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Balancing Birds

CTR-200 / 225 / 250 / 260

Center of Mass



The center of mass* of any object is the point where the mass of the object is concentrated. If you support an object at its center of mass it will balance—or be in a state of ‘static equilibrium.’ A simple way to find the center of mass of a solid rod or pole is to support the pole horizontally on one finger from each hand. Carefully slide your fingers together, constantly watching the object—moving each finger in such a way as to keep the object level. When your fingers meet, you will be at the center of mass, at which time you can easily hold up the pole with only one finger, as long as it can withstand

the entire weight of the pole. Try it with a meter stick or a broom. If the object is uniform, like the meter stick, the center of mass will be at the exact geometric center; if the object is irregular in shape, like the broom, the center of mass will be much closer to the heavier end.

Obviously, there are many objects where this method will not work. For flat, nearly two-dimensional objects (like a piece of cardboard), you can use a plumb line. Attach a piece of string with a weight tied to the end of it (some metal washers work well, but anything will do) to a pushpin. Use the pin to tack an irregular cardboard shape to a bulletin board; making sure that the cardboard is hanging from the pin loosely (you may need to work the pin around to ensure the object hangs loosely). Trace the plumb line’s location onto the cardboard shape. Do this several times, moving the pin around the edge of the object each time. The center of mass will be at the intersection of all of the plumb line tracings you have made.

In most cases the center of mass of an object is a point with physical mass (the center of a ball for example). In other instances it can be located at a position that has no “physical mass”—for example, the center of a donut or other torus. If the object is irregular in shape, the center of mass is always located closer to the more massive end. However, as long as a plumb line

* Center of Mass? I thought it was Center of Gravity?

The terms “Center of Mass” and “Center of Gravity” may be used interchangeably as long as the discussion remains in a gravitational field. In a micro-gravity or ‘weightless’ environment such as outer space, “center of mass” is the correct term, and is very important in the propulsion of spacecraft, as the thrust of the engines must pass through the center of mass in order to prevent the spacecraft from veering off course or starting to spin.

Center of Mass

continued

dropped from the center of mass falls within the area of an object's base of support, an object will not topple. For example, a person bending over to pick up an object from the floor, or a cantilevered balcony, or something as simple as a truck parked on a hillside.

Here is a simple experiment to show how this works: Place a quarter on the floor about 30" from a wall. Stand with your back and heels of your feet right up against the wall, and try to pick up the quarter. Don't cheat! The vast majority of people will not be able to do it—when people bend over, their derrière extends back to balance them, which keeps the center of mass over their feet. Standing against the wall, your derrière cannot counterbalance you.

With balancing toys, stability is built in. They are constructed so that their center of gravity always remains below the pivot point. If the toys are tipped in any direction, the center of gravity is raised. This results in gravity exerting a restoring force (actually a torque), which pulls it back towards an upright position. As long as the center of gravity is below the pivot point, an object will remain in stable equilibrium, even when pushed "off-center."

That's all very interesting, but what about the bird?



The Balancing Bird Demo and our Small Balancing Birds are a great example of this phenomenon. These birds are so well balanced (the center of mass is so well plotted), that they will maintain their equilibrium at nearly all times, and will recover from a great degree of upset. The bird's balance point is its beak—and it's interesting to see what you can make it balance on. We have made it balance on the point of a very dull pencil!

How does the bird manage to do this? The outstretched wings have weights located at the tips. Looking at the bird from above (tail towards you), it appears that the majority of it is 'behind' the balance point. However, the wing tips are just 'ahead' of the beak—and that is where the extra weights are located—perfectly located to equal the mass of the rest of the bird. In addition, this location allows the weights to exert a good bit of torque to the entire bird. Think of it as having a set of levers that act on the body of the bird, constantly working to return it to a level attitude.

The wings and tail may not balance perfectly. If not, have your students decide where to add weight to the bird's body to have it balance perfectly.



NGSS Correlations

Our Balancing Bird Demonstration and our Small Balancing Birds, together with these lesson ideas, will support your students' understanding of these Next Generation Science Standards (NGSS):

Elementary

3-PS2-1

Students can use the Balancing Bird in the plan and to conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

3-PS2-2

Students can use the Balancing Bird to make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

Middle School

MS-PS2-2

Students can use the Balancing Bird in the plan of 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-PS2-4

Students can use the Balancing Bird in an investigation to construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

High School

HS-PS2-4

Students can use the Balancing Bird as an introduction to an investigation to use mathematical representations of Newton's Law of Gravitation to predict the gravitational forces between objects.

Suggested Science Idea(s)

3-PS2-1 • 3-PS2-2 • MS-PS2-2 • MS-PS2-4 • HS-PS2-4

Students can use the Balancing Bird in an investigation to understand Center of Mass. It will maintain its equilibrium at nearly all times, and will recover from a great degree of upset. The bird's balance point is its beak. Students can further explore disrupting the state of equilibrium by adding paperclips to the wings, pressing down on one wing or the tail.

Students can investigate their own center of mass by standing on their left foot on a block of wood. What happens to their body when you ask them to reach left with their left arm? Their right arm and right leg will move to regain balance or Center of Mass. How does this resemble the Balancing Bird? Ask them how center of mass helps in riding a bike, skateboard, surfboard, or snowboard.

