TEACHER LESSON PLAN

EGG CRASH! ~~DESIGNING A COLLISION SAFETY DEVICE~~

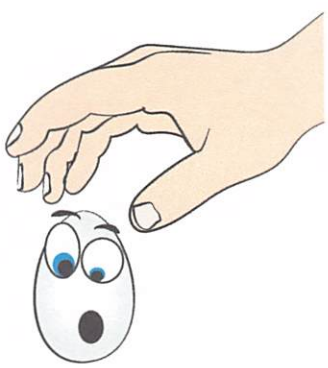
ENGINEERING A CRASH CUSHION

DEFINITIONS

momentum: the inertia of moving objects; product of the mass and the velocity of an object (p = mv)

impulse: product of force and time interval during which the force acts (F x t); impulse equals change in momentum, Ft=Δ(mv)

**For complete NGSS Performance Expectations, please download the Full Standards Alignment PDF from the ~~IIHS -HLDI in the classroom~~ homepage.* Crash Science in the Classroom



Key Question(s)

- How do people survive major vehicle collisions?
- How do the laws and principles of physics demonstrate the effectiveness of seat belts and airbags?

Grade levels: 5–12
Time required: 50 minutes

Objectives

Students will:

- describe a collision in terms of changing momentum, impulse, impact force, and impact time.
- observe and document the effectiveness of safety devices such as seat belts and airbags by designing, building, testing, and evaluating a ~~safety device~~ to protect an egg during a collision, with a hard-surface. crash cushion

Next Generation Science Standards*

Motion and Stability: Forces and Interactions

- HS-PS2-1 HS-PS2-3, MS-PS2-2, 4-PS3-1

Engineering Design

- HS-ETS1-2, MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, 3-5-ETS1-1, 3-5-ETS1-2, 3-5ETS1-3

Background Information

When Newton described the relationship between force and inertia, he spoke in terms of two other physics concepts: momentum and impulse. Newton defined momentum as the product of an object's mass and velocity (see "Momentum Bashing"). Newton defined impulse as the quantity needed to change an object's momentum.

To change an object's momentum, the mass of the object, the velocity of the object, or both have to change. If the velocity of an object increases (accelerates) while its mass remains constant, its momentum also increases. In his second law, Newton said that in order to accelerate (or decelerate) a mass, a force must be applied. This notion is often expressed using the equation F=ma. A force "F" is needed to move a mass "m" with an acceleration of "a." The greater the force applied to an object, the greater its acceleration (i.e., the greater its change in velocity) and the greater its change in momentum.

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MATERIALS NEEDED

For each group of 2-3 students

» 10 sheets of 8.5" x 11" copier paper
» One meter of masking tape
» One pair of scissors
» One raw, grade A medium or large egg (plus a few extra for accidental breakage before testing!)
» **OPTIONAL:** One plastic "Easter" egg for conducting practice "dry" runs with the collision safety devices

Per Student

» One copy of the "Egg Crash! Designing a Collision Safety Device" Student Activity Sheet

For the entire class

» 15-20 sheets of newspaper
» Two to three meter sticks
» One stepladder (2 meters/6 feet tall)
» Hard-surfaced floor, walkway, or playing surface (e.g., basketball court)

Background Information (continued)

In addition to changing momentum by changing the amount of force applied to a moving object, changing the amount of time a force acts on an object also changes momentum. Applying the brakes briefly to a moving vehicle slightly reduces its momentum. Applying the same braking force over an extended period of time greatly reduces the vehicle's momentum. Similarly, slamming on the brakes of a moving vehicle for a short period of time reduces the vehicle's momentum much more than lightly tapping on the brakes for that same period of time. The product of a force and the time it is applied to an object is called impulse. Impulse is mathematically represented as impulse = force x time interval

The greater the impulse exerted on a moving object, the greater its change in momentum. The amount of damage/injury that occurs in a collision is directly related to the impulse of a collision. Lengthening the time during which a "stopping" force is applied to a vehicle (and its occupants) in a collision reduces the final "net" force acting on the vehicle and its occupants when they finally come to a stop. Seat belts and airbags are examples of two major safety features that apply these laws of physics to reduce injuries in collisions. Both features help lengthen the amount of time between when the stopping force is first applied to a vehicle (e.g., crashing a car head-on into a wall) and when the occupants inside the car actually collide with the dashboard, steering wheel, or other vehicle structure.

