Crash Cart Barrier Project Teacher Guide

Set up

We recommend setting the ramp at an angle of 15° and releasing the cart 40 cm away from the barrier. While crashing the cart into a wall works, if this is difficult to set up, you can replace the wall with a cardboard box. Tape it down to the floor or table so it doesn't move at impact. Make sure students start with a control by crashing the cart into the wall/cardboard box without a barrier. An essential skill for students will be matching the correct "spike" on the graph with the moment of impact. If the video function of the PocketLab app is available, have students record their trials while taking video. They can then go back and review the impact to make sure they are using the correct reading.

You can use either the "Acceleration" graph (which shows acceleration on all three axes of the PocketLab), or the "Acceleration Scalar" graph (which shows the aggregate acceleration of all three axes). The "Acceleration Scalar" graph will be easier to read, so it can be used to scaffold the difficulty of the lab if necessary. If students use the "Acceleration" graph, make sure they know which axis the PocketLab will experience the acceleration at impact. You can also use the two-graph mode and look at data from both graphs in real time.

It will be extremely important for students to conduct multiple trials. We recommend five at the minimum.

Expected Results

Students should eventually come to the conclusion that barriers which increase the time of the impulse get the best results. Because the velocity and mass of the cart is controlled, so too is the momentum at impact. The cart will come to a stop every time during the initial collision (when the cart changes directions), so the impulse (change in momentum) during the initial collision will therefore also always be the same. Because force and time are inversely proportional (*impulse = force x time*), by increasing the time of the impulse, the force experienced will have to decrease to keep the impulse the same. For students to come to this conclusion, push them to think about the equation for impulse throughout the experiment. Students may notice that with effective barriers, the acceleration at impact has a lower value AND the "spike" of the graph takes a longer time. Because acceleration is proportional to force, students can conclude that the "spike" they are seeing is really the impulse of the collision. By increasing the time of the impulse, they reduce the force experienced.

Designs that are most effective are designs that crumple at impact. The crumpling of the barrier slows the time of the collision and reduces the force experienced by the cart. At first, students may try to design barriers that are very strong and don't crumple, because the crumpling of the barrier looks like "damage." This is why it is important to allow them to learn from their designs and continue to build new barriers.

Our Results

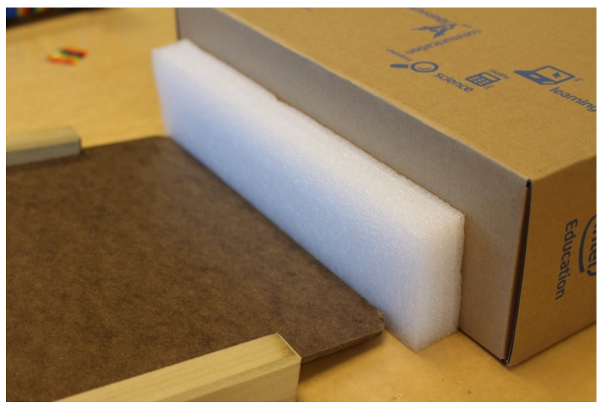
We crashed our cart into a cardboard box, and then tested four barriers. The results are below:

Cart Crash with no barrier	
TRIAL	**MAX ACCELERATION (m/s^2)**
Trial 1	72.49
Trial 2	51.23
Trial 3	27.42
Trial 4	45.25
Trial 5	65.41
Average	**52.36**

Travel distance: 40 cm
Angle of ramp: 15°
Mass of cart:

Cart Crash with Styrofoam Barrier	
TRIAL	**MAX ACCELERATION (m/s^2)**
Trial 1	23.08
Trial 2	23.65
Trial 3	49.25
Trial 4	40.58
Trial 5	36.00
Trial 6	44.61
Average	**36.195**

Travel distance: 40 cm
Angle of ramp: 15°
Mass of cart:



Cart Crash with Air Bag Barrier	
TRIAL	**MAX ACCELERATION (m/s^2)**
Trial 1	31.41
Trial 2	19.71
Trial 3	13.62
Trial 4	22.93
Trial 5	19.00
Trial 6	12.52
Average	**19.865**

