LAB 12

Lab Handout

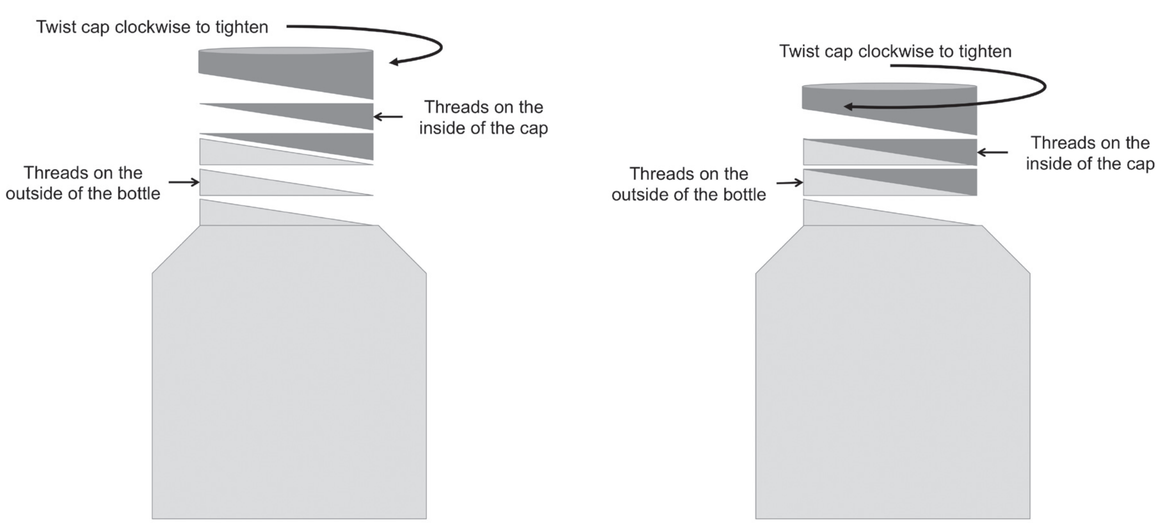
Lab 12. Torque and Rotation: How Can Someone Predict the Amount of Force Needed to Open a Bottle Cap?

Introduction

With the invention of the modern twist cap, there have been major advances in the ways that food and beverages can be packaged; in fact, it is difficult to find a bottle that does not close by using a twist cap. Common twist caps are used to seal soda bottles, gallon milk jugs, jars of pasta sauce, and even small bottles of medicine. Twist caps lock onto bottles and jars using threads—like a screw—on the underside of the cap; the outside of the bottle opening also has a set of threads. When the cap is placed over the bottle opening, the threads match up, and twisting the cap causes the threads to lock together and form a tight seal on the bottle. The threads of the twist cap and the threads on the bottle fit together like two ramps sliding past each other. The friction between the thread surfaces keeps the cap from coming loose by accident. Figure L12.1 shows how the threads of the cap and bottle fit together.

FIGURE L12.1

Cross-section of a threaded twist cap being screwed onto a threaded bottle



When companies are packaging different substances in bottles and jars that use this twist-top style of lid, they must ensure that the lids are installed with the proper amount of torque so that they form a good seal. A proper seal ensures that nothing leaks out and the food or drink stays fresh. When a net torque is applied to an object, the object will rotate.

The rotation of the object is related to two primary factors: (a) how strong of a force was applied to the object and (b) the location where the force was applied.

Think about closing the door to your science classroom. If you close the door by pushing on the handle, the door closes very easily. In this example, a small force is required when it is applied far away from the axis of rotation (the hinges of the door). When the same force is applied to the door, but halfway between the hinges and the handle, the door may not close. Because the location of the applied force is closer to the axis of rotation, the applied torque is decreased and the door may not close. If you want to close the door by applying a force at a location closer to the hinges, you likely need to apply a greater force.

Torque, and the relationship between the location of the applied force and the magnitude of the applied force, is important across many other relationships. Along with opening and closing bottle caps, torque plays an important role in tightening the lug nuts on your car's wheels, turning on a water faucet, and turning door handles. Part of the design process of tools and devices that twist is finding a balance between the location where a person will apply a force and the force needed to create a large enough torque. If you were to take apart a door handle, the part that actually turns to open your door is a small rod. The bulk of the handle is there to change the amount of force required to open the door.

Your Task

Use what you know about torque, proportional relationships, and systems and system models to design an investigation to determine the relationship between the force applied to open a bottle cap and the location from the axis of rotation the force is applied. Your goal is to create a mathematical model that will allow you to predict where a force must be applied on a bottle cap to open the cap for any specified force.

The guiding question of this investigation is, ***How can someone predict the amount of force needed to open a bottle cap?***

Materials

You may use any of the following materials during your investigation:

Consumables
- String
- Tape

Equipment
- Safety glasses or goggles (required)
- Plastic bottle modified with ruler or meterstick attached to the cap
- Spring scales (or force sensor with interface)
- Meterstick
- Hanging mass set
- Table clamp

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Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Wash hands with soap and water after completing the lab.

Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and carry out an experiment. To accomplish this task, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- How could you keep track of changes in this system quantitatively?
- How will you know the torque required to unscrew the cap?
- What variables do you need to measure to calculate torque?

To determine *how you will collect the data,* think about the following questions:

- What scale or scales should you use when you take your measurements?
- What equipment will you need to collect the data?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of the data you collect?
- How will you organize your data?

