Lab Handout

Lab 16. Linear Momentum and Collisions: When Two Objects Collide and Stick Together, How Do the Initial Velocity and Mass of One of the Moving Objects Affect the Velocity of the Two Objects After the Collision?

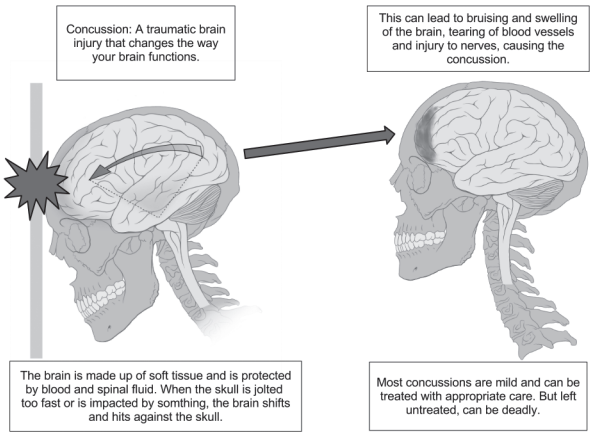
Introduction

The incidence of traumatic brain injury (TBI) is on the rise in the United States (CDC 2016). At least 1.7 million TBIs occur every year in this country, and these injuries are a contributing factor in about a third (30.5%) of all injury-related deaths (Faul et al. 2010). Adolescents (ages 15–19 years), older adults (ages 65 years and older), and males across all age groups are most likely to sustain a TBI (Faul et al. 2010). A TBI is caused by a bump, blow, or jolt to the head, although not all such events result in a TBI. TBIs can range from mild to severe, but most TBIs are mild and are commonly called concussions (CDC 2016). A single concussion, however, can cause temporary memory loss, confusion, and impaired vision or hearing. It can also cause depression, anxiety, and mood swings. Multiple concussions can make these symptoms permanent.

A concussion is caused when a person's brain hits the inside of the skull. This can occur when a moving person hits a stationary object (like running into a glass door), when a stationary person is hit by a moving object (like a person getting hit in the head by a baseball), or when two people collide with each other (like two people running into each other while playing a sport). As can be seen in Figure L16.1, when the skull is jolted too fast or is impacted by something, the brain shifts and hits against the skull. The "harder" the brain collides with the inside of the skull, the more severe the concussion.

FIGURE L16.1

Movement of the brain during a concussive event



Scientists have shown that the momentum of a collision is related to the severity of a concussion. Consider for example, what happens when a person is hit in the head with a ball. This often happens to softball players, baseball players, and soccer players. When a person is hit in the head by a moving ball, the severity of the concussion will be related to the momentum of that moving ball. Momentum is a function of both the mass of an object and its velocity. As an object accelerates, its

momentum increases. And, for two objects moving at the same velocity, the object with the greater mass will have a greater momentum.

Scientists have been studying collisions between two objects, such as cars, for some time. More and more scientists, however, are now studying the types of collisions that happen during different kinds of sports to better protect athletes from concussions. One type of collision that appears to be related to a high incidence of concussion is tackling in football. Tackling often results in two bodies staying together after the collision; Figure L16.2 shows one example of this. In this example, a defensive player (who is moving) collides with the quarterback (who is stationary). The defensive player holds on to the quarterback after the initial collision so they stay together as they fall to the ground. One goal of this line of research is to determine how the velocity of the moving object (or an athlete) before the collision affects the velocity of the two objects stuck together after the collision. In this investigation, you will have an opportunity to explore this relationship.

FIGURE L16.2

A collision between two football players

Your Task

Use what you know about momentum, collisions, systems, tracking the movement of matter within systems, and the importance of considering issues related to scale, proportion, and quantity to design and carry out an investigation that will allow you to understand what happens when two objects collide and stick together.

The guiding question of this investigation is, ***When two objects collide and stick together, how does the initial velocity and mass of one of the moving objects affect the velocity of the two objects after the collision?***

Materials

You may use any of the following materials during your investigation (some items may not be available):

- Safety glasses or goggles (required)
- 2 Dynamics carts (with Velcro or magnetic bumpers)
- Dynamics track
- Motion detector/sensor and interface
- Video camera
- Computer or tablet with data collection and analysis software and/or video analysis software
- Electronic or triple beam balance
- Cart picket fence
- Mass set
- Stopwatch
- Meterstick or ruler

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. Keep fingers and toes out of the way of moving objects.
3. Wash your hands with soap and water after completing the lab.

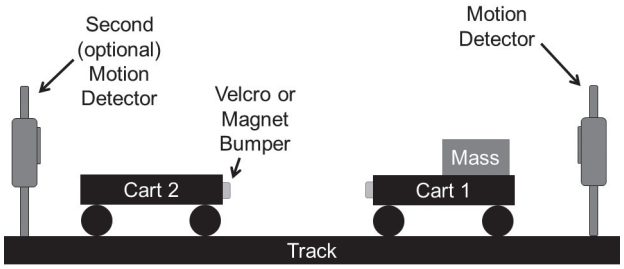
Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and carry out at least two different experiments. First, you will need to determine how changing the initial velocity of a moving object affects the velocity of the two objects after the collision. Next, you will need to determine how changing the mass of the moving object affects the velocity of the two objects after the collision. Figure L16.3 shows how you can use motion detectors/sensors to measure the velocity of a moving object (in this case, a dynamics cart) before and after a collision. The velocity of the moving object can also be measured by using a video camera and video analysis software. Before you can design your two experiments, however, you must determine what type of data you need to collect, how you will collect it, and how you will analyze it.

FIGURE L16.3

One way to measure the velocity of a moving object before and after a collision



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 components of the system under study interact?
- How will you track the movement of matter within this system?
- How could you keep track of changes in this system quantitatively?
- What factors affects the momentum of an object?
- How will you determine the velocity of each object?
- What will be the independent variable and the dependent variable for each experiment?

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

- What other factors will you need to control or measure during each experiment?
- Which quantities are vectors, and which quantities are scalars?
- For any vector quantities, which directions are positive and which directions are negative?
- What scale or scales should you use to take your measurements?
- What equipment will you need to collect the measurements you need?
- 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 and organize the data you collect?

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

- What type of calculations will you need to do?
- What types of patterns might you look for as you analyze your data?
- Are there any proportional relationships you can identify?
- What types of comparisons will be useful to make?
- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

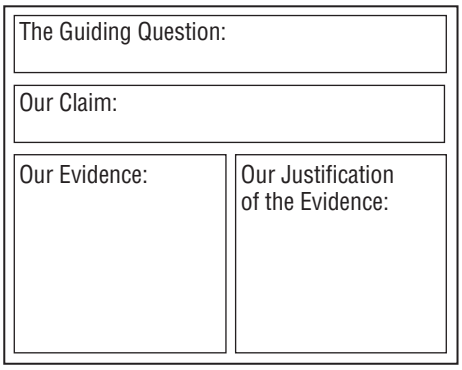
As you work through your investigation, you may want to consider

- the difference between observations and inferences in science, and
- how the culture of science, societal needs, and current events influence the work of scientists.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your initial argument needs to 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 L16.4.

FIGURE L16.4
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:

LAB 16

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!

References

Centers for Disease Control and Prevention. 2016. TBI: Get the facts. *www.cdc.gov/traumaticbraininjury/get_the_facts.html*.

Faul, M., L. Xu, M. M. Wald, and V. G. Coronado. 2010. Traumatic brain injury in the United States: Emergency department visits, hospitalizations and deaths. Atlanta, GA: Centers for Disease Control and Prevention, National Center for Injury Prevention and Control.