



Name: _____ Class: _____ Date: _____

CRASH SCIENCE IN THE CLASSROOM

PROJECT PEDESTRIAN

Day 1 - Measuring Baseline Crash Pulses of Unmodified Cars



DAY 1 MATERIALS NEEDED

For each group of 2-3 students

- » 1 Hot Wheels® toy car or similar toy car
- » 4 sections of Hot Wheels® track
- » 3 Hot Wheels® track connectors
- » 2 game dice or 4 pennies
- » 4-6 textbooks or similar-sized track supports
- » 1 pre-cut foam pad or similar soft padded object to cushion the sensor
- » 1-2 pairs of scissors
- » 1 metric ruler, 30 cm length
- » 1 foam packing peanut
- » 1 paper Pedestrian Crash Test Dummy outline
- » 15 cm of transparent tape
- » 50 cm of masking tape
- » 1 wireless acceleration sensor
- » 1 Bluetooth® 4.0 capable computing device (e.g., smartphone, tablet, laptop computer)

Per student

- » 1 “Project Pedestrian” Student Activity Sheet
- » 1 calculator
- » 1 pair of safety glasses

Optional (per class)

- » Wireless connection to online document storage site (e.g., Google Docs, iCloud, Dropbox)

Optional (per group)

- » 1 camera-enabled device (e.g., smartphone or tablet with camera)

Safety notes for Day 1 and Day 2:

- » Follow all general lab safety procedures.
- » Use caution when working with scissors.
- » Wear safety glasses when conducting collision simulations.
- » Wash your hands with soap and water after completing this activity.

Key Question(s)

- » How can the front ends of vehicles be designed to minimize pedestrian injuries in a crash?

Purpose

- » To design a bumper for a small toy car that provides the best protection to a pedestrian crash test dummy in a simulated collision
- » To analyze crash pulse graphs from simulated collisions to determine which types of materials and bumper designs provide the best protection to pedestrian crash test dummies in a simulated collision
- » To describe a vehicle-pedestrian collision in terms of changing momentum, impulse, impact force, and impact time
- » To analyze a data table to determine the age groups at greatest risk of death in vehicle-pedestrian collisions
- » To make inferences about the potential effectiveness of automatic emergency braking systems in different vehicle-pedestrian scenarios

Did You Know?

In the past 10 years, the number of pedestrians killed by motor vehicles in the U.S. has drastically increased and most pedestrian crashes occur in cities. Along with vehicle crash avoidance technologies such as pedestrian detection sensors and automatic braking systems and traffic engineering improvements such as more sidewalks, overpasses, and medians and lower speed limits, vehicle front ends can also be designed to reduce the type and severity of pedestrian injuries in a collision and save lives. In this simulation activity, you will apply the same physics laws and concepts that automotive scientists and engineers use to design vehicle front ends that reduce pedestrian injuries and deaths in collisions.



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Procedure

Part A. Pedestrian Crash Test Track Assembly

1. Watch the activity’s Introduction video at classroom.ihs.org/project-pedestrian
2. Connect the four sections of Hot Wheels® track together using three track connectors.
3. With books as a support, create an elevated starting ramp for the toy car by securing one end of the track to the stack of books. See Figure 1.
4. Measure straight upwards from the table or floor to a spot on the track 23 cm above the table or floor. Mark this point as the starting line. Secure the top of the track to the books with a strip of tape (See Figure 1).
5. At the bottom of this elevated starting ramp, create a 60-cm long straightaway on a flat, hard surface (floor or table top) and use a strip of masking tape across the end of the track to secure it to the floor or table.
6. Place the piece of foam padding provided (e.g., small pillow, stuffed animal, etc.) at the end of track to catch the sensor and car after the collision (See Figure 1).



