Pullback Toy Motor Dissection

What's that clicking noise?: Reverse Engineering in Action

Figure 1: pullback toy car

Figure 2: pullback toy tractor

Recommended Grade Level: 7-12

NGSS Science & Engineering Practices
- Asking Questions (for science) and Defining Problems (for engineering)
- Using Models
- Planning and Carrying out Investigations
- Analyzing and Interpreting Data
- Obtaining, Evaluating, and Communicating Information

Preparation
- obtaining spring-powered pull-back toys (ordering online or local purchase -- whichever option is feasible and best fits the situation in terms of availability, quantity, price and time)
- gathering or obtaining other materials -- see next section
- setting out motors, toys and other materials for student use (a few minutes)

Materials Needed (ideally for each individual student; pair or small group also possible)
- Pullback toy (the type that you roll back and forth to wind up)
- Small Phillips screw driver
- Small flat screw driver
- Needle-nose pliers
- Small plastic bag for saving loose parts
- Bamboo skewer -- or other suitable item (see Step 8 and Figures 14, 15, 16 in **What to Do** section)

Background Information
Some spring-powered toys operate by merely winding the spring with a key or knob and then letting the spring power the toy after it is released. There is also a pullback version where the toy is rolled backward until the spring is wound, and then released; hence the term pullback motor. There is a more sophisticated but still very common version of a pullback motor which allows the car to be rolled back and forth until a "clicking" sound is heard which indicates that the toy is fully wound.

The engineering question or problem presented here is to determine how this clicking sound is made and what its role is in the operation of the motor, and in the process to learn more about the overall working of the motor. To do this you will take apart, or "dissect," the pullback motor in a toy. The process of taking

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something apart to determine how it works is called "reverse engineering." The process may be either "destructive" or "non-destructive," depending upon whether or not it can be successfully reassembled. It is not required for this activity that you reassemble the toy, but it would be advisable to save the pieces in the event that you end up wanting to try to do this.

The section that follows gives detailed directions and photos for taking apart, or dissecting, a pullback toy. Alternatively, the dissection might also be done by just taking the tools in hand and doing it, with an absolute minimum of instructions. The last page of this write-up is a single page of instructions for that very process. And sometimes a middle-ground of structure or guidance proves best. It is hoped that this write-up may prove to be useful as a resource for determining the potential utility of the activity for a particular class or group of students and for putting together the best approach for those students if the activity seems useful.

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What To Do

1. Obtain a "back-and-forth" pullback toy (see previous section for description; see also Figures 1 and 2).

2. Use a small Phillips screwdriver to remove the body of the toy so that you are left with the 4-wheel chassis and exposed motor. See Figures 3 and 4
(Save the screw in the event you later want to try reassembling the car! You can screw it part way back into the removed body to avoid losing it.)
NOTE: The toys used here are dissectible by just unscrewing pieces and/or prying them apart. If you are looking for toys yourself you should be aware that some that have parts which are glued together and will have to be broken apart to dissect them. Sometimes this is not a problem, but sometimes it can make the dissection significantly more difficult.