To determine *how you will analyze the data,* think about the following questions:

- What types of patterns might you look for as you analyze your data?
- Are there any proportional relationships that you can identify?
- What type of calculations will you need to make?
- What type of table or graph could you create to help make sense of your data?
- What types of mathematical relationships might you use to model the system under study?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

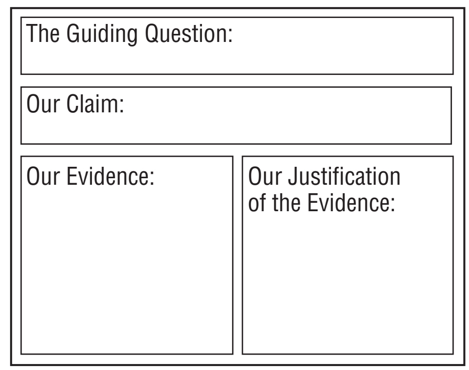
- the difference between data and evidence in science, and
- the role of imagination and creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your argument must include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L12.2.

FIGURE L12.2

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

Checkout Questions

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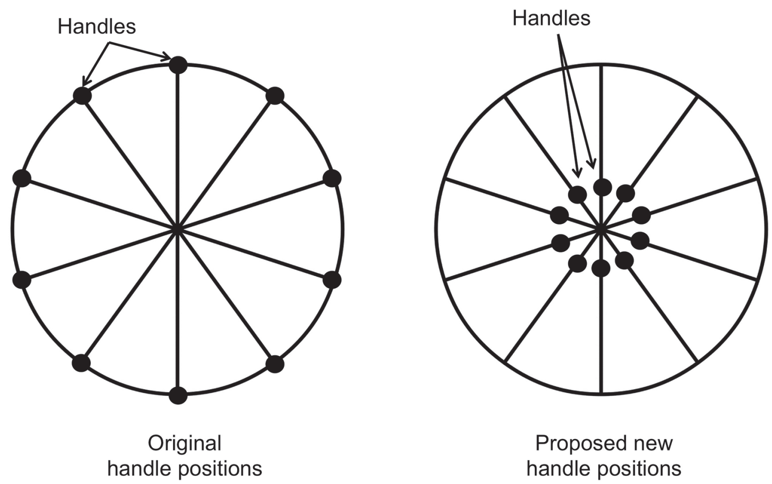
1. A contestant on a game show was spinning a large wheel to try and win money. The contestant was spinning the wheel as hard as he could, but the wheel only spun around a couple of times. The contestant suggested moving the handles closer to the center so that he and other players could make the wheel spin more with each push. The suggested change is shown below.



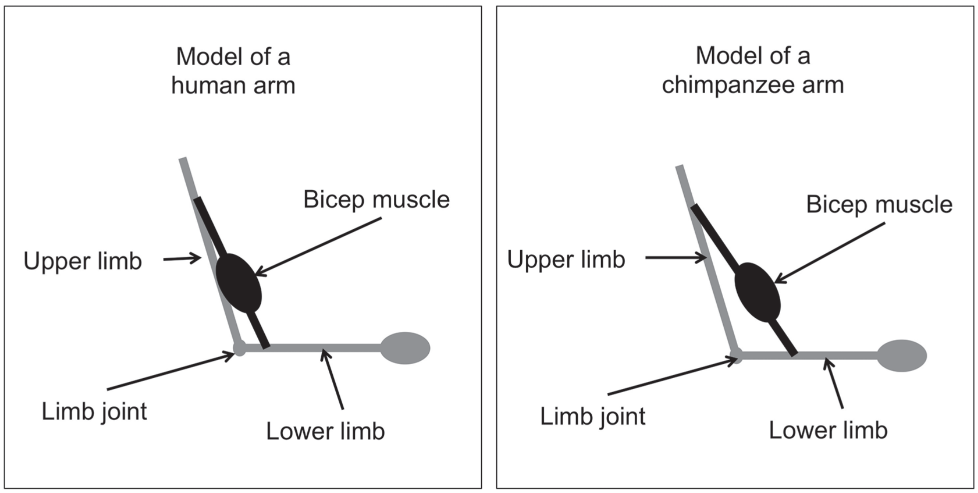
Will moving the handles closer to the center of the wheel help the contestants get more spins per push?

a. Yes
b. No

Explain your answer, using what you know about torque and rotational motion.

2. The bones and muscles found in humans and chimpanzees are almost identical. Chimpanzees, however, are much stronger than humans even though they are smaller. One explanation for this difference in strength is that the muscles of

chimpanzees are attached to the bones in slightly different ways than those of humans; therefore, chimpanzees are able to generate a greater torque with smaller muscles. The diagram below shows where the bicep muscle is attached to the upper and lower limb in a human arm and in a chimpanzee arm. When thinking about this, remember that muscles can only contract, so a bicep muscle pulls the lower limb toward the upper limb.



Use what you know about torque to explain why the difference could result in greater torque.

3. In science, it is possible for a variable to be proportionally related to two other variables.

   a. I agree with this statement.

   b. I disagree with this statement.

   Explain your answer, using an example from your investigation about torque and the rotation of bottle caps.

4. Science requires imagination and creativity.

    a. I agree with this statement.
    b. I disagree with this statement.

    Explain your answer, using an example from your investigation about torque and the rotation of bottle caps.

5. There is a difference between data and evidence in science. Explain what data and evidence are and how they are different from each other, using an example from your investigation about torque and the rotation of bottle caps.

6. In science, identifying the system under study is a prerequisite for being able to mathematically model the system. Explain why this statement is true, using an example from your investigation about torque and the rotation of bottle caps.