Figure 1- Crash Test Track Set-Up
Height of starting line above table (cm) = 23 cm



Figure 2 - Sensor base
(Left) Two dice or (Right) four pennies

Part B. Preparing the sensor

1. Tape two dice or a stack of four pennies together to form a small platform for the sensor (see Figure 2).
2. Tape the wireless sensor on top of the two-dice or stack of pennies (See Figure 3). The sensor will represent the Pedestrian Crash Test Dummy and will measure the impact of the crash on the dummy in g’s.
3. Prepare the wireless sensor to record the impact by following these steps:
 - a. Turn on the sensor.
 - b. Pair the sensor with your computing device (e.g., tablet, smartphone, laptop, et.). If needed, refer to the sensor’s owner’s manual for pairing instructions.
 - c. Open the sensor’s app or software on your computing device. If the sensor can record multiple types of data (e.g., acceleration, light, altitude), select “acceleration.”
 - d. Adjust the sampling rate (i.e., how many data points are measured in one second) to at least 50 points per second.

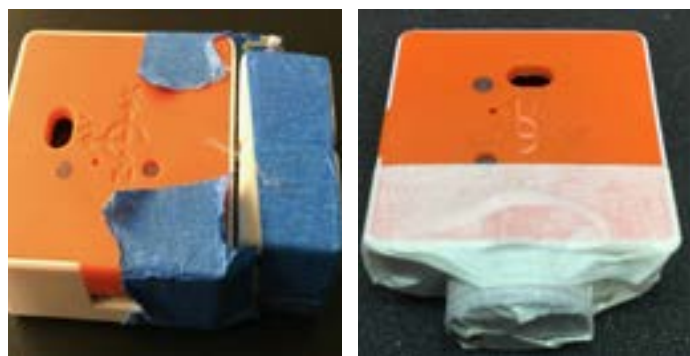


Figure 3 - Sensor attached to base
(Left) Sensor on dice or (Right) Sensor on pennies



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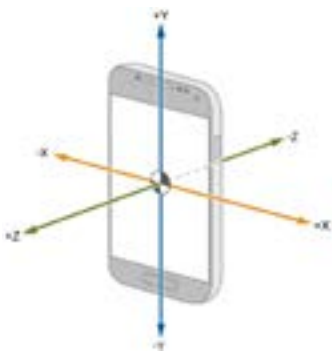


Figure 4 - Sample x, y, and z axes (z-axis measures front-to-back movement)

- e. If the sensor is a 3-axis accelerometer, select the Z-axis. The Z-axis measures movement from the front face of the sensor toward its backside (as well as from the backside to the front). See Figure 4 for an example of X, Y, and Z-axes on a smartphone.
 - f. Select measurement units of g's for acceleration.
 - g. Test if sensor is recording on the Z-axis by tapping the front of the sensor with your finger while watching the sensor's application or software display on your computing device (e.g., tablet, smartphone, or laptop). You should see a downward "spike" (negative range) on the graph. **NOTE: The downward "spike" on the graph indicates the sensor is moving backwards so all of the g measurements you record should be written as negative numbers in your Data Tables.** The harder you tap on the front of the device, the bigger the "spike" will appear on the screen. Engineers and scientists call the graph's "spike" a crash pulse. Larger "spikes" or crash pulses mean bigger impacts.
 - h. In its role as the pedestrian in your simulated collisions, the car will strike the sensor when released. To help the sensor more accurately measure the impact of the crash on the Pedestrian Crash Test Dummy, tape one packing peanut along with the paper Pedestrian Crash Test Dummy outline against the lower front of the sensor as shown in Figures 5 and 6.
4. Place the sensor on the track's flat straightaway on the table or floor so that the front of the sensor is exactly 34 cm from the far end of the track. It is extremely important to place the sensor at this same spot for every trial. Mark this spot by writing "Crash Site" with a line below it on a piece of tape and securing the piece of tape next to the track so that the line on the piece of tape is exactly 34 cm from the far end of the track (See Figure 7)



Figure 5 - Packing peanut attached to sensor



Figure 6 - Pedestrian Crash Test Dummy attached to packing peanut on sensor



Figure 7 - Crash site marked at 34 cm from far end of track



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Part C. Measuring Baseline Crash Pulses of Unmodified Cars

