Science Unit: *Physics Ideas*
Lesson 5: *Gyroscopes*

School year:	2006/2007
Developed for:	Tecumseh Elementary School, Vancouver School District
Developed by:	Paul Nagelkerke (scientist), Marie Chomyn and Fern Louie (teachers)
Grade level:	Presented to grades 6-7; appropriate for Grades 3-7 with appropriate modifications.
Duration of lesson:	1 hour and 20 minutes
Notes:	These activities are likely to take longer than the estimated duration. Originally they were set up in a station approach with an instructor. Students continued to work on science activities during the week following the lesson.

Objectives

1. Learn about static and dynamic stability.
2. Learn about rotating objects and gyroscopic effects.
3. Explore the effects of gyroscopic precession, and gyroscope shape.

Background Information

Tops have been used as toys for thousands of years; they have been commented on by Plato, Homer, Aristophanes, Virgil, and tops dating to 3500 BC have been found in ancient Mesopotamia (modern day Iraq).

Making an object spin requires an input of energy, just like making an object move in a straight line. As an object rotates this rotational energy is slowly dissipated, through friction in the bearings and friction with the air.

A rotating object displays a very unique effect; it does not fall over as long as it is spinning. The secret to this effect is the interaction of rotation and the applied force. Any force trying to tip over the top is deflected by 90 degrees and this deflection is known as the gyroscopic effect.

A top tends to spin vertically with gravity forcing it vertical, while a gyroscope has a stationary frame that allows it to rotate at any orientation besides vertical. A gyroscope with a gimbal frame will maintain its orientation no matter which way the base is moved. This is the basis of steering mechanisms for torpedoes and artificial horizons in airplanes. These mechanical systems have been replaced with electronic systems that can perform the same function using laser beams being fired around a loop of fiber optic cable.

Vocabulary

Top	A spinning toy
Gyroscope	A spinning rotor in a series of gimbal rings allowing the rotor to maintain its orientation regardless of the motion of the external frame.
Precession	A gyroscope's 'wobble' as it slows down

Materials

- 8 simple tops
- 4 Tippy Tops
- 4 Gyroscopes (with starting string, and stand). Rulers for activity 3.

In the Classroom

Introductory Discussion

1. Demonstration
    - Demonstrate static stability of a non-rotating Tippy Top and instability of the other tops and gyroscope when not spinning.
    - Spin the simple tops to show the dynamic stability, and gyroscopic precession as the top slows down. (do not demonstrate the Tippy Top, let the students be surprised).
    - Spin the gyroscope and demonstrate its ability to spin vertically, horizontally, and not fall when suspended from one side.
2. Short description of other items to discuss or review.
    - Try to envision how the top is able to stay upright.
3. Summary of instructions for science experiment/activity.
    - Describe the top as if it was sitting in front of you, and you are looking down on it. Describe the rotation of the top as clockwise or counterclockwise as you look down on it, force direction as away from you or towards you, and resulting rotation as tipping to the right or left.
4. Briefly describe safety guidelines.
    - Be careful with the tops and gyroscope, do not drop them or let them fall on the floor. Try not to get your fingers or hair stuck in the gyro, it can give you friction burns.

Science Activity/Experiment

Four stations are set up in the classroom. One or two adults can run the entire class.

Divide the students into four equal groups. Save some time at the end of each station time to discuss the student observations.

Part 1 – Simple Top

- Students place the top right-side up and upside down without spinning. Is it stable? Record your observation and draw a picture of the final position of the top in each case.
- Spin the top on the table. Is it more stable as it spins? Record your answer and draw a picture of the spinning top.
- What is the direction of precession as the top slows down? Does it wobble in a clockwise or counterclockwise direction? Is it in the same or opposite direction of the top's spin?
- Spin the top on a book. Gently rock the book, does the top stay upright while it spins?

Part 2 – Tippy Top

- Place the non-spinning top on its round bottom, and pointy top. Is it stable? Record your answer and draw a picture in your science journal of the top in its resting position.
- Spin the top with the round part downwards. Is the top dynamically stable? Draw a diagram of the top in an unstable and stable position. What is the direction of spin once the top is stable?
- Spin the Tippy Top with the stem downwards. Is it dynamically stable?

Part 3 – Gyroscope

- Identify the rotor and gimbal frame. Draw a diagram of the gyro and label the main parts.
- Try to balance the non-spinning gyroscope on its end and sides. Is it stable when not spinning?
- Use the string to spin the gyroscope, place with the axis of rotation vertical like the top. Is it dynamically stable when standing on its end?
- As the gyroscope slows down, is the precession or wobble in the same direction as the gyroscope's rotation?
- Spin the gyroscope and place it on its side. Is it stable when spinning on its side? Pick up the gyroscope by looping a string around one end, or balancing one end on the stand. Is the direction of rotation the same or opposite to the rotation of the rotor?
- Spin the gyroscope and stand it on its end. Keep the frame of the gyro from spinning. Press the straight edge of a ruler against the top of the gyroscope and press horizontally forwards. Does the gyro lean right or left? Repeat with the gyro spinning in the other direction. Does the direction of spin affect the direction of reaction force?

Science Journal: Students will record their observations and draw relevant diagrams of each experiment.

Closure Discussion

Examples of questions to ask students

1. Gyroscopes and tops are nice toys, but what can they be used for?
2. Why does the Tippy Top flip over? Would it still flip over on a very slippery surface?

References

1. http://www.spintastics.com/HistoryofTop.asp
2. http://www.physics.montana.edu/demonstrations/video/1_mechanics/demos/tippytop.html
3. http://outreach.web.cern.ch/outreach/public/nl/physics_fair/Exp36.html.

Extension of Lesson Plan

1. Build a model of a two-wheel vehicle using a gyroscope for stability (like a bicycle or a Segway), and demonstrate to the class.
2. Does the gyroscopic effect require energy? Spin three gyroscopes at the same speed, let one rest on its side, one on its end, and one be suspended by a string or on a stand. Which stops first?