

## Roly - Poly

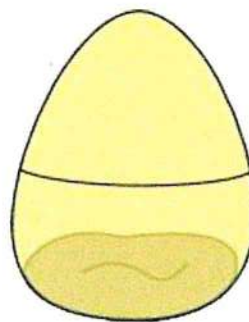
### Materials:

3 1/2 inch plastic Easter Egg (Oriental Trading CO.)  
Modeling Clay (or Steel Washers and Glue/Caulking Compound)  
Markers, felt, and glue

### Objectives:

To observe Stability.

To understand the relationship of Center of Mass and Gravitational Equilibrium.



### Procedure:

Separate the two sections of the egg. Press a piece of modeling clay into the end of the section having the larger radius. Assemble the egg and test the shell for stability. When you are satisfied with the result, remove the clay and press into the section having the smaller curvature (the more pointed section). Re-assemble the egg and test for stability.

After you have assembled the egg in the most stable configuration, decorate with a felt-tip pen or by gluing felt facial features on the outside of the egg.

### Questions:

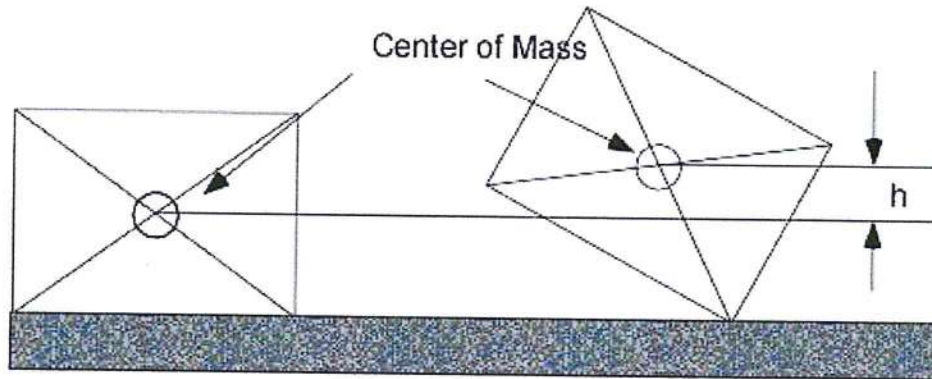
1. Describe the stability when the clay is in each of the two ends of the egg.  
Explain any difference.
2. What makes the Roly-Poly return to its upright position after being tilted?
3. Explain how other balancing toys would apply the same science.
4. Design (on paper) at least one other balancing toy using the same science as the Roly-Poly.

### Extensions:

1. Use different size eggs to make a family of Roly-Polys.
2. Instead of having the clay at the larger end, place it at the thinner end of the egg. Try to balance the egg. Why is this more difficult than when the clay is in the fatter end?

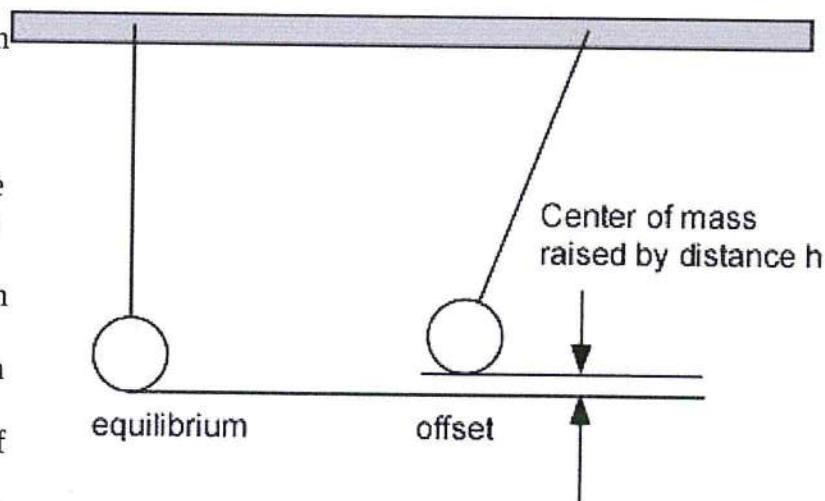
## ROLY-POLY (The Explanation)

Equilibrium requires that the sum of both the forces and the torque acting on a given object be zero. Stability depends on the energetic when the object in question is displaced by a small amount. It is possible to balance a long slender object, but the balance is unstable if a small movement results in a decrease in gravitational potential energy. Any object always tends toward the minimum energy condition, and in a gravitational field this means that the object will spontaneously move in a direction to decrease the potential energy if possible.