Advance Preparation

» Assemble sets of collision safety device building supplies (paper, masking tape, scissors, and plastic eggs, if available) for each group. Set raw eggs aside until it is time for actual collision safety device testing.
» Select and prepare a "crash site" to test students' devices by spreading newspaper on the floor to cover an area of approximately one square meter. Place the meter sticks and a ladder next to the "crash site."
» Watch the activity's Introduction and Conclusion videos at classroom.iihs.org/egg-crash and decide if you want to incorporate them into the lesson.
» For additional lesson advice, watch the Teacher Tips video for this activity located under the Teacher tab at classroom.iihs.org/egg-crash

Safety Considerations

» Scissors can cut skin. Caution students to direct sharp edges or points away from themselves and others.
» Follow all general stepladder safety procedures. See the safety notes attached to the ladder or osha.gov.
» Make sure students wash their hands thoroughly with soap and water after handling raw eggs, especially if they crack or break.

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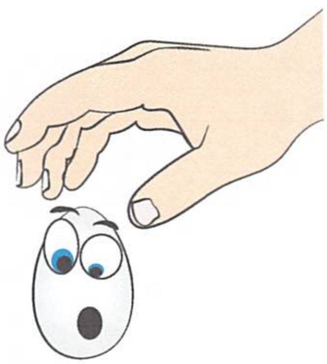

Procedure

1. Ask the following engagement question: If you were running, tripped and knew you were going to fall, would you rather fall on hard concrete floor or soft grass? Why?

2. Ask students to share any personal experiences they have had or stories they have heard about people surviving major vehicle collisions with little to no personal injury. Then ask them how they think people are sometimes able to survive and walk away from major vehicle collisions. Students will often describe such survivors as "lucky." Now, ask students if they really think surviving a major vehicle crash is just luck or if it is determined by the laws of physics.

3. Explain that scientists and engineers regularly use and apply the laws of physics in order to design vehicle structures and added features in order to minimize the physical damage to vehicles and injury to vehicle occupants in the event of a collision. Tell students that, as part of the engineering design process, scientists and engineers often build models to simulate collisions and test the potential effectiveness of different vehicle safety designs and added safety features. Explain that during this activity, students will be working in groups to design, build, test, and evaluate the effectiveness of a "~~collision safety device~~" (landing pad) to protect a raw egg during a collision with a hard surface (floor). "Crash Cushion"

4. Divide students into groups and distribute all collision safety device building supplies (except raw eggs) and worksheets. Refer to the worksheet and review the Key Questions, the Purpose of the activity, and the Did You Know? information. Optional: Show the activity's Introduction video.

5. Review the Design Challenge, Engineering Design Parameters, and Procedure for the activity. Encourage groups to conduct test runs of their devices using plastic "Easter" eggs if available. Remind groups that their ~~safety device~~ crash cushion must protect their raw egg from repeated collisions from increasing heights (i.e., greater momentum). Also emphasize the fact that even a slight crack in their egg represents an injury and will disqualify them from the next round of competition. Finally, remind them that they are also disqualified if their egg is damaged from bouncing or rolling out of their landing pad once it lands.

6. Refer to the worksheet and instruct groups to complete the two "Pre-Testing" Analysis Questions together as a group (i.e., a drawing and description of their completed device.)

7. Allow groups 20 minutes to build and test their devices with plastic eggs only. After the design/testing time limit has expired, bring everyone to the testing area and distribute a raw egg to each group.

   Do not allow any pre-testing of devices using actual raw eggs!

8. Before testing, have each group make a brief 30-second to 1-minute "sales pitch" for their ~~safety device~~ crash cushion explaining the rationale for their design and why they think it will protect the egg. Next, determine the order of testing for the devices or ask groups to volunteer. Finally, before beginning actual testing, ask students to predict which ~~safety device~~ crash cushion they think will win and why.

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Procedure (continued)

9. Complete all groups' test drops for Round 1 before beginning Round 2 with groups whose devices were successful in Round 1. Continue this cycle, increasing the drop height by 0.5 meters in each round, until you reach a drop height at which only one ~~safety device~~ crash cushion is successful and is declared