Gyroscopic Stabilization STEMonstration

Hands-On Activity

Background Information

In the Gyroscopic Stabilization STEMonstration, NASA astronaut Nick Hague demonstrates how gyroscopes are used to counteract instability and keep spacecraft stable while flying. A gyroscope is a spinning wheel with its mass concentrated far from its axis of rotation. As they spin, gyroscopes resist rotation along any axis other than their spin axis. By attaching a gyroscope to a spacecraft, its stability is transferred to the spacecraft.

In this activity, students will make a model gyrostat, a modified gyroscope inside a rigid case, to explore rotational stability and learn how gyroscopes can be used to keep objects stable.

Grade Range:
9-12

Time Needed:
45-60 Minutes

Materials List:
Per Student or Team:

- 2-4 rectangular pieces of cardboard (5"x6" approx.)
- 1 gyroscope
- String for gyroscope
- Gyroscopic Stability STEMonstration video
- Tape (e.g., duct, scotch, masking)
- Scissors
- Marker or pencil

Career Connection

It takes a team of experts in many fields on the ground to keep missions safe, stable, and on course. Check out these three essential careers related to gyroscopic stability and NASA's human space exploration missions.

Aerospace Engineer (Attitude Control & Dynamic Specialist)

Designs systems like control moment gyroscopes (CGMs) that manage spacecraft orientation and stability. Analyzes rotational dynamics to ensure spacecraft stay correctly aligned for power and communications.

Flight Dynamics Officer

Works in NASA mission control to monitor the orientation and trajectory of spacecraft. Uses knowledge of orbital mechanics and gyroscopic motion to manage momentum and ensure the International Space Station stays stable.

Aerospace Engineering Technician

Supports engineers by building, testing, and troubleshooting spacecraft systems, including those involved in guidance and stability.

Activity Procedures

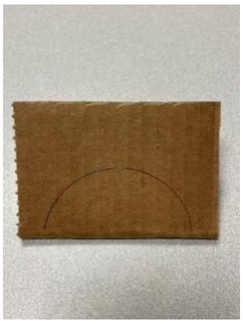
Safety

Ensure safe cutting techniques and scissor handling. Carefully support the piece of cardboard being cut and use caution with placement of your supporting hand. Avoid moving around the room with scissors.

Preparation

1. Cut out two to four rectangle pieces of cardboard. Use the gyroscope as a template to measure what the size your cardboard pieces should be and fold the cardboard squares in half.

2. Using the gyroscope as a template, trace the outer edge to make a semicircle on the cardboard pieces the same size as the gyroscope.



3. Cut out the semicircle and add a small notch in the middle of each piece of cardboard.

4. Unfold each square and stack all four pieces of cardboard around the gyroscope and secure the pieces with tape. The gyros #cope should be oriented parallel to the cardboard. Color or shade one side of the gyrostat to help with visuals during spinning. Carefully thread the string through the gyroscope, following the instructions included by the gyroscopes manufacturer.

Facilitate the Challenge

Watch the Gyroscopic Stability STEMonstration video. The International Space Station has four different Control Moment Gyroscopes (CMGs), consisting of steel wheels at different orientations that spin at a constant speed of 6,600 revolutions per minute. Not only do the CMGs keep the station stable, but they can also be repositioned to induce a gyroscopic force and change the orientation of the station. Use the gyrostat model to test gyroscopic control. Compare your observations on Earth with what you observed happening with the demonstration in space. Check out the Vestibular System STEMonstration for an in-depth explanation of the major, minor, and intermediate axes.

Spin Demonstration	Observation on Earth	Observation in space (from the STEMonstration video)
1. Major Axis		
2. Minor Axis		
3. Intermediate Axis		

1. **Major Axis:** Demonstrate gently rotating the gyrostat, without spinning the gyroscope, along the major axis. This would mean spinning it flat, like a frisbee or helicopter blade. The entire gyrostat should be stable as it spins.
2. **Minor Axis:** Demonstrate gently rotating the gyrostat, without spinning the gyroscope, along the minor axis. This would be spinning it lengthwise, like spinning a pencil or arrow. The entire gyrostat should be stable as it spins.
3. **Intermediate Axis:** Demonstrate gently rotating the gyrostat, without spinning the gyroscope, one time along the intermediate axis, and catch it. This should be a single flip of the gyrostat, end over end, with the flat side facing you. The gyrostat should twist in mid-air as it spins. This should be apparent by the reversing of the colored surface on the opposite side.

Discussion Questions: Gyroscopes on Earth

By building your own gyroscope and watching the demonstration aboard the International Space Station, you've seen firsthand how a spinning object resists changes to their orientation. In space, this same principle keeps the International Space Station stable and properly oriented to ensure solar panels point toward the Sun, docking ports face the correct direction, and astronauts aboard the space station stay safe. Here on Earth, gyroscopes help airplanes stay level in flight, keep ships steady at sea, and even assist with balancing bicycles and motorcycles.

1. How do control moment gyroscopes (CMGs) on the International Space Station differ from the smaller gyroscopes used in drones or smart phones?
2. How might gyroscopic technology need to be adapted for spacecraft traveling beyond Earth's orbit, such as to Mars, where real-time control from Earth isn't possible?
3. How could an understanding of gyroscopic motion benefit someone pursuing a career in aviation, maritime navigation, or autonomous vehicle design?

This activity was developed in collaboration with the U.S. Air Force Academy.

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