TEACHERS GUIDE

TIPPE TOPS
ITEM # 4647-00

ENERGY - MOTION

Demonstrating an unexpected outcome is a surefire way to capture your students' attention and to begin breaking down misconceptions. Amaze friends and students as the Tippe Top spins and appears to go against the laws of nature.

Materials

- Computer and video recorder or smart phone/tablet with video recording capabilities
- slow motion app
- stopwatch

Goals & Objectives

See page 8 for Next Generation Science Standards (NGSS)

INTRODUCTION

Tippe Tops are a fun and engaging way to teach physics and science process skills in the classroom. Used in early childhood and elementary school classrooms, these toys will surprise, delight, and allow students to practice science skills as well as construct their own scientific knowledge.

The Tippe Top's unexpected behavior provides ample opportunities for older students – middle school through college - to learn and grapple with the complex concepts of friction, torque, momentum, and rotational force.

Use Tippe Tops for introductory demonstrations as well as for safe, hands-on student experimentation. Can you figure out how the top seemingly defies gravity and lifts its body up off the surface upon which it is spinning? Can you explain why the direction of the rotation changes when the top inverts?

HISTORY

Invented in 1950, the Tippe Top has delighted and captivated children and physicists, alike. The counter-intuitive behavior that a Tippe Top exhibits has fascinated physicists for even longer. Even Lord Kelvin kept notes in the mid-1800's of his experiments with spinning oblong stones and the inexplicable rise of their center-of-mass (Bretcher, Kenneth. "Spin Dynamics of Kelvin's Pebbles, Jellett's Eggs, and Shiva's Lingam Stones").

How It Works

The center-of-mass of the Tippe Top is separate from the geometrical center of the top. When spun on a flat surface, the rotational axis is through the center-of-mass. The point of contact with the surface is directly below the geometrical center and offset from the rotational axis. The top slides, or drags, in a circle around the rotational axis. The friction caused by the top dragging along the surface creates torque which, in turn, rotates the stem of the Tippe Top downward. When the stem comes into contact with the surface, the additional friction creates enough torque to rotate the top up onto the stem.

The rotational direction of the Tippe Top changes as the stem (and axis of symmetry) goes from vertical to horizontal to vertical again. When the top is horizontal, it is no longer spinning about the axis of symmetry. When the rotation about this axis resumes, it does so in the opposite direction. The angular momentum is in the same direction, but the rotation around the axis of symmetry is reversed, because it has flipped upside down.
(See page 7 for supporting graphics)

{{PD-1996}} Nobel Prize-winning physicists, Wolfgang Pauli and Niels Bohr watching on with fascination at the unexpected behavior of the spinning Tippe Top.

ACTIVITIES

For younger students, focus on science practice skills such as predicting, making observations, and explaining at an age appropriate level. More complex physics concepts can be addressed using the same activities with middle school through college-level students.

1. Catch their attention.
Use Tippe Tops as the “engage” step of the 5-E method or as a way to capture students’ attention in an introduction to a lesson or unit about the scientific concepts listed in this guide. Before demonstrating the Tippe Top, ask students to predict what will happen when the top is spun. Alternatively, have students work in small groups to make observations and predictions about the Tippe Top before they spin the tops. Afterwards, ask students to explain differences between their predictions and their actual observations.

2. Compare the behavior of Tippe Tops with that of other kinds of tops. Make video recordings of the different tops and observe them in slow motion to make additional qualitative and quantitative observations.

3. Explore the effects of speed. Try spinning the Tippe Tops at different speeds to determine what works best for successful inversions. Encourage younger students to use comparisons such as “faster” and “slower”. For more advanced grades, use a video camera and a slow motion app, or another method, to measure rotational speed as well as time to complete inversion. Compare different sizes of Tippe Tops. Compare results on different surfaces (rough vs. smooth) to make additional conclusions about the effect(s) of friction.

4. Explain it. Have students create a diagram and/or argument to explain the forces and other phenomena of how the Tippe Top works.

5. Challenge students to experiment with additional objects that behave similarly to Tippe Tops. Try some of the same activities with these other objects. Examples to try could be hard-boiled eggs, egg-shaped or oblong stones or wood, four marbles glued together in a pyramid, finger rings, or have students create/discover their own.