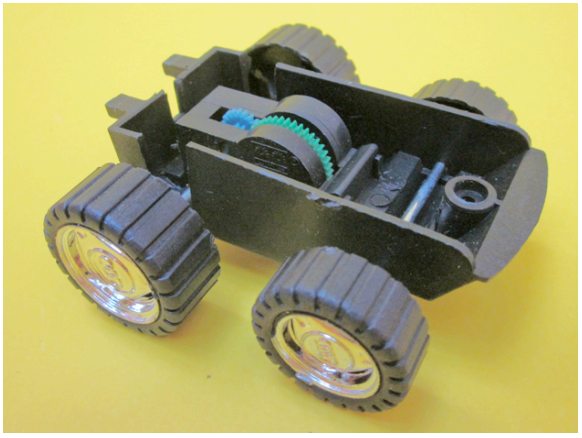

Figure 3: toy car stripped to chassis

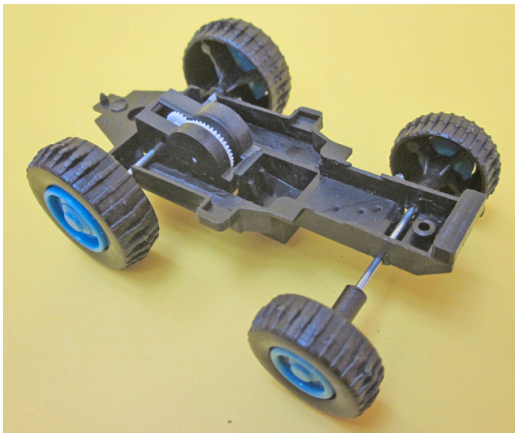

Figure 4: toy tractor stripped to chassis

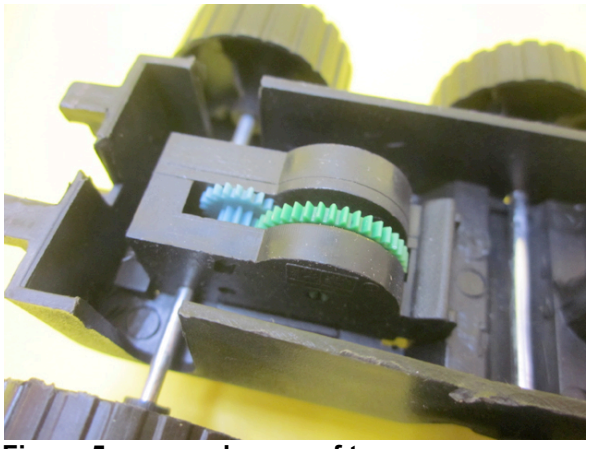

Figure 5: exposed gears of toy car

3. Play with the chassis/motor assembly and carefully observe the "back-and-forth" process of winding the car and then letting it unwind. Notice in particular the behavior of the exposed portions of the gears as shown in Figure 5.

4. Use a small flat screwdriver to gently pry the clip at the front end of the motor to remove the rear wheels/motor assembly from the rest of the chassis. See Figures 5 and 6.

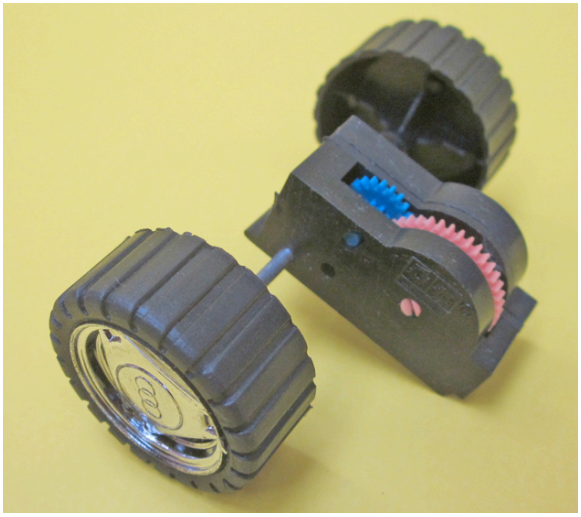

Figure 6: rear wheels/motor assembly of toy car

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5. Use the rear wheels/motor assembly to again observe the "back-and-forth" winding process and the unwinding, as you did with the chassis/motor assembly. Again closely observe the behavior of the exposed portions of the gears, but this time also observing the bottom of the motor unit (Figure 7) as well as the top (Figures 6 and 8) since the bottom is now exposed to view. This increased viewing access also allows you to get a better idea of the overall arrangement of the gears. Note also the ends of the shafts which protrude into or through the openings in the side walls of the motor unit, as well as the shapes of these openings.

