Lesson 6 Teacher Reference

# Optional Collision Introduction

The transition into using velocity graphs and algebra to predict and model force in Lesson 6 involves a few different elements of cognitive lift and may be too abstract for some student populations. The sequence below, along with the optional slides located at the end of the Lesson 6 slide deck, and the handout included at the end of this teacher reference are meant to provide an alternative framing that is more concrete and more hands on and clarifies the individual steps of the work in a coherent way. This alternate, more-scaffolded sequence will add 20-25 minutes to the lesson.

To build an understanding of why we're using our sensor cart to model a real-life collision, students should understand the following steps.
1. "Crash force" is relevant for safety in collisions. The sensor cart lets us measure crash force directly.
2. We can't usually measure crash force in a real collision, but we can measure velocity.
3. Calculating a force prediction from velocity values should be possible, but we don't yet know how good our model is.
4. We can use velocity to predict the force for a test collision, then check the force measurement to see how our model may need to be revised.

### Materials Preparation

Materials:

- sanitized safety glasses with side shields
- smart cart
- smart cart track
- wall or large brick
- sticky tack
- computer with data collection software (see https://youtu.be/1LLZEYo1Yzk or https://youtu.be/iJB1o6W0xqY

Before beginning the lesson, review the directions for setting up the software to display force versus time and speed versus time graphs for the type of smart cart you are using. *Note: You will not need to watch the whole video until Lesson 10. We are not using the sensor cart for "crumple zone" work in this lesson; you're just introducing the cart as an instrument that can collect force and velocity data.*

- Pasco system: https://youtu.be/1LLZEYo1Yzk

- Vernier system: https://youtu.be/iJB1o6W0xqY

In order to model a sudden stop, place your smart cart track with the end against a wall or large brick. Wrap the force sensor of your cart with sticky tack and place a wide, flat piece of sticky tack on the wall where the force sensor makes contact. Your goal here is to prevent the cart from bouncing so that students can see the cart stop quickly. Try this ahead of time so you have a reliable method, then remove the sticky tack from the cart for the initial introduction of the cart to students.

## Safety Protocols

When working with the materials, the following safety precautions are necessary.

- Students must conduct the experiment under the supervision of qualified personnel who can respond quickly to any unforeseen circumstances.
- Students involved in setting up the equipment and conducting the experiment must be properly trained in handling the sensor carts and understand the experimental procedures.
- Wear appropriate personal protective equipment (PPE) including sanitized safety glasses with side shields during the setup, experimentation, and takedown segments of the activities.
- Secure loose clothing, wear closed-toe shoes, and tie back long hair.
- Clear the workspace of any obstacles or hazards that could interfere with the experiment or cause accidents during the collision.
- Make sure that all parts of the carts are properly secured and stabilized before conducting the collision test. Follow manufacturer guidelines for setup and operation.
- Immediately clean up anything that falls on the floor, so it does not become a slip or fall hazard.
- Maintain a safe distance from the collision area during the activity to avoid injury from flying debris or malfunctioning equipment.
- Following the activity, inspect all equipment for any damage or wear and tear. Repair or replace any damaged components before further use.
- Wash hands with soap and water once all equipment is put in appropriate storage areas.

## Optional Lesson Sequence

In place of presenting **slide D**, use the following sequence for **slides C1-C4**.

**Orient to a crash test of a car hitting a fixed barrier.** Show **slide C1** and say, *Watch this video of a crash test and then turn and talk. What do you notice? Would you model this collision as a bounce, a sudden stop, or something in between?* Play the first 3 seconds of the video

(https://www.youtube.com/watch?v=8lEsbcUSoU8) over and over again while students talk, then ask students to share their ideas with the whole class. Listen for responses such as these:

- The car stops, and the dummy hits hard.
- The car doesn't really stop, but we could model it that way.
- The car gets totaled.
- I'd model this as a bounce because the car doesn't stop, it keeps rolling backward.
- Someone would probably be killed if that was a person.