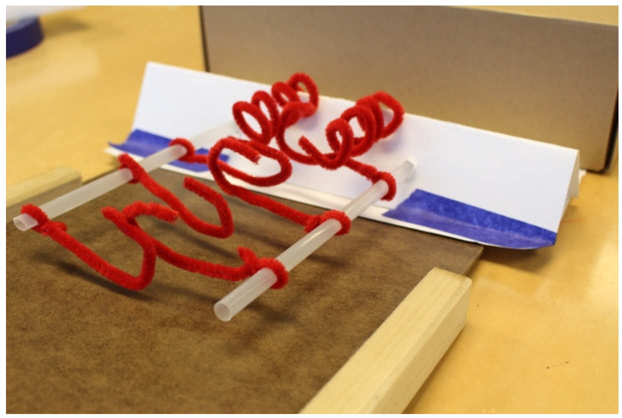
Travel distance: 40 cm
Angle of ramp: 15°
Mass of cart:

Cart Crash with Robby’s Barrier	
TRIAL	**MAX ACCELERATION (m/s^2)**
Trial 1	17.49
Trial 2	30.93
Trial 3	12.76
Trial 4	7.74
Trial 5	12.74
Trial 6	19.15
Average	**16.801**

Travel distance: 40 cm
Angle of ramp: 15°
Mass of cart:

Cart Crash with Clif’s Barrier	
TRIAL	**MAX ACCELERATION (m/s^2)**
Trial 1	18.13
Trial 2	14.8
Trial 3	21.19
Trial 4	11.26
Trial 5	17.15
Trial 6	11.73
Average	**15.71**

Travel distance: 40 cm
Angle of ramp: 15°
Mass of cart:



Name: ______________________________________ Period: _______________ Date: ________________

Crash Cart Barrier Project

Investigation

Nearly 1.3 million people die from car accidents worldwide each year, according to the World Health Organization. In order to reduce traffic fatalities high-speed roadways must be made safer. Building crash barriers along highways that reduce the impact force experienced by the passengers of the car in a crash can save lives. But how should these barriers be built?

Objective

Using the available supplies, build a crash barrier that will reduce the force experienced by the cart as it

crashes into the wall. You must build at least three models of a crash barrier and collect acceleration data using PocketLab for each model. Using the data collected from your crash barrier models, draw a conclusion about how to design optimal crash barriers to prevent traffic fatalities.

Required Equipment/Supplies

-PocketLab
-Dynamics Cart
-Wall
-Ramp

Materials For Building Crash Barrier
Newspaper, cardboard box, construction paper, notecards, straw, glue gun, stapler, tape, etc.

Discussion[1]

If a big truck and a small car are traveling at the same speed, which vehicle is harder to stop? We intuitively know it is the truck, but why? It is harder to stop the truck because it has more momentum. Momentum is the product of an object's mass and velocity. We can think of momentum as inertia in motion.

Equation for momentum: $p = m \cdot v$
where $p = momentum \quad m = mass \quad v = velcoity$

In this experiment, you will control the cart's mass and velocity and therefore its momentum going into the crash.

Impulse is a measurement of the change in momentum. If the mass of an object isn't changed, the only way to change an object's momentum will be to change its velocity. To change an object's velocity is to accelerate the object. Acceleration is a result of a force. The greater the force acting on the object the greater its acceleration/change in velocity. The impulse, or change in momentum, of an object depends upon the force acting on the object and the length of time that the force acts upon it.

Equation for impulse: $J = F \cdot \Delta t$
where $J = impulse \quad F = force \quad \Delta t = change\ in\ time$

[1] Paul Hewitt, "Conceptual Physics" (Pearson, 2009), 48-49

Because the momentum of the cart as it rolls down the ramp is controlled, the change in momentum/impulse from the cart at full velocity to zero velocity will also be controlled. Knowing that, your crash barrier must reduce the force as measured by the PocketLab's accelerometer of the crash. (Note: Acceleration and force are proportional as shown in Newton's Second Law of Motion).

Pre-Lab Questions

The objective of your crash barrier is to reduce the force experienced by the cart. Thinking about the information from the discussion section above, identify how this is possible? What will your crash barrier need to do during the crash in order for it to reduce the force experienced by the cart?

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Think about how you want to build the most optimal crash barrier that will reduce the force experienced by the cart. Predict what that barrier will look like and explain how you will make it.

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Lab

Control Crash (no barrier): Collect data of the cart crashing into the wall without a barrier.

Test your Control Crash by following these steps (conduct multiple trials):

1) Line the ramp up with the wall.
2) Secure the PocketLab to the cart.
3) Sync the PocketLab to your device.
4) Select the Acceleration or Acceleration Scalar graph
5) Place cart on a controlled height on the ramp.
6) Begin recording the acceleration data
7) Release the cart.