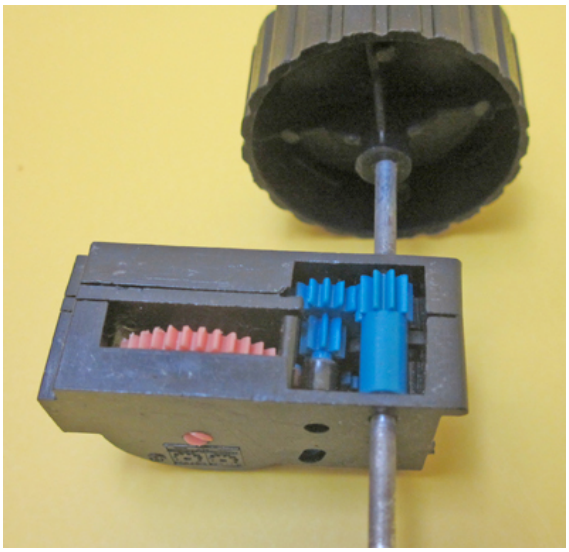

Figure 7: bottom of toy car motor showing exposed gears

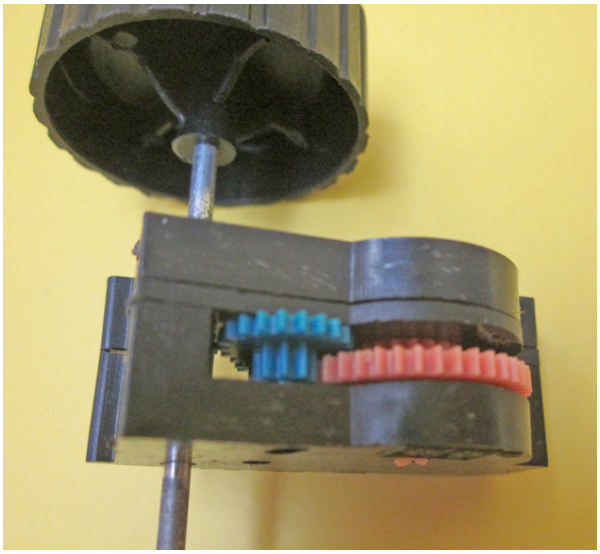

Figure 8: top of toy car motor showing exposed gears

6. Carefully pry apart the motor housing, which consists of two halves in these examples. See Figures 9 and 10. This will almost certainly result in gears falling out as you proceed. Our goal is to examine the coiled spring which you will find located in one side of the motor housing. **DO <u>NOT</u> REMOVE THE COILED SPRING!** The parts are small and may be awkward to handle, but try to use your fingers, a screwdriver, or anything that you might consider useful (e.g., a wooden craft stick, a piece of tape, etc.), to keep the spring in its housing as you pull the halves of the motor apart.
Try not to lose any gears (some are very small) in the event you later want to consider their role in the motor's operation or you want to try reassembling the motor. (A small plastic bag is provided for saving these parts.)

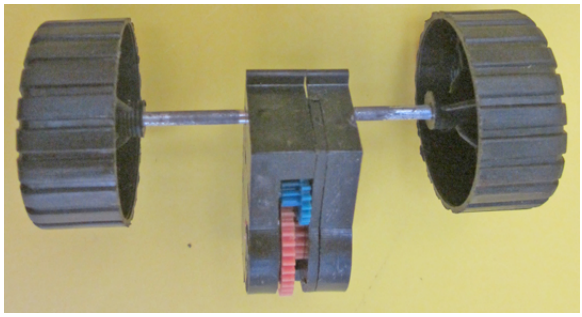

Figure 9: toy car with motor unit intact

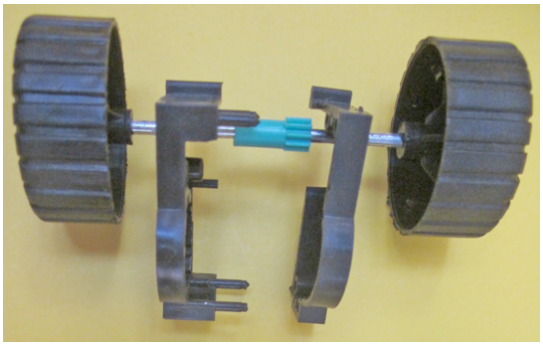

Figure 10: toy car with motor housing split

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7. Once you've gotten the spring in it's housing clearly visible, as in Figure 11, examine it carefully. Try to work out a description of what you see, and then try to describe what you think happens to the spring as the toy is subjected to the back-and-forth pullback winding process. What's that clicking noise? How is it made? How does it relate to the operation of the motor?

