Teacher Notes

Rotational Inertia: Getting to the POINT… Let's Balance!

Logistics

Class age/size: Middle School/groups of 2-3

Materials (per group):

- One 1.25 cm dowel rod; approximately 90 cm in length
- Approximately 225g of clay

Time: 20-25 minutes

Location: Room with a lot of open space

Safety: Students need to be spread out and have room for the activity. It will be good to have spotters to make sure students don't run into each other and do not get hit by sticks.

Objectives/Standards

Observe how the distribution of mass along an object impacts the rotational inertia of the object.

- **NGSS: MS-PS2-2.** Plan 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.** Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. **MS-PS3-2**. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. **HS-PS2-1.** Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.
- **SEP:** Ask questions and define problems, plan and carry out investigations, analyze and interpret data, construct explanations and design solutions, engage in argument from evidence
- **Math:** MP1. Make sense of problems and persevere in solving them. MP.3. Construct viable arguments and critique the reasoning of others.

Introduction

Students have encountered the idea of inertia many times in their lives without knowing the definition. Anyone that has had to move a heavy object

knows all about inertia. When moving the object, it is difficult to get it started, but once it starts to move, it is easy to keep moving. The same is true for objects that rotate as well. However, the rules are slightly different because the farter the mass is from the point of rotation, the greater the rotational inertia and the harder it is to start the object rotating. This is commonly seen when figure skaters spin faster when their arms are closer to her body.

Activity/Activities

1. Have the students in groups of 2-3.
2. Give each group 1 dowel rod and clump of clay.
3. Teams will have 3 minutes to decide how to "design" their rod to balance the longest on an individual's index finger. The following RULES are to be discussed:
    - ALL of the clay must be placed on the dowel rod. There are no restrictions on how many locations the clay may be attached to the dowel.
    - No clay may touch the skin while balancing. This is to prevent individuals from trying to create a stable base using clay.
    - You may only use your index finger to balance the dowel rod vertically.
    - Be sure groups have spread out away from other groups.
    - Non-balancing partner will act as spotter to prevent accidents.
4. Following the initial design phase, a trial run of the competition will be done to test designs against other designs. Have each group choose an individual to balance the dowel rod, place the rod on their index finger, and wait for your cue to release their free hand from the rod at the same time. You may choose to declare a group, or groups the "winner" at this time to allow other groups to observe some characteristics of the designs that led to longer balancing times.
5. All 3 additional minutes for redesign/practice before the final competition.
6. For the final competition, follow the same procedure as Step #3, again showcasing "winning" designs for further review.

Conclusion

1. **What are the characteristics of the most successful designs? The least successful designs?**
   What we are looking for here, is an acknowledgement of the location of the clay being further away from the center of rotation, in this case the index finger. Designs where the clay is placed closer to the index finger

will most likely result in a shorter balance time relative to those where the clay is towards the end of the rod.

2. **What is the role of the clay?**
   The role of the clay is to prevent the end of the dowel from rotating freely, thus allowing the individual to have more time to react and keep the rod from tipping over. If the group is having difficulty answering this question, ask them to balance the dowel with no clay on the end vs. placing the lump of clay around the end of the dowel. It will be much easier to balance the dowel with the clay than without it.

3. **Why does the clay play this role?**
   Rotational inertia is a measure of how much an object resists changes in rotation. With the axis of rotation effectively being the end of the dowel at the location of the finger, the farther away the mass is located from the axis of rotation the greater the rotational inertia and the slower the stick will be to topple. To demonstrate this, have the student hold the rod without any clay and carefully swing the rod as if casting for fish. Then, have students swing the rod with the clay at the end. Prompt them to notice which is more difficult. Explain that the mass distribution at the end of dowel rod makes it more difficult to swing. Thus, the dowel rotates more slowly when the mass is at the top. This allows you more time to adjust and maintain balance. Conversely, when the mass is at the bottom, the stick has less rotational inertia and will topple quicker.

   If they are having a difficult time understanding rotational inertia, they have all experienced linear inertia. When their bodies move forward when a car stops suddenly, is an example of an object staying in motion and not wanting to stop. It being easier to keep a heavy object moving instead of starting to get it to move is an example of objects staying at rest and not wanting to move.