

- 2 rulers
- Table or countertop (for set-up)
- Toy car

How To:

1. Use an ice pick or awl to make a hole (approx. 0.5-inch diameter) in the middle of the lid of a plastic water bottle. Secure the lid back onto the empty bottle. **Safety: An adult should assist when using an ice pick or awl.**
2. Locate a spot in your house to construct your Rube Goldberg Machine, ideally a tabletop or kitchen cabinet. Watch [this video](#) of a similar chain reaction to get an idea of what you'll be building.
3. Construct and test each of the following individual reactions to make sure they work:
 - **Marble, paper towel roll, toy car, and rulers:** Place two rulers parallel to each other, approximately 2 inches apart. Place a marble between the 2 rulers at one end. Hold the paper towel roll at an angle above the marble and roll the toy car through the paper towel roll so that it exits and collides with the marble. Make sure the marble rolls fast enough to reach the end of the rulers.
 - **Dominoes:** Set up 20-30 dominoes vertically in a line, approximately 1 inch apart from each other. Knock over the first domino and make sure that a chain reaction of domino-falling happens. Reset your dominoes.
 - **Pencils:** Now, rubber band the pencils together with all the erasers facing the same direction. Place the bundle of pencils balancing vertically on the eraser side at the end of the domino chain reaction so that the bundle is also knocked down.
 - **Chapter books:** Place the three softcover chapter books standing vertically in a line about 3-4 inches apart from each other. Knock over the first book and make sure that a chain reaction of book-falling happens.
 - **Water bottle and chapter books:** Place the two hardcover chapter books about 4 inches away from each other (lying down horizontally) at the very end of your table or counter so that the edge of each book is lined up with the edge of the counter. Next, stand the empty water bottle in between the books and knock it over, towards the end of the table. Make sure that the lid (with the hole in the top) is now *just* over the edge of the table or counter. The chapter books should make sure that the water bottle falls in a straight line, so adjust as needed.
 - **Empty glass and chair:** Finally, place your empty glass on your chair, and place the chair below the lid of the turned-over water bottle so that the glass is *directly* underneath the cap of the water bottle.
 - *NOTE: We recommend placing paper towels beneath this glass to avoid a mess during the milk pour. Also, if the distance between the water bottle lid and glass is greater than 1-2 feet, you can use aluminum foil to construct a funnel around the rim of the glass so the milk has a larger target.*
4. Now you're ready to construct your Rube Goldberg Machine! Using all the reactions that you just tested, work backwards to connect them and create a chain of reactions:
 - Set up the empty glass and chair directly beneath the spot where the water bottle will fall.
 - Set up the water bottle (still empty) and hardcover chapter books.
 - Set up the three softcover chapter books so that the last one will fall and knock over the water bottle.
 - Set the pencils about 4 inches away from the first chapter book.
 - Place the dominoes so that they knock over the bundle of pencils.
 - Set up the marble, paper towel roll, toy car, and rulers so that the marble will knock over the first domino after rolling into it.

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5. Time to test! Make sure that your entire Rube Goldberg Machine now works together to knock over the water bottle.
6. Once you've accomplished this, fill the water bottle about $\frac{3}{4}$ full with milk and see if your machine will pour milk into the glass!
7. Note: If this doesn't work on the first try, don't give up! Engineers often must test their designs many times to make them work successfully. Here are some troubleshooting tips:
 - Adjust the angle of the paper towel roll to make the marble roll either faster or slower to knock over the first domino.
 - Change the spacing of the dominoes, pencils, or books so that they fall over either faster or slower.
 - Add or take away pencils from the bundle so that it falls down as the dominoes hit it and it knocks over the books.
 - Adjust the spacing of the hardcover books at the end of the chain reaction so they hold the water bottle in place.
 - Use a taller chair so the milk doesn't have to fall as far into the glass.
8. Now that you have had practice building one holiday Rube Goldberg Machine, design another holiday-themed chain reaction of your own! Read about simple machines below and decide what type of Rube Goldberg Machine you would like to create next.

STEM Explanation:

Simple machines make doing work easier! Work is the amount of energy required to move an object a certain distance. Rube Goldberg Machines use many different simple machines in a chain reaction to perform work that completes a task. The six types of simple machines are the **lever**, **wheel & axle**, **pulley**, **inclined plane**, **wedge**, and **screw**.

Lever – A board or bar that rests on a fulcrum and lifts or moves objects. Examples include door handles, light switches, and hinges.

Wheel & Axle – A rod or pole centered in a wheel that allows the wheel to turn around it. Examples include fans, merry-go-rounds, bicycles, and car wheels.

Pulley – A wheel & axle combined with a rope or string that allows us to move objects up and down. Examples include window blinds, ship sails, and elevators.

Inclined Plane – A ramp that allows things to go from low to high or high to low. Examples include wheelchair ramps, skate parks, and ladders.

Wedge – Two inclined planes put together that can either separate objects apart or hold objects together. Examples include axes, saws, scissors, push pins, nails, and staples.

Screw – A twisted inclined plane that can move things from low to high in a circle. It can also hold things together. Examples include jar lids, light bulbs, bottle caps, or circular stairways.

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In the Rube Goldberg Machine you just created, the paper towel roll acted as an inclined plane, each domino and book acted as a lever, and the toy car rolled because of its wheel & axle components. Think of other ways that simple machines may help you complete a holiday task and build a Rube Goldberg Machine that does the task for you. Be creative! Here are some ideas to get you started:

- A Rube Goldberg Machine that uses a pulley system at the end to drop a bow on top of a gift-wrapped present.
- A Rube Goldberg Machine that uses an inclined plane (i.e. slanted PVC pipe or plastic tubing) at the end to deliver water to your tree.
- A Rube Goldberg Machine that uses a lever at the end to press the “play” button on a stereo for holiday music!

Career Connection:

Mechanical engineers design machines using physics, mathematics, and engineering skills. They use simple machine concepts of energy and work to construct large machines such as cars, robots, and roller coasters.

Resources:

https://www.youtube.com/watch?v=H7_pTs785kg

<https://www.pinterest.com/pin/AbI9Xsh1qPSh5kzU8moVm4jFUGz5WAja5c9Wz3OzVXuBjF39UoQWjll/>

http://idahoptv.org/sciencetrek/topics/simple_machines/facts.cfm

<https://media.rubegoldberg.com/site/wp-content/uploads/2017/10/Rube-Goldberg-Lesson-Plans.pdf>

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Ideas for Materials (for additional Rube Goldberg Machines)

Things that roll

- Balls: tennis, baseball, ping-pong, etc.
- CDs
- Marbles
- Rolls of tape
- Skateboard
- Soda cans
- Spools
- Toy cars or trains
- Wind-up toys

Ramps

- Books
- Cereal boxes
- Craft sticks
- Paper towel rolls
- Plastic tubing
- PVC pipe
- Rulers
- Toilet paper rolls
- Toy train tracks or marble runs
- Trays
- Wooden blocks or boards

Miscellaneous

- Aluminum foil
- Binder clips
- Cardboard
- Clothespins
- Craft sticks
- Cups
- Dominoes
- Fan
- Funnels
- LEGO bricks
- Mousetrap
- Plastic water bottles
- Straws
- String or rope
- Wooden dowels

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