**Introduce the sensor cart as a tool for data collection.** Show **slide C2** and say, *We have one of these sensor carts that allows us to collect data about speed and force. We won't be able to recreate a collision of the size we saw in the video, but we can still crash the cart into a wall and see what happens.*

Open the graph display software for your sensor cart (see the videos for either the Pasco system https://youtu.be/1LLZEYo1Yzk or the Vernier system https://youtu.be/iJB1o6W0xqY). Set up the cart to show force measurements and display this on the projector screen. Show the cart to students and collect data while a student pushes on the force sensor. Then set up the cart to measure velocity and collect data while a student rolls the cart back and forth on a table. Say, *The way this cart system talks about speed is by using the term* velocity*. For now, think of this graph as a speed versus time graph. We will find out more later. about why it uses the word* velocity

Show **slide C2** again, and ask, *How should we model the car crash in the video using our sensor cart? If we want to keep it simple, can we start with a sudden stop and then try a bounce later to see how those graphs compare?*

**Test a "sudden stop" scenario in the classroom to introduce students to the velocity graphs made by the sensor cart.** Use the "sudden stop" test as an opportunity to get students engaged in the act of using the sensor cart. Add the sticky tack to the force sensor, and explain to students that this will ensure that the cart stops still against the wall. Show the velocity graph on the projector screen again and get students' assistance in recreating the collision they saw in the crash test video as a "sudden stop". Ask questions to help students make the connection between the large-scale crash test, the smaller-scale sensor cart test, and the algebraic model that allows us to predict force on the cart. For example, as the class is performing the sensor cart test, ask students, *Why are we crashing this sensor cart against the wall? But the car in the crash test sort of bounced backward--why aren't we having our cart bounce backward? But if the force on the cart is what we want to find, why do we care about speed data?*

If you have time, remove the sticky tack from the cart and the wall and perform another collision to show that the cart does indeed bounce backward.

**Use the "sudden stop" velocity graph to calculate a predicted force using ∆velocity and ∆time data.** Distribute to each student a copy of the *Collision 0 Predictions* handout included as the last two pages of this document and show **slide C3**. Read through the safety precautions together. Then display **slide C4.** Say, *This graph shows a collision that's very similar to the one we did together just now, but it used a cart with a known mass of 0.6 kg. Let's try using the graph to get the data we need to calculate force.* Either ask students to work through the graph analysis and algebraic calculations themselves or, if you think that students might struggle with this graph analysis, complete that analysis as a class.

**Introduction to Collision A:** Show **slide C5**. Ask students to turn their *Collision 0 Predictions* handout over and make a Notice and Wonder chart on the blank side. Watch the video on **slide C5** (https://youtu.be/wmlCn22dTwk) from the beginning and ask students to write down noticings and wonderings. Stop the video at 2:04 and show the actual cart movement again from 2:00 to 2:04 a few more times. Ask students to write down one last round of noticings and wonderings about just the movement of the cart during this collision. Ask students to share their ideas, and accept all responses. Call attention to comments that point out that the car reverses direction in the collision.

Distribute *Collision A/B Predictions* and show Collision A one last time, playing until the end of the video so students can see when the data collection begins and ends.

