ST[EMpower]

PAPER SPINNING TOPS

MATERIALS

- round toothpicks
- 6 pieces paper (can use junk mail paper)
- markers / color pencils
- pencil
- metal ruler
- glue sticks
- white school glue
- sheet wax paper

Choose one:

- scissors
- paper cutter
- craft knife or box cutter and craft cutting pad

POWER WORDS

- **gyroscopic**: acting like a gyroscope
- **orientation**: the physical position or direction of something
- **rotation**: rotating around a center axis

Gyroscopic Motion: Stability in Spinning Tops

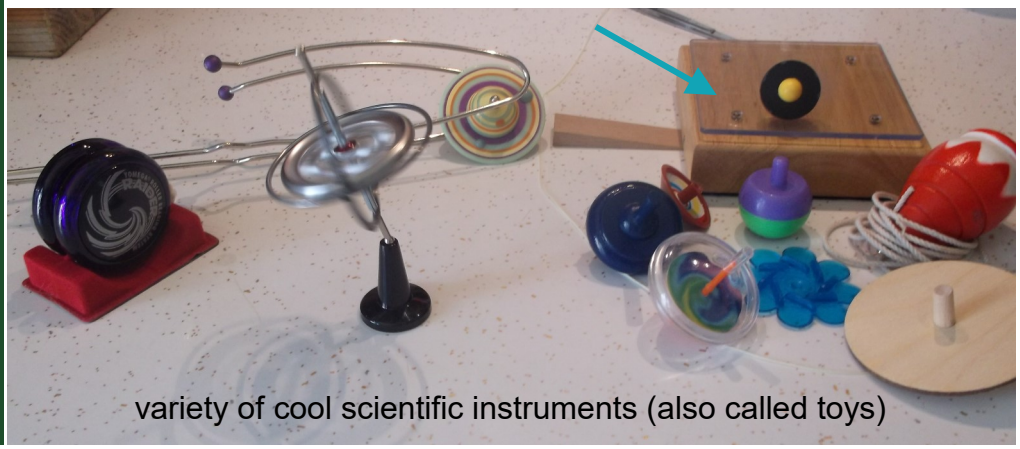
Gyroscopic motion is the tendency of a rotating object, like a spinning top or the Earth, to maintain the **orientation** of its **rotation**. The object will resist any change in its axis of rotation.

A **spinning top** is governed by a **gyroscopic force**. The top maintains its orientation, and is stable until air friction slows it and gravity pulls it down.

A **gyroscope** is a spinning top in a stable frame. It easily balances on the base (or your finger) as it spins about a constant axis.

The blue arrow (image below) points to a magnetic spinning top. The base has a very strong magnet. With an accurate and precise spin, you can lift the top into that magnet field. The top will spin suspended in the air for many days before falling.

Celestial objects spin. Our Sun and Earth maintain stability because they rotate on their axes. Pulsars are the remains of giant blue stars after they supernovae. What remains is the core, called a neutron star. Pulsars can spin up to one quarter the speed of light at their equator (43,500 miles/second)!

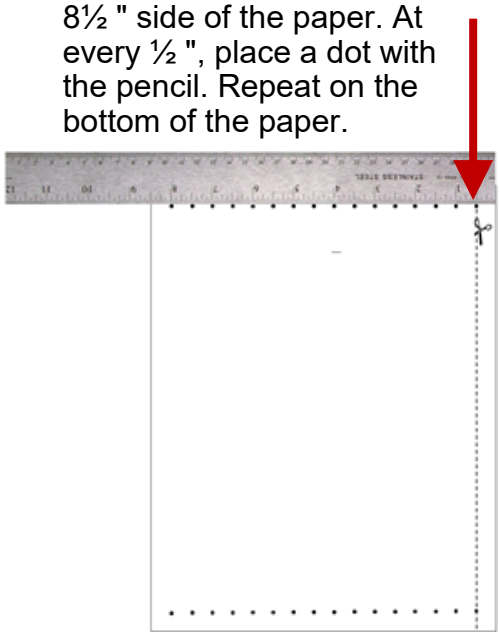


variety of cool scientific instruments (also called toys)

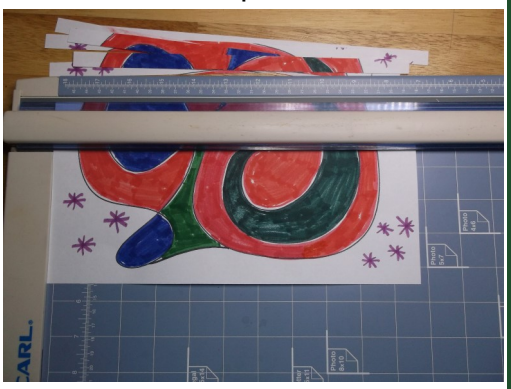
DO:

- Color the 6 pieces of paper with markers in a bold design.