1. Place the toy car near the top of the track so its front end is at the starting line, 23cm above the tabletop/floor.
2. Find the “Start” recording button on the screen of your computing device (e.g., tablet, smartphone, or laptop). Press the “Start” button to begin data recording.
3. Release the toy car.
4. Press the “Stop” button to end data recording after the simulated collision.
5. Record the value displayed at the peak of the crash pulse as a negative number in the “Acceleration” column next to Trial #1 in Data Table 1.
6. Repeat Steps 1-5 for at least 5 trials.
7. After one of the trials, draw a copy of the crash pulse graph produced by the sensor’s software in the Data Table below (or if possible, take a screen shot and save the file to your class’s online document storage folder).
8. After all trials are completed, calculate the average of all of the accelerations recorded for all of your simulated collisions and record the average in the bottom of the Acceleration column.

Data Table 1. Baseline Crash Pulses of Unmodified Cars

TRIAL	ACCELERATION (g)	CRASH PULSE GRAPH FROM TRIAL # _____
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
AVG		



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CRASH SCIENCE IN THE CLASSROOM

PROJECT PEDESTRIAN

Day 2 - Measuring Crash Pulses of Cars with Modified Bumpers



NOTE: Before designing and testing your modified toy car bumpers, assemble your Pedestrian Crash Test Track Assembly exactly as it was constructed on Day 1. Then, when instructed to by your teacher, collect the modified bumper design building materials listed below.

DAY 2 MATERIALS NEEDED

For each group of 2-3 students

- » 2 cotton balls
- » 2 cotton squares
- » 2 pipe cleaners
- » 3 plastic drinking straws
- » 2 pre-cut pieces of dish sponge
- » 1 quarter-sized lump of soft clay or Play-doh®
- » 3 foam packing peanuts
- » 1 pre-cut square of plastic bubble wrap

Engineering Challenge Rationale

Most struck pedestrians are hit by the front of a passenger vehicle. Most serious injuries result from pedestrians hitting vehicle bumpers, hoods, or the windshield area.

Engineering Design Challenge

Using the building materials provided, follow the design parameters below to design, build, test, redesign, and re-test a bumper attached to a toy car’s front-end to reduce the crash decelerations (measured in g’s) between the toy car and a pedestrian crash test dummy in a simulated collision.

Design Parameters

- » Bumpers cannot touch or interfere with the car’s wheels.
- » Bumpers cannot touch the track.
- » Nothing may be added to the track or sensor to slow the car.
- » Building materials may only be selected from those provided by the teacher.
- » You do not have to use all of the bumper construction materials provided.

Part D. Brainstorm, Design, and Build Modified Bumpers

1. Brainstorm ideas with your partners to design a bumper from the materials provided that reduces the crash decelerations recorded on the pedestrian crash test dummy’s sensor in simulated collisions.
2. Draw your group’s car with modified bumper design in the space below and use labels to indicate the materials used to build the bumper.

CAR WITH MODIFIED BUMPER DESIGN



PROJECT PEDESTRIAN

Day 2 - Measuring Crash Pulses of Cars with Modified Bumpers



1. Briefly describe your team’s modified bumper and the reasoning behind your design and chosen materials. In other words, explain WHY you chose the particular design features and materials for your new bumper.

2. Build and attach the modified bumper to the car. If possible, take a picture of the car with the modified bumper and save the file to your class’s online document storage folder. Label the files with your group members’ names and class period. If your teacher requests, print a picture of the design to include with this activity sheet.

Part E. Test, Gather Data, and Analyze Modified Bumper Performance

1. Place the car with the modified bumper at same starting line height used for the Unmodified Car on Day 1.
2. Find the “Start” recording button on the screen of your computing device (e.g., tablet, smartphone, or laptop). Press the “Start” button to begin data recording.
3. Release the toy car.
4. Press the “Stop” button to end data recording after the simulated collision.
5. Record the value displayed at the peak of the crash pulse as a negative number in the “Acceleration” column next to Trial #1 in Data Table 2.
6. Repeat Steps 1-5 for at least 5 trials.
7. After one of the trials, draw a copy of the crash pulse graph produced by the sensor’s software in the Data Table below (or if possible, take a screen shot and save the file to your class’s online document storage folder).
8. After all trials are completed, calculate the average of all of the accelerations recorded for all of your simulated collisions and record the average in the bottom of the Acceleration column.

