Gyrotops

Safety Precautions

- Ask an adult to punch or drill the hole in the middle of the cardboard or wooden disk.

Vocabulary

- angular momentum - the product of moment of inertia and angular velocity
- angular velocity - rate of change of angular position of a rotating body
- axis of rotation - circular movement of an object around a center
- linear velocity – how fast an object moves in a straight line
- mass - the amount of matter in an object
- moment of inertia - an object’s resistance to angular acceleration
- precession - the slow movement of the axis of a spinning body around another axis
- radius - half the distance across a circle
- uniform mass distribution – mass of the object is distributed equally across and within an object

Materials and Equipment

- 1 round wooden or cardboard disk
- 1 machine screw #10
- 3” x 24 pitch
- 2 washers #10
- 2 nuts #10 (small nuts)
- 1 acorn cap
- 4 to 6 stainless steel nuts for mass (large nuts)
- double-stick tape or white glue
- drill

Construction

1. Drill or punch a hole in the center of the wooden or cardboard disk.
2. Thread one small nut and washer about a third of the way up the screw.
3. Put one of the cardboard or wooden disks on the screw directly against the washer.
4. Thread the other washer and the other small nut on the screw against the disk.
5. Tighten the nuts and washers against the disk.
6. Thread and tighten the acorn cap on the bottom of the screw.
7. Place 4 to 6 large steel nuts symmetrically around the edge of the top surface of the disk using double-stick tape or glue. If using 4 nuts, place them 90 degrees apart. If using 6 nuts, place them 60 degrees apart.
8. Hold the screw near the top and spin it. This may take some practice.
9. You can adjust the height of the disk by loosening and retightening the washers and the small nuts.
10. Try this experiment again with the same disk, or use another disk, but place the steel washers close to the screw instead of at the edge of the disk.

Questions

1. Which disks are the easiest to spin? those with the steel washers at the edge or in the middle, close to the screw? those without any steel washers?
2. What happens to the disks with no washers or the disks with the washers at the edge as they start to slow down?

This work is licensed under a
Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.
Dr. Denise Meeks, tucsonkosmicgirl@gmail.com

Research
The disks and steel nuts placed around the edge have higher *moment of inertia*, higher *angular momentum*, and higher *linear velocity* than disks and steel nuts placed at the center, near the screw. Disks without steel nuts have a *uniform mass distribution*.

As the spinning disks slow down, the axis of rotation (the screw) demonstrates *precession*. The axis of rotation begins to move in a circle.

Hypothesis
What is your hypothesis? Be sure to include your "best guess" answers to the 2 questions above.
1.

2.

Experiment
1. Spin each disk and record the results. This may require a little practice.

Data and Observations
- Which disks were the easiest to spin?

- Which disks were the hardest to spin?

Analysis
1. Which disks were the easiest to spin? those with the steel washers at the edge or in the middle, close to the screw? those without any steel washers?