Record your graph and data from your trials here

Crash Barrier 1: Use the materials provided to design a crash barrier that will reduce the force experienced by the cart.

List of materials used for Crash Barrier 1

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Explain the decisions that went into the design of the barrier below.

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Draw a diagram of Crash Barrier 1 here

Test your Crash Barrier by following these steps (conduct multiple trials):

1) Place your barrier against a wall.
2) Line the ramp up with the barrier.
3) Secure the PocketLab to the cart.
4) Go to the Acceleration or Acceleration Scalar
5) Place cart on a controlled height on ramp.
6) Begin recording the acceleration data
7) Release the cart from controlled height.

Record your graph and data from your trials here

Was this design effective? Why or why not?

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Crash Barrier 2: Use the materials provided to build a crash barrier that improves upon your previous design to reduce the force experienced by the cart.

List of materials used for Crash Barrier 2

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Explain the decisions that went into the design of the barrier below.

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Draw a diagram of Crash Barrier 2 here

Test your Crash Barrier by following these steps (conduct multiple trials):

1) Place your barrier against a wall.
2) Line the ramp up with the barrier.
3) Secure the PocketLab to the cart.
4) Go to the Acceleration or Acceleration Scalar
5) Place cart on a controlled height on ramp.
6) Begin recording the acceleration data
7) Release the cart from a controlled height.

Record your graph and data from your trials here

Was this design effective? Why or why not?

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Crash Barrier 3: Use the materials provided to build a crash barrier that improves upon your previous design to reduce the force experienced by the cart.

List of materials used for Crash Barrier 3

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Explain the decisions that went into the design of the barrier below.

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Draw a diagram of Crash Barrier 3 here

Test your Crash Barrier by following these steps (conduct multiple trials):

1) Place your barrier against a wall.
2) Line the ramp up with the barrier.
3) Secure the PocketLab to the cart.
4) Go to the Acceleration or Acceleration Scalar
5) Place cart on a controlled height on ramp.
6) Begin recording the acceleration data
7) Release the cart from a controlled height.

Record your graph and data from your trials here

Was this design effective? Why or why not?

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Conclusion

Which of your three designs was most effective at making the most optimal crash barrier? Support your conclusion with evidence that you gathered from the lab and scientific reasoning that explains why the data support your conclusion.

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If you wanted to make cars safer during head-on collisions with other cars, what would you design the front of the car to do at impact? Relate your answer to your conclusions about crash barriers.

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Lab Extension

The federal highway administration wants you to design crash barriers to install at highway interchanges and exits. Not only must your barrier be effective, but it also must be cost efficient. With your class/teacher decide on a per-unit cost for each of the different materials that you are allowed to use for building your crash barrier. Include those costs in table 1.

Table 1: Cost per unit

Material	Cost (Dollars)

Your challenge is to build a cost efficient barrier that would still save lives. A good barrier will have a low force experienced at collision while also being cost efficient.

While building your new crash barrier, write down every material used in Table 2. Add up the total cost of the barrier. Test the barrier in the same way you tested your previous barriers.

Table 2: Crash Barrier Cost

Material used	Per unit cost	Number of units	Total cost of material
		Total Cost of Barrier	

Use the following equation to find the cost efficiency of your barrier:

$$Barrier\ Cost\ Efficiency = (Max\ Acceleration\ of\ Collision)(Total\ Cost\ of\ Barrier)$$

Remember you want the lowest possible force at collision, so in this case a lower number is more cost efficient.

Explain the decisions that went into the design of the barrier below.

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Draw a diagram of the Crash Barrier here

Test your Crash Barrier by following these steps (conduct multiple trials):

1) Place your barrier against a wall.
2) Line the ramp up with the barrier.
3) Secure PocketLab to cart.
4) Go to the Acceleration or Acceleration Scalar
5) Place cart on a controlled height on ramp.
6) Begin recording the acceleration data
7) Release the cart from a controlled height.

Record your graph and data below

Was this design effective? Why or why not?

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Plot the Maximum Acceleration at Collision and the Total Cost of Barrier for all the lab groups in the class.

Maximum Acceleration at Collision versus Total Cost of Barrier

Where on the graph should the best crash barrier be located? Why?

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Which group's design do you think the federal highway administration would use? Why?

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Having the lowest cost efficiency doesn't necessarily mean it is the best barrier. Explain.

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