***Note**
It is always wise to DO an experiment ahead of time to be able to best present it to the class. !

DISCUSSION

Additional Discussion and Real Life Applications

1 *Observe the Tippe Top carefully. Does it appear to change rotational direction? Why or why not?*

2 *Would the Tippe Top work on a frictionless surface? Why or why not? How could you find out and/or support your answer?*

3 *Hardboiled eggs can be used to demonstrate the same phenomena as a Tippe Top. Would a raw egg work? Why or why not? How could you find out and/or support your answer?*

4a *Tippe Tops and their behavior have fascinated physicists over the years. To extend understanding and incorporate technical science literacy into the lesson, have students read one or more of the technical articles listed in the resources section.*

4b *Follow with a class discussion that may include some or all of the following:*

- *Student questions or confusions that come up from the reading. These may be conceptual or may be related to the writing format.*
- *Student summaries of the article(s) in their own words. Check for understanding and address misconceptions.*
- *What follow up questions do students have that could be addressed by conducting their own investigations?*
- *Why do students suppose that so many scientists have found Tippe Tops to be so intriguing?*
- *If using multiple articles: How has the scientific understanding of Tippe Top phenomena changed over time?*

GLOSSARY

Vocabulary:

- angular momentum
- friction
- gravity
- inversion
- moment of inertia
- precession
- rotational force
- torque

RESOURCES

J.A. Jacobs. “Note on the Behavior of a Certain Symmetrical Top”, Am. J. Phys. 20, 517 (1952).

C.M. Braams. “The Symmetrical Spherical Top”, Nature 170, 31 (1952).

G.N. Copley. “The Symmetrical Spherical Top”, Nature 170, 169 (1952).
(Historical remarks to Braams’ Nature article.)

C.M. Braams. “On the Influence of Friction on the Motion of a Top”, Physica 18, 503 (1952).

N.M. Hugenholtz. “On Tops Rising by Friction”, Physica 18, 515 (1952).

C.M. Braams. “The Tippe Top”, Am. J. Phys. 22, 568 (1954).

W.A. Pliskin. “The Tippe Top (Topsy-Turvy Top)”, Am. J. Phys. 22, 28 (1954).

A.R. Del Campo. “Tippe Top (Topsy-Turnee Top) Continued”, Am. J. Phys. 23, 544 (1955).

I.M. Freeman. “The Tippe Top Again”, Am. J. Phys. 24, 178 (1956).
(Follow-up on Del Campo’s article.)

D.G. Parkyn. “The Rising of Tops with Rounded Pegs”, Physica 24, 313 (1958).

J.B. Hart. “Angular Momentum and Tippe Top”, Am. J. Phys. 27, 189 (1959).

F.F. Johnson “The Tippy Top”, Am. J. Phys. 28, 406 (1960).

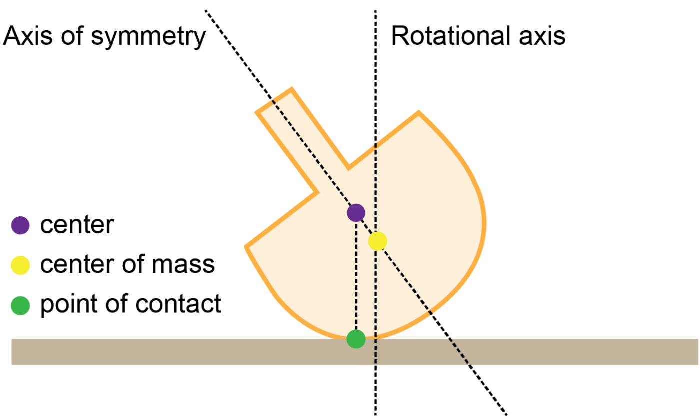
R.J. Cohen “The Tippe Top Revisited”, Am. J. Phys. 45, 12 (1977).

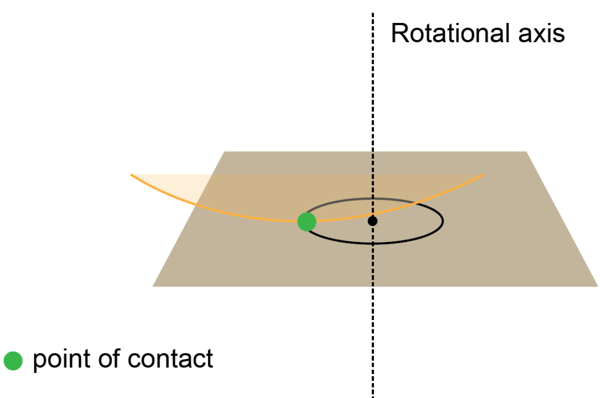
H. Leutwyler. “Why some tops tip”, Eur. J. Phys. 15, 59 (1994).
(Mathematical analysis based on conservation laws.)

A.C. Or. “The dynamics of a tippe top”, SIAM J. Appl. Math. 54, 597 (1994).

S. Ebenfeld and F. Scheck. “A new analysis of the tippe top: Asymptotic states and Liapunov stability”, Annals of Physics 243, 195 (1995).

N.M. Bou-Rabee, J.E. Marsden, and L.A. Romero. “Tippe top inversion as a dissipation-induced instability”, SIAM J. Appl. Dyn. Sys. 3, 352 (2004).


Axis of symmetry
Rotational axis
center
center of mass
point of contact


Rotational axis
point of contact

Next Generation Science Standards

Students who demonstrate understanding can:

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object.

HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.

Standards Key

K = Kindergarten
3 = 3rd Grade
(numbered by grade)
MS = Middle School
HS = High School
PS = Physical Science
LS = Life Science
ES = Earth Science

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HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative position of particles (objects).