Figure 12 shows the spring removed from the motor housing. NOTE: If you wish to try step 8, or if you wish to try to reassemble the motor, it's probably best ***not*** to take the spring out of the housing. The word probably is used, because it is in fact possible to put the spring back into the housing, but it's difficult and requires patience, as this writer can attest! But in its own way that, too, was a rewarding experience!

Figure 13 shows a closer view of the spring still in the motor housing.

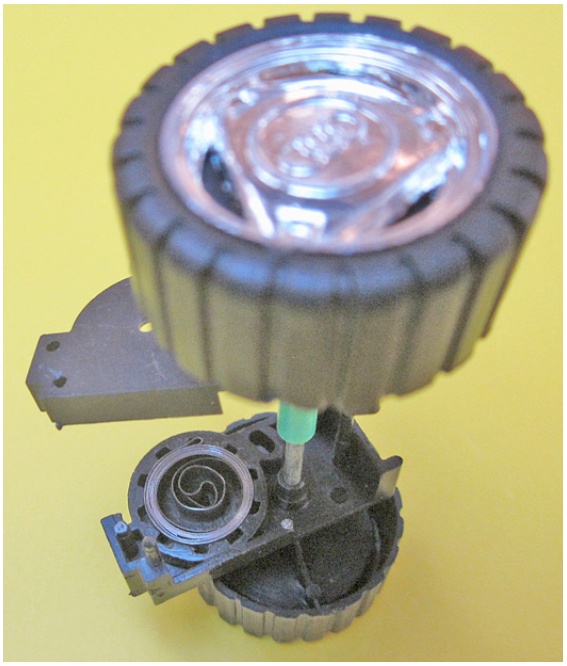

Figure 11: exposed spring of toy car

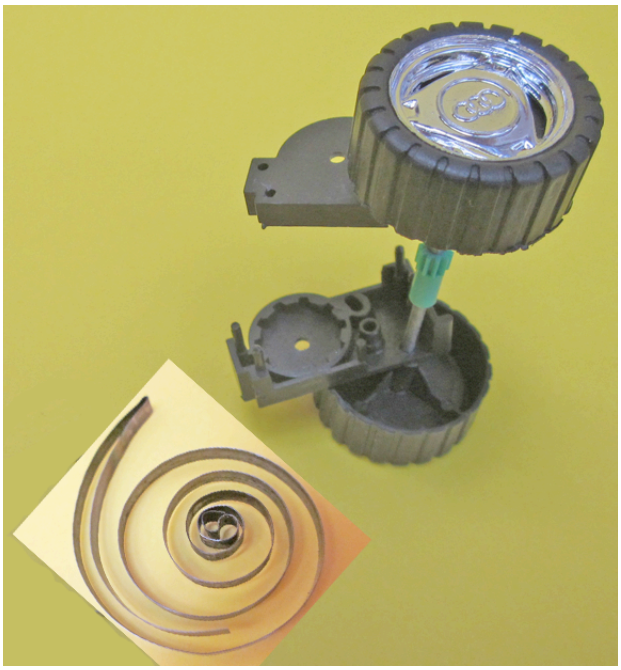

Figure12: removed spring of toy car

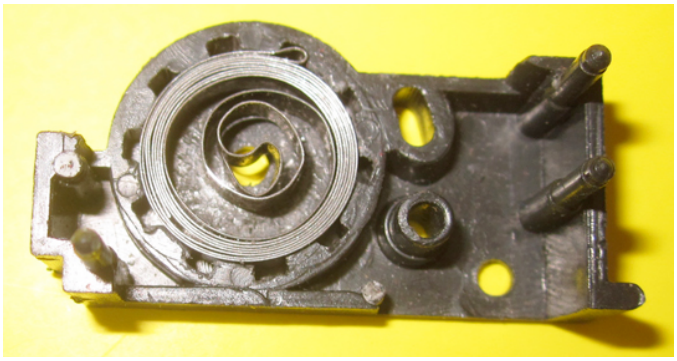

Figure 13: close-up of exposed spring still in motor housing

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8. Once you've finished examining the spring in it's housing, you might consider trying to use a pair of needle-nose pliers to grab the exposed spring at it's center and tighten it while it remains in the housing, until you hear it click. If you then keep tightening you should hear a succession of clicks. This is tricky to do and still keep the spring in the housing. Figures 14, 15 and 16 show the use of the needle-nose pliers, with a bamboo skewer placed across the spring to keep it in the housing.