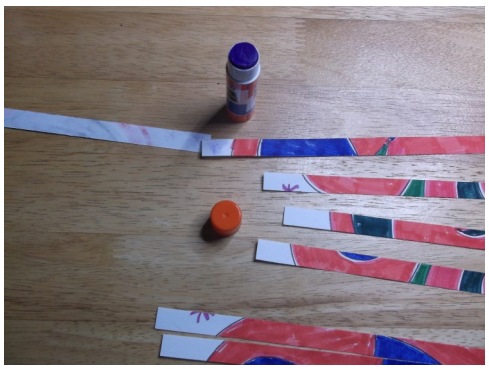
- You need long strips. Set the ruler along the top of the 8½ " side of the paper. At every ½ ", place a dot with the pencil. Repeat on the bottom of the paper.



- Align a ruler to dot at the top and bottom of the page. Press down the ruler to keep secure, and draw a line **perpendicular** to the paper connecting the dots (red arrow on image above).
- There are three options to cut your paper into long strips.
  - Cut each ½ ” strip down the length of the paper with a pair of scissors.
  - Place your paper on the craft pad. Align and press down the metal ruler to the first two dots running the length of the paper (red arrow on image left). With the craft knife, press the blade against the ruler, press down, and pull across the paper to cut the strip. Repeat until you have cut the entire sheet of paper, or 17 strips total.



  - Use a paper cutter to cut your 17 long strips from each of your 6 sheets of paper.



POWER WORDS

- **perpendicular**: at an angle of 90° to a given line, plane, or surface

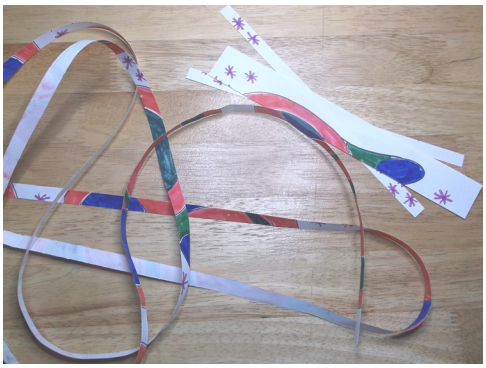
HINT:

Cut as evenly as possible. The more uniform each strip, the better the top.

Glue your strips as straight as possible. The image to the right shows a slight “V”. Make sure the paper is as straight as possible. The straighter your paper string, the better.

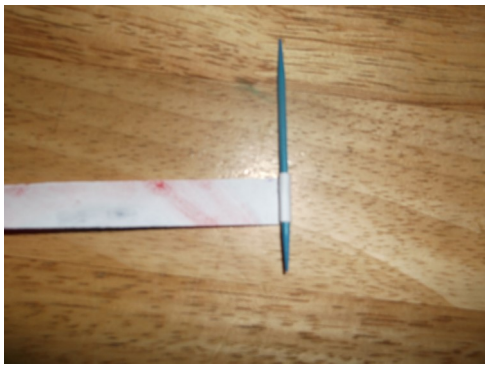
FASCINATING FACTS

- Spin tops are among the oldest toys ever discovered by archaeologists. A clay top unearthed in Iraq was dated to 35th century BC—nearly six thousand years ago.



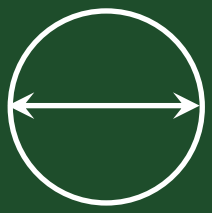
- Protect your tabletop. Use a piece of wax paper.
- You will make 3 paper tops each a different size. Align the paper strips end to end and use the glue stick to join them all together to make a paper string.
- For your first top, use a single piece of paper. The paper string will be about 14 feet long made from the 17 strips of that single sheet.
- For your second paper string, use 2 sheets of paper. Your paper string will be about 28 feet long made from 34 strips.
- For your third paper string, use 3 sheets of paper. Your paper string will be about 42 feet long made from 51 strips of paper.
- Allow the glue to dry completely.
- To make the disk of the top, coil the paper around a toothpick. Apply glue to the back side of the paper string on one end. Use a toothpick as a guide, roll the end of the paper to start a coil.
- Once you have 10 turns of paper, remove the toothpick. Continue winding the paper string into the coil.
- Throughout the winding, verify the toothpick still can slip into the center hole.

- I am right handed, so lefties, you will need to modify these directions. With your left hand, align the edges of the paper string with your thumb and middle finger, using your index finger to help hold down the paper to keep it tight. Turn the paper disk with your right hand. Add a bit of glue stick glue at every seam (10" or so) of paper to hold into place. Add a bit of glue stick glue to the last end, and secure into place. The disk will be about 1" in **diameter**.
- Repeat with your 28 foot paper string. Your top will be about 2” in **diameter**.