2. What happened to the disks with no washers or the washers at the edge as they start to slow down?

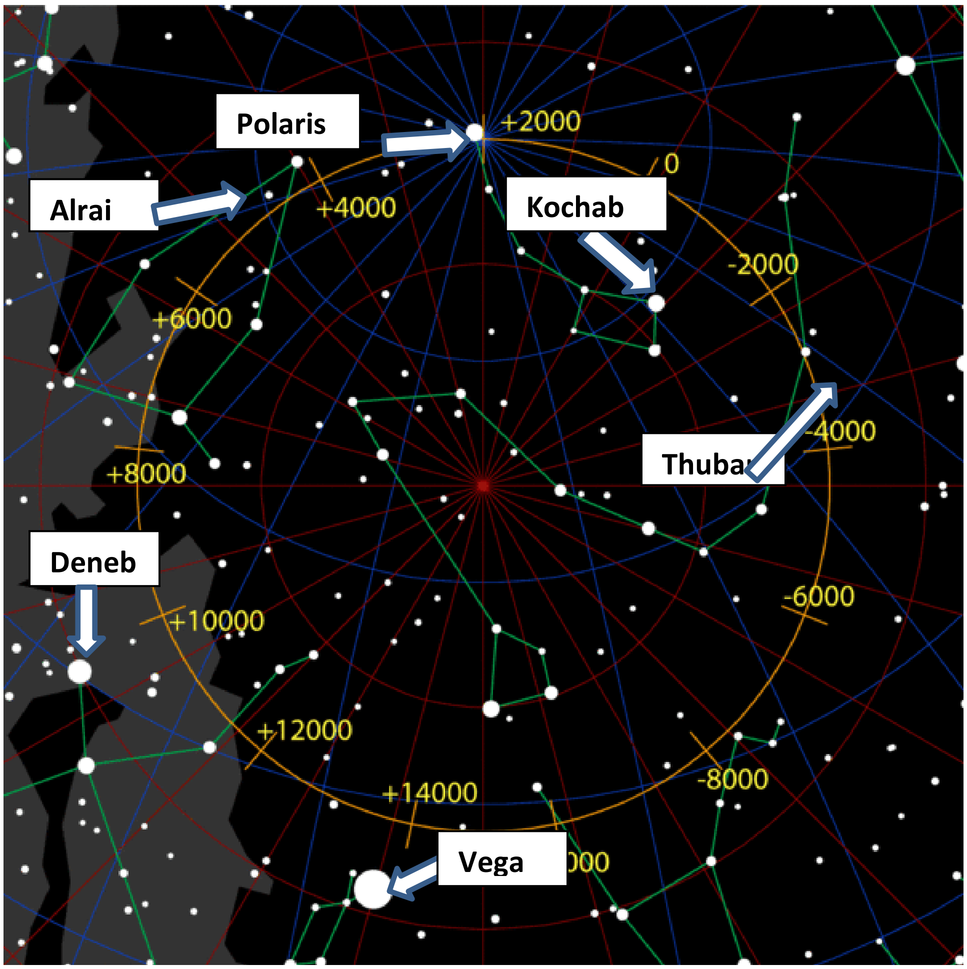
Conclusions
Disks with most of the mass placed at the edges are easier to spin and spin longer than disks with the mass placed at the center.

This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.
Dr. Denise Meeks, tucsonkosmicgirl@gmail.com

Science and Math (optional information)

The Earth also behaves like our gyrotops, with the north pole pointing to different "north stars" during a 26,000 year cycle.

North stars	Year	Constellation
Thuban	3000 BC	Draco
Kochab	500 BC	Ursa Minor
Polaris	now	Ursa Minor
Alrai	5200	Cepheus
Deneb	10000	Cygnus
Vega	14000	Lyra



Source: https://en.wikipedia.org/wiki/Precession#/media/File:Precession_N.gif

Rotating (spinning) objects have angular momentum. The faster they spin, the higher the angular momentum:

angular momentum $L = mvr$

m = *mass* (total mass of the steel nuts and disk)
v = linear velocity
r = *radius* (distance of the steel nuts from the screw)

This work is licensed under a
Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.
Dr. Denise Meeks, tucsonkosmicgirl@gmail.com

Spinning objects also have *angular velocity*:

$$\text{angular velocity} = \omega = \frac{v}{r}$$

Using a little algebra, we can determine that the linear velocity of the nuts at the edge of a disk is greater than the linear velocity of the nuts at the center of another disk if both disks spin at the same angular velocity:

$$\text{linear velocity } v = \omega r$$

The *moment of inertia* of a rotating disk depends on its mass (the steel nuts), and their distance (radius) from the *axis of rotation* (the screw).

When the steel nuts are at the center of the disk, the disk behaves like a very small disk, since most of the mass is in the center. That means that the radius is close to 0 and the moment of inertia is very low, close to 0.

$$\text{disk moment of inertia} = \frac{1}{2}mr^2 = 0.50mr^2$$

When the steel nuts are at the edge of the disk, the disk behaves more like a hoop, since most of the mass is at the edge, so the radius is larger than 0 and the moment of inertia is larger than 0.

$$\text{hoop moment of inertia} = 1.00mr^2$$

This work is licensed under a
Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License.
Dr. Denise Meeks, tucsonkosmicgirl@gmail.com