Figure 14: using needle-nose pliers

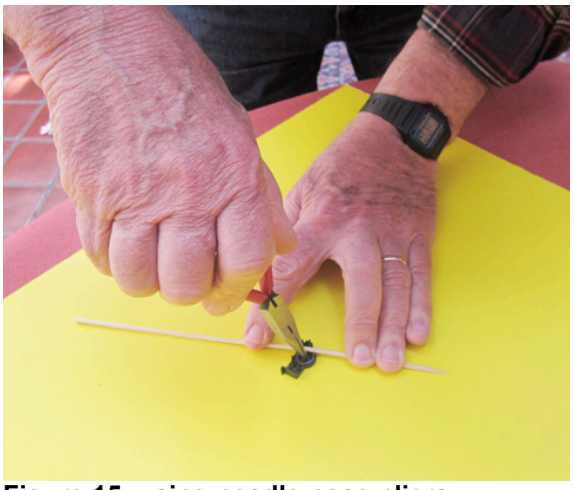

Figure 15: using needle nose pliers

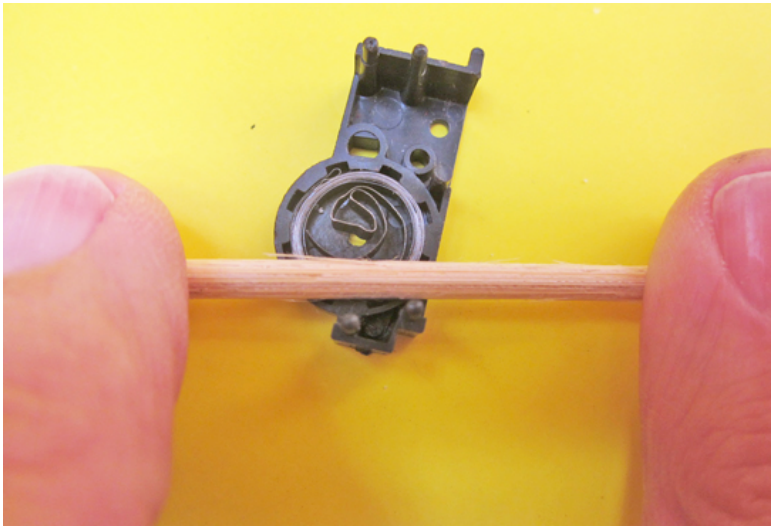

Figure 16: use of bamboo skewer to keep spring in housing

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What's Going On?
Reverse engineering is a process used in the real world of engineering to help understand how things work. This knowledge may in some cases serve as a basis for improved or innovative design.

For the specific question of the clicking noise in the pullback motor, it can be seen that there is a little "loop" on the outer end of the spring that fits into the recesses on the inner wall of the housing. Initially the loop may be in circled recess A (red in color) in Figure 14. As the spring is wound and tightened, the force pulling the loop eventually becomes so large that the loop is pulled into the next circled recess B (blue in color), making a single click in the process. If the loop slips several recesses in quick succession, this provides the continuous clicking noise. This mechanism prevents over-winding and breakage.