Data Table 2. Crash Pulses with Modified Bumper

TRIAL	ACCELERATION (g)	CRASH PULSE GRAPH FROM TRIAL # _____
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
AVG		



PROJECT PEDESTRIAN

Day 2 - Measuring Crash Pulses of Cars with Modified Bumpers



- Based upon your observations and the recorded accelerations, what worked well and what did not work well in your modified bumper design?

Part F. Redesigning Modified Bumper Based on Observations and Data

- Based on your observations and data from Part E, redesign the bumper to improve its performance.
- Retest your new design by repeating Steps 1-8 above and complete Data Table 3.

Data Table 3. Crash Pulses with Redesigned Bumper

TRIAL	ACCELERATION (g)	CRASH PULSE GRAPH FROM TRIAL # ____
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
AVG		

- If possible, take a picture of the redesigned bumper and save the file to your class's online document storage folder. Label the file with your group members' names and class period. If your teacher requests, print a picture of each design to include with your activity sheet.



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CRASH SCIENCE IN THE CLASSROOM

PROJECT PEDESTRIAN

Day 3 - Analyzing Project Results and Investigating Real-World Pedestrian-Vehicle Crash Safety Data and Testing Protocols



Part G. Analyzing Test Results and Drawing Conclusions

Analysis Questions

1. Which of your group’s designs (original unmodified car, car with modified bumper, or car with redesigned bumper) was **most effective** at reducing crash decelerations in your simulated collisions? Support your conclusion with observations and data from your investigations.”

2. Watch the activity’s Conclusion video at classroom.iihs.org/project-pedestrian. After your class review of the concepts of momentum, impulse, impact force, and impact time that were covered in your previous crash-related activities, use all four of these terms to explain how your group’s modified or redesigned bumper decreased (or tried to decrease) the impact force during the impact with the pedestrian.

Crash Questions - Investigating Real-World Crash Data and Testing Protocols

Pedestrian Deaths at Intersections

Traffic engineering improvements at intersections and mid-block crossings can reduce pedestrian crashes. For example, special warning signs and pavement markings can be used to encourage pedestrians to look for turning vehicles. Likewise, for drivers, rapid-flashing beacons at crossings can draw their attention to pedestrians.

Examine the data table in Figure 9 on pedestrian deaths at intersections and answer the following questions:

1. Rank the four age-groups (from most to least) by the percentage of deaths that occurred at intersections.



PROJECT PEDESTRIAN

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- If you were a traffic engineer, describe an improvement you could make to intersections to possibly reduce the fatalities in the age-group with the highest percentage of deaths at intersections.

PEDESTRIAN DEATHS BY OCCURRENCE AT INTERSECTION AND AGE, 2018										
	< 13 years		13 - 19 years		20 - 69 years		≥ 70 years		Total*	
	Number	%	Number	%	Number	%	Number	%	Number	%
Non-intersection	130	83	187	75	3,820	78	533	60	4,721	75
Intersection	27	17	64	25	1,091	22	357	40	1,562	25
Total*	157	100	251	100	4,911	100	890	100	6,283	100

*Total includes other and/or unknowns, data from the U.S. Department of Transportation's Fatality Analysis Reporting System

Figure 9

Automatic Emergency Braking System Tests

Reducing pedestrian crashes is the goal of the IIHS tests of vehicle automatic emergency braking (AEB) systems. These systems bring the vehicle to a safe stop, or reduce its speed, before a pedestrian is struck. The tests address three common pedestrian crash scenarios.