This is a familiar condition. A box is stable when sitting flat on the floor. If rotated about one corner, the box tends to rotate in a manner that will result in lowering the center of mass. The rotation is back toward the original situation unless rotated so far as to pass the center of mass through a maximum. At this point, further rotation in the same direction will lower the center of mass and the box will spontaneously rotate in that direction. The original condition is stable, meaning that the box will remain in that position if left alone.

Some objects or orientations are less obvious. A pendulum at the bottom of the arc is stable because rotation in any direction raises the center of mass. If left alone, the pendulum will remain stationary with the center of mass hanging below the point of support. If displaced slightly, the mass will tend to swing back to the equilibrium position.

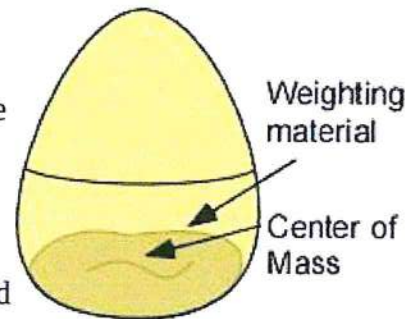


Other shapes or objects are not as familiar, and the resultant stability may be less obvious. The "thinking cap" made of a coat hanger and two tennis balls is stable because the center of mass is located under the point on which the "cap" is suspended.

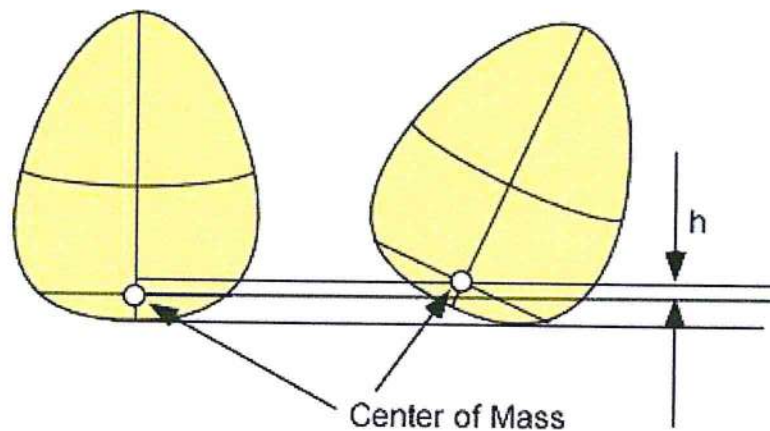
Mass may or may not be located at the center of mass. For example, a basketball is hollow inside, but the center of mass is at the center. It is that mathematical point where the mass of the entire rigid object is concentrated for purposes of gravity or for Newton's second law.



The Roly-Poly is a device which takes advantage of this stability to re-position itself when rotated out of position. An extra mass is located near the larger radius end, meaning that the center of mass will be located inside the weighting material (near the end). From the outside, the Roly-Poly looks as if the center of mass will be high up inside the egg although in reality it is near the bottom. Stability comes from the same physics as with the box.



When the Roly-Poly is rotated, the center of mass rises, as illustrated below. Any small rotation lifts the center of mass, so the Roly-Poly will tend to rotate back to the original position.



To construct the toy, take a plastic Easter egg and separate the sections. A heavy mass must be attached to the bottom of the section with larger radius of curvature.

Modeling clay will work without any additional adhesive. Washers or heavy nuts may also be used, but must be glued in place. When the weight is attached, assemble the egg and decorate.

**Extensions:** Locate a set of mobiles and demonstrate them. E. g., a bird shaped toy which balances on the beak, a belt holder made of wood cut into a shape that swings the center of mass of the belt under the support point, and the thinking cap made of tennis balls and a coat hanger.