POWER WORDS

- **dimeter**: a straight line passing from side to side through the center of a body or figure, especially a circle or sphere



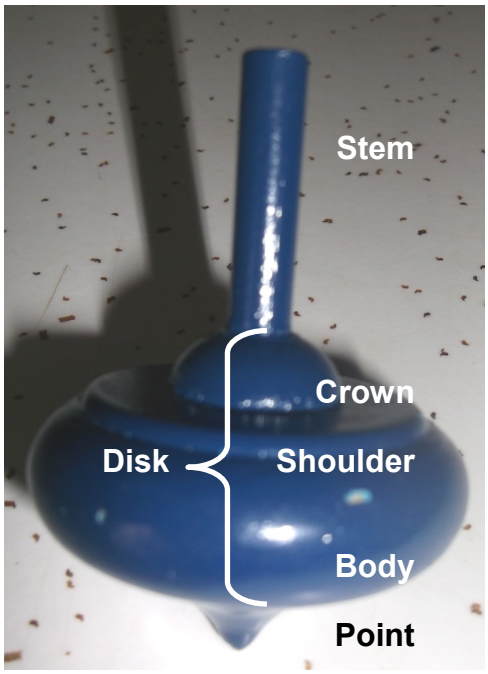
FASCINATING FACT

- Interested in levitating magnetic tops? Check out this YouTube video! https://www.youtube.com/watch?v=mn7IedCgva0
- Crazy spinning top tricks!: https://www.ripleys.com/weird-news/awesome-spinning-tops/

- Repeat with your 42 foot paper string. Your top will be about 3” in **diameter**.
- The toothpick is 2 1/2" long. About 3/4" from one end, dab white school glue about 1/2 inch wide.
- Insert the toothpick into the paper disk until the school glue is completely inside the small toothpick hole in the center. Allow to dry.
- Repeat with your other two top disks.

Adjusting Your Tops:

- Try forming a cone with your top. It may shift the balance. The larger the disk, the more you can adjust the shape.
- You may need to snip a bit of the long piece of toothpick (the stem) to balance your top (leaving 1"). Start with about ¼” and test. You can trim up to ½”, leaving about 1” stem to spin.



REFLECT

- Compare your three tops. The only difference among the three is the size of the disk (and the mass increasing using 1, 2, and 3 sheets of paper). How are they similar? How are they different?
- Can you come up any reasons why their spins are different?

Explanation:
A spinning top seems to defy gravity while spinning. It spins in a **vertical** position. It eventually falls over when it stops spinning.

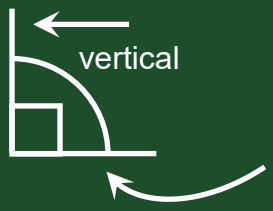
Torque is required to rotate an object. The **torque** is equal to the rate of change of **angular momentum**. Wow, that is tough to understand, but you already understand this concept. How about this:

- If an ant runs as fast as it can, and hits a wall, what happens? SPLAT!
- If an elephant runs as fast as it can and hits a wall? The wall is smashed (also not too good for the elephant).
- What happens if we put the ant in a cannon and blast it into the wall?

(Continued on page 5)

POWER WORDS

- **angular momentum**: an object spins around instead of moving in a straight line (e.g. a car); the bigger and faster things are, more difficult to stop or change direction than lighter or slower things
- **torque**: twisting force that tends to cause rotation
- **vertical**: at right angles to a horizontal plane; in a direction, or having an alignment, such that the top is directly above the bottom



FASCINATING FACT

- Tops made from fruits, nuts and seeds have been discovered amongst indigenous tribes throughout the world.

- There is an ant-sized hole in the wall.
- What if we put an elephant in a cannon and blast it into the wall? What wall?

Momentum is the measurement of mass in motion. **Angular momentum** is the measurement of mass in rotational motion. There is nothing mysterious about that!

Does the size of the disk have any impact on spinning tops? Yes. How about how tall the point is? Yes, but that has to do with the center of gravity of the top. Larger disks with shorter points are more stable.

APPLY

- What happens when you pedal a bicycle? The wheels have angular momentum. They use the torque force to spin. Have you ever held a bicycle while it is spinning? It is really hard to change the tire's orientation.
- What other materials that you find around the house can be made into tops? How about quarters? What about bottle tops? Can you spin a thumb tack?

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CITATIONS

Information:

- Kaplan, Harvey, Hirsch, Andrew (2013) Gyroscopic Motion: Show Me the Forces!. The Physics Teacher 52(1) p 30-33.
- Explanation of spinning tops: http://www.physics.usyd.edu.au/~cross/SPINNING%20TOPS.htm
- Fascinating facts: https://www.artofplay.com/blogs/articles/history-of-spinning-tops

Images:

- Making paper tops: Barbara J. Shaw, Ph.D., Colorado State University Extension, Western Region
- NASA bicycle wheel Originally published in The Technology Teacher, October 2002, by the International Technology Education Association Navigating by Good Gyrations : https://www.nasa.gov/pdf/404920main_Navitigating_Gyrations.pdf