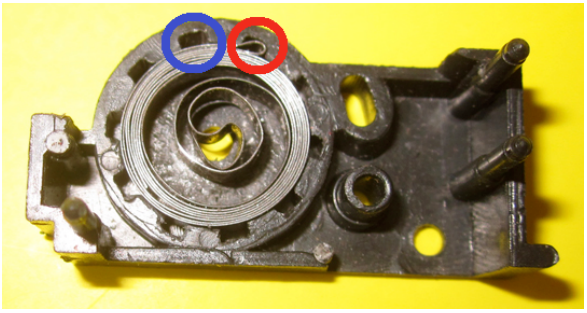

Figure 17: mechanism of the clicking noise

Going Further
• Try to reassemble the motor. See the website below for a video of the dissection and reassembly of a pullback motor.
• Make an illustrated presentation of the construction of the motor, using drawings and/or photos and/or a display of the parts.
• Explain the working of the motor, including one or more of the following aspects: (a) the role of different size gears, (b) the mechanism that only winds the car when it's being moved backward in the back and forth motion and (c) the origin and role of the clicking noise. This could include using the illustrated presentation noted in the previous item.

Recommended Web Sites:
(1) http://www.youtube.com/watch?v=6b_aWe5FT7A Video of dissection and reassembly of a pullback car.
(2) http://en.wikipedia.org/wiki/Pullback_motor Wikipedia site for Pullback Motors.
(3) http://www.me.utexas.edu/~me302/classnotes/Dissection.html Lecture notes for a Mechanical Engineering course titled Introduction to Engineering Design and Graphics. Defines Reverse Engineering and Mechanical Dissection and discusses application to a mechanical toy.
(4) Do a Google search for the following: AC 2008-1170: REVERSE ENGINEERING TO DESIGN FORWARD. The URL is incredibly long, and doesn't lend itself to inclusion here. Hopefully you will arrive at a paper by Steven Shooter, a Mechanical Engineering professor at Bucknell University, describing an activity in which engineering students use mechanical dissection and reverse engineering to design a better stapler. The experience is based on an actual real-world case.
(5) http://gicl.cs.drexel.edu/images/e/e5/ASEE.Workshop.Handout.pdf Hands-on dissection exercises for a power screwdriver, a jigsaw, a hand-mixer, and a coffee maker.

More
Sources for pullback toys include the following:

Party City	Oriental Trading Company
Giggletime Toy Company	US Toy Company

The toys used in this workshop were priced from $0.59 (tractor) to $0.75 (truck) at this writing. There are lots of other pullback toys, but the very cheap ones tend to be very tiny, and the larger ones can be quite expensive. If possible it's best to buy a single toy (or a single bag of toys it that's the way they come) so you can check in advance for the size of the motor and the overall suitability of the toy for dissection (glue joints can be a concern). If you find a toy you really like, and you plan to do the activity again in the future, it's advisable to buy as large a supply as you can reasonably finance, since a particular toy may come and go -- what you see this year may or may not be available when you look again in the future.

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Dissecting a Spring-powered Motor for a Pullback Toy

What's that clicking noise?: Reverse Engineering in Action

Materials:

- Pullback toy (the type that you roll back and forth to wind up)
- Small Phillips screw driver
- Small flat screw driver
- Needle-nose pliers
- Other useful tools or materials as needed and available (e.g., a wooden craft stick, a piece of tape, etc.)
- Small plastic bag for saving loose parts

What to Do:

Run the toy back and forth to wind it up. Notice the clicking noise that occurs when the car is fully wound. Our engineering activity here is to determine how this clicking sound is made and what its role is in the operation of the toy's spring-powered pullback motor, and in the process to potentially learn more about the overall working of the motor.

Take apart, or "dissect", the toy. It is not required for this activity that you reassemble the toy, but it would be advisable to save the pieces in the event that you end up wanting to try to do this.

The process of taking something apart to determine how it works is called "reverse engineering." The process may be either "destructive" or "non-destructive," depending upon whether or not it can be successfully reassembled.

What's Going On?

When you have learned as much as you can about the clicking noise, present your findings in a way that would allow a person who had not had taken the toy apart to understand what you learned.

Going Further:

Some extensions that provide a further challenge are:

- try to reassemble the toy so that it works again
- try to gain either a partial or total understanding of the working of the gearing mechanism
- communicate your knowledge of the working of the gearing mechanism as clearly as possible

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