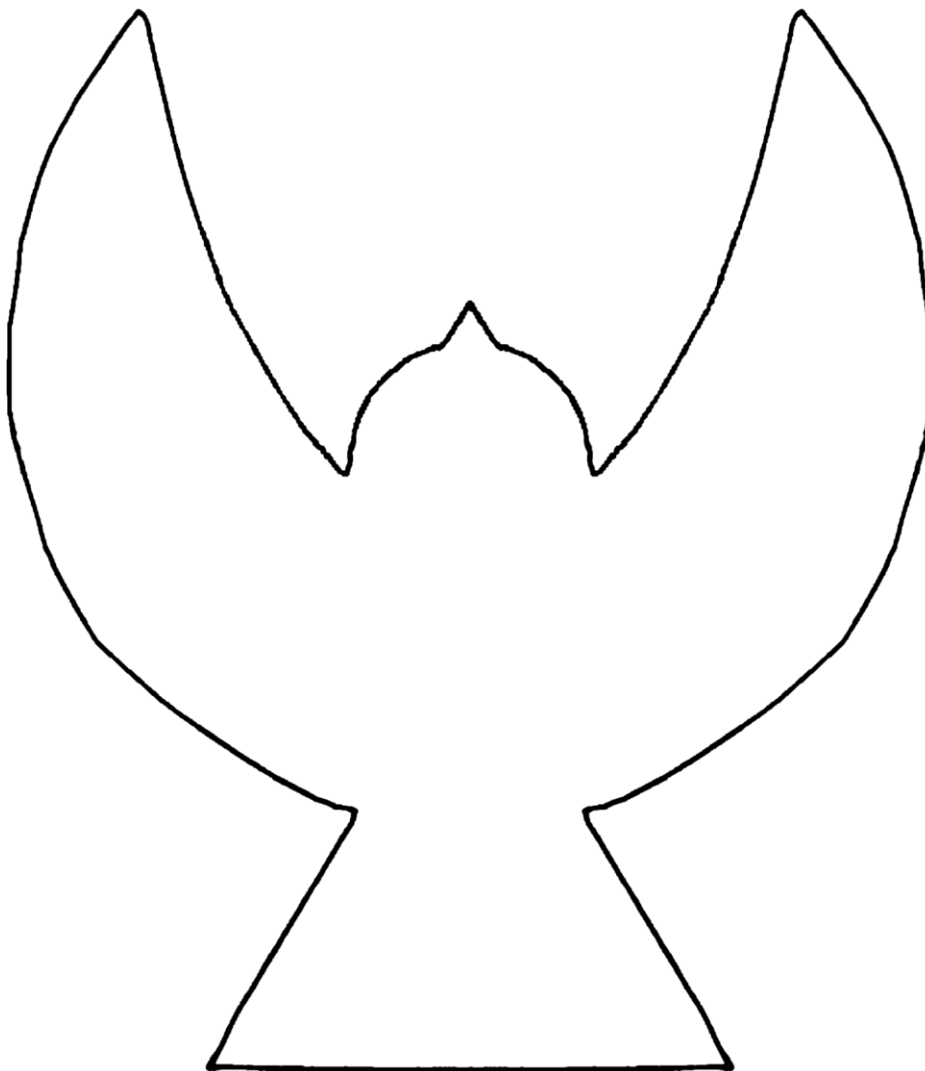
Things to Try

Using some tape and coins, can you make bird unstable? How much mass does it take?

Use a bent paperclip to hold the coins farther away from the bird. Does it take more or less overall mass to make it unstable than without the paperclip extension? Does the distance the mass is held away from the bird make a difference? Is farther away from the bird better than closer? Why?

Using the bird pattern below, cut a bird out of card stock. Try to balance the bird on the tip of your finger. Where does the bird balance? Use tape to attach two pennies to the front tip of the wings on your card stock bird. Try to balance it again. Do you notice a difference in where it balances? What accounts for the difference?

Bird Pattern



Take Your Lesson Further

As science teachers ourselves, we know how much effort goes into preparing lessons. For us, “*Teachers Serving Teachers*” isn’t just a slogan—it’s our promise to you!

Please visit our website
for more lesson ideas:

TeacherSource.com/lessons

Check our blog for classroom-tested
teaching plans on dozens of topics:

<http://blog.TeacherSource.com>

To extend your lesson, consider these Educational Innovations products:

Balancing Bird Puzzle (CTR-270)

Our Balancing Bird Puzzle is a wonderful do-it-yourself physics puzzle for students of all ages. Comes with four pre-cut wooden pieces, four ceramic ring magnets and assembly instructions. No glue required. After they build their wooden birds, students must set the magnets along the bird’s wingspan to determine its center of gravity. But where, exactly, should those magnets be placed? That’s where the fun—and learning—begins!



Classic Gyroscope (GYR-270)



The toy gyroscope has been in production since 1917 and has been a classic educational tool for generations. Use the power of physics to balance the gyroscope on its pedestal, a fingertip, the edge of a glass, or even a string. Gyroscopes are used in robotics, space exploration, and they are even used to stabilize movie cameras. Each gyroscope is packed in a clear styrene box with starting string, pedestal, and instructions for several amazing tricks. Measures 4.75 inches tall.

The PhiTOP (TOP-410)

This beautifully crafted top does for angular momentum what Newton’s Cradle does for linear momentum. When spun, it starts out horizontal and then, surprisingly, stands upright. Wow! In the process, it illustrates the difference between equilibrium and stability. The rise of the ‘center of mass’ is a fascinating physics problem. It will spin for minutes on end, producing a marvelous optical illusion as it slows down. Encourages exploration of force, mass, density, gravity, friction, and time. Egg is ~5 cm tall (2 in.).



The SpillNot (PHY-300)

The SpillNot is a fabulous solution to the ubiquitous problem of spills when carrying liquids. The fundamental laws of physics will easily and surprisingly keep the contents in the container! A very functional item that also graphically illustrates the effects of centripetal force. Your cup will not runneth over!