because of the materials provided. If so, encourage them to make their vehicles unique and different from other toy cars available at stores.

**Activity Scaling**

* For lower grades, reduce the number of available materials and provide a more defined design task. For example, define the type of toy to be designe (such as a robot, electric car, helicopter, etc.) or provide pre-constructed individual toy components.
* For upper grades, give students additional money, materials and time. Challenge them to make their toys functional as well as aesthetically pleasing. When they have finished constructing their final designs, have groups develop short commercials for their toys.

**Additional resources**

[Can Toys Create Future Engineers](http://www.newyorker.com/online/blogs/currency/2013/12/can-toys-help-create-future-engineers.html)? Dec. 12, 2013 *New Yorker* feature on GoldieBlox and other STEM toys.

[Fun and Games](http://www.graduatingengineer.com/articles/20000728/Fun-and-Games). Article on engineering and computer science graduates who create toys for a living.

[How It’s Made: Model Cars](http://www.youtube.com/watch?v=p8on-DLWt74). National Geographic video of design and manufacturing process [YouTube 5:11]

Notre Dame engineering students [modify a toy car](http://www.youtube.com/watch?v=AO6XEbpksXM) for child with cerebral palsy. [YouTube 1:37]