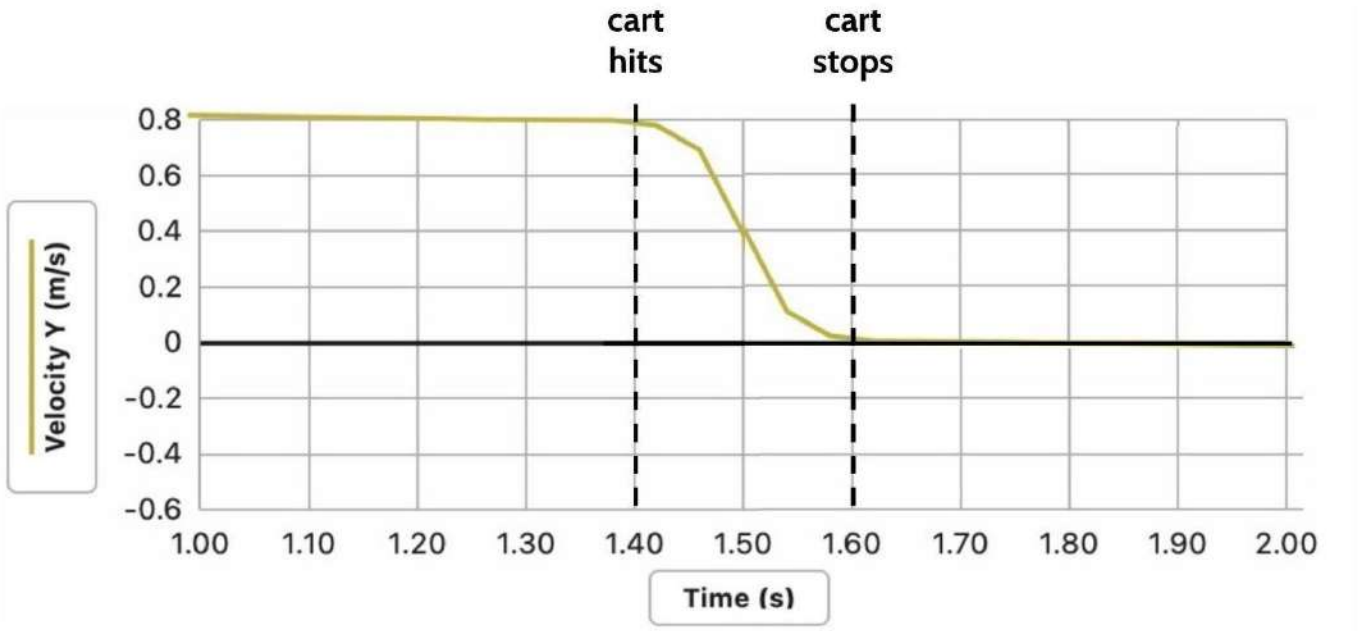
Resume the sequence in the *Teacher Guide* with **slide E**. Be sure to read the guidance callouts in the *Teacher Guide* about the video that is used with **slide D** and **slide C5**.

## Safety Protocols

When working with the demonstration materials, the following safety precautions are necessary.

- Only conduct the activity under the supervision of qualified personnel who can respond quickly to any unforeseen circumstances.
- Students involved in setting up the equipment and conducting the experiment must be properly trained in handling the sensor carts and understand the experimental procedures.
- Wear appropriate personal protective equipment (PPE) including sanitized safety glasses with side shields during the setup, experimentation, and takedown segments of the activities.
- Secure loose clothing, wear closed-toe shoes, and tie back long hair.
- Clear the workspace of any obstacles or hazards that could interfere with the experiment or cause accidents during the collision.
- Make sure that all parts of the carts are properly secured and stabilized before conducting the collision test. Follow manufacturer guidelines for setup and operation.
- Immediately clean up anything that falls on the floor, so it does not become a slip or fall hazard.
- Maintain a safe distance from the collision area during the activity to avoid injury from flying debris or malfunctioning equipment.
- Following the activity, inspect all equipment for any damage or wear and tear. Report any damage to the instructor so any damaged components can be repaired or replaced before further use.
- Wash hands with soap and water once all equipment is put in appropriate storage areas.

**Collision 0 Predictions: A 0.6-kg cart traveling at approximately 0.80 m/s hits a wall and stops.**




| Collision 0 | |
|---|---|
| **Variables** | |
| mass (kg) | **0.6 kg** |
| Δ time (s) | |
| Δ velocity (m/s) | |
| Force (N) | |

*Equation:*

$$F = \frac{m * \Delta speed}{\Delta t}$$

*Calculations:*