- Closely examine the drawings in Figure 10 depicting three IIHS pedestrian crash test scenarios. With your partner, identify and discuss the similarities and differences between these three scenarios using the following criteria:
 - The driver's ability to see the pedestrian (i.e., examine the driver's line of sight, look for anything blocking the driver's view of the pedestrian)
 - The height of the pedestrian crash-test dummy
 - The speed of the vehicle
 - The direction of pedestrian's motion compared to the road (i.e., pedestrian is walking parallel to the road, pedestrian walks perpendicular to the road)

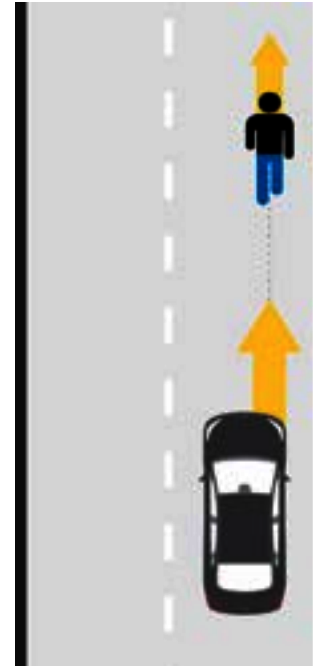
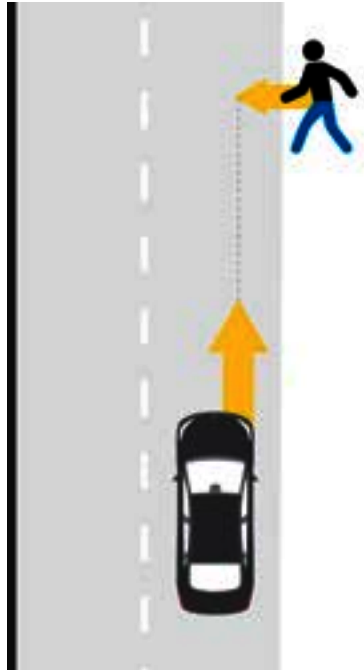
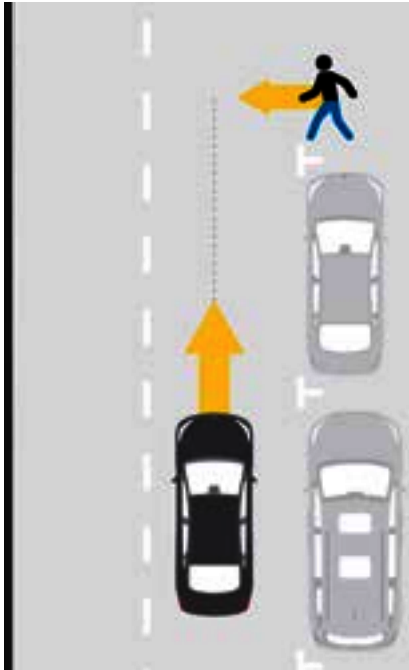


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Day 3 - Analyzing Project Results and Investigating Real-World Pedestrian-Vehicle Crash Safety Data and Testing Protocols



IIHS Pedestrian Crash Test Scenarios for AEB Systems



Scenario 1

Perpendicular child: Child runs into road; a parked car and SUV obstruct the view — tests run at 12 and 25 mph

Scenario 2

Perpendicular adult: Adult walks across road — tests run at 12 and 25 mph

Scenario 3

Parallel adult: Adult in right lane near edge of road, facing away from traffic — tests run at 25 and 37 mph

Figure 10

- a. Based on your observations of these three scenarios and what you have learned about the physics of pedestrian-vehicle collisions, if you were an automotive engineer responsible for designing effective AEB systems, which scenario would you consider the most challenging for the AEB system to detect and brake in time to avoid a collision with a walking pedestrian? CIRCLE ONE:

Scenario 1

Scenario 2

Scenario 3

- b. Refer to the positions of the pedestrians and vehicles as well as the additional data provided for the scenarios to justify your answer.

Four horizontal lines for student response.

Additional crash test data:
» Child dummy is 45-inches tall (114 cm)
» Adult dummy is 6-feet tall (1.83 m)
» 12 mph = 19.3 km/h
» 25 mph = 40.2 km/h
» 37 mph = 59.5 km/h