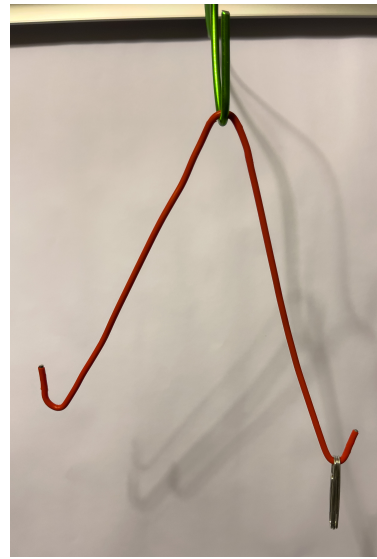


W-shaped balance



Adding weights

Paper Clips: *How to Tell When Your Country is Past the Point of No Return*

#### Instructor Notes

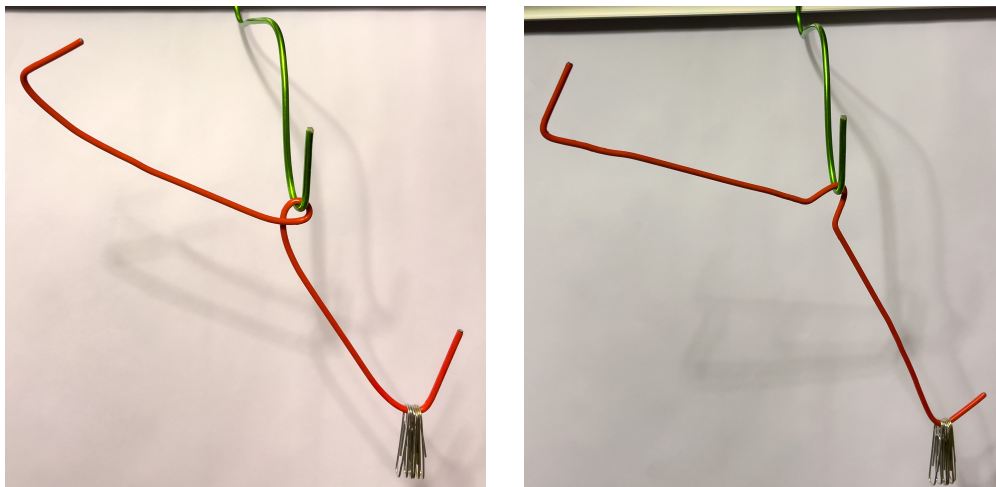
This is a very open-ended lab and you should expect and value many different ideas. It works best as a two-part lab. For the first part students work in teams of three in break-out groups, experimenting and writing team reports on their own. Give the teams plenty of time. The second part is plenary. Each team should present its report to the whole class. One way to do this is to have each team prepare a poster and then have teams walk around looking at each others' posters. After everyone has seen all the reports, the instructor can moderate a discussion pulling together all the observations, explanations, and terminology that came up in the team posters. As usual, be sure to value different contributions. This is a good time to introduce some of the standard terminology that is used. Here are some of the things that should come up:

- When you add a single weight to the balance, it typically oscillates for a while and then settles down into a new “equilibrium point.” These are examples of “attracting equilibria.”
- Students may talk about leverage or torque – that the twisting force of a weight depends on the weight and its distance (measured horizontally) from the fulcrum, or pivot point. When you add a weight to one side of the balance that side tips downward and all the weight on that side moves closer to the pivot point. At the same time the other side tips up and all the weight on that side moves further from

the pivot point. The result is a new equilibrium. This is a good opportunity to talk about how you would quantify the leverage or torque of the left and right side of the balance – that is, the bent jumbo paper clip.

- The most important observation is what happens when the angle A is obtuse. At first adding small weights, one at a time, produces small changes but then you reach a “tipping point” or “point of no return” and the balance slides off its hanger and falls to the ground. There are two key ideas here – first, an accumulation of small changes can produce a sudden dramatic change and, second, that change might be irreversible. The opportunities here for analogies to current events are many.
- The importance of the parameter A. If A is acute then the system is stable – the sharper the angle A, the more stable the balance. This, again, is a good place for discussion – what characteristics of our body politic make it more stable or less stable?

You should expect and welcome lots of other observations and ideas. As one example, a team might experiment with a balance that is not symmetric – that is, the two inside legs of the W are not equal – or might design an inventive balance like one of the two below.



Playing with balance is a great example of the synergy between the arts and the sciences. I've tested presents based on this idea using the craft wire and vinyl tip end caps shown on the next page. I used 3mm diameter (8 gauge), aluminum craft wire (\$13.99 for 10 meters in February 2022) and vinyl round tip end caps (inner diameter 2.5mm \$6.99 for 100 in February 2022) available from Amazon.com at:

[https://www.amazon.com/dp/B08TM5RS4V?ref=ppx\\_yo2\\_dt\\_b\\_product\\_details&th=1](https://www.amazon.com/dp/B08TM5RS4V?ref=ppx_yo2_dt_b_product_details&th=1)  
[https://www.amazon.com/dp/B07XDQXC39?ref=ppx\\_yo2\\_dt\\_b\\_product\\_details&th=1](https://www.amazon.com/dp/B07XDQXC39?ref=ppx_yo2_dt_b_product_details&th=1)



I used these as presents for three different Zoom holiday gatherings, each with three generations. The basic idea was to create mobiles using the craft wire for hangers and with other objects hanging from the hangers. The vinyl end caps are used to cover the rough edges when the wire is cut into pieces. In preparation for the Zoom gatherings I asked a “leader” at each site to have a pair of needle nose pliers like the one shown below handy.



We began by doing some simple balance experiments but in all three gatherings everyone went off into different directions, creating all sorts of cool things. There were some mobiles but lots of other very inventive ideas. Among my favorites were some really cool eyeglasses. Everyone had a lot of fun and learned a bit of math – from balance to arclength.