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

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* **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.

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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 is a great example of this phenomenon. It is so well balanced (the center of mass is so well plotted), that 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—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.

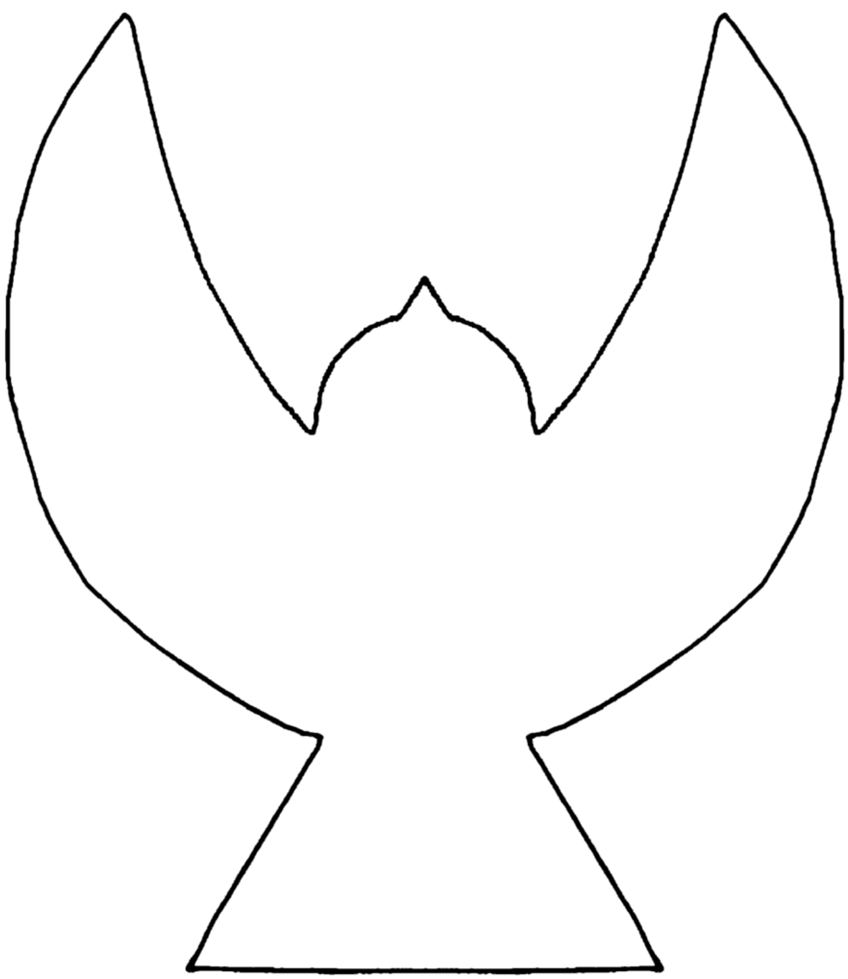
The wings and tail may not balance perfectly. If not, have your students decide where to add weight to the bird's body to have it balance perfectly.

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?

Our **Center of Gravity Kit** (WK-4) takes all of this another step further, allowing you to move the center of mass to nearly any point in the apparatus, letting you to observe how the changes affect how the object balances.



Bird Pattern

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This is a 'must have' for your science table. When assembled, this mysterious device will balance upon a point or slide down fishing line from one side of your room to the other. Students can easily bend the wires so that it balances at different angles. It demonstrates the advantage of keeping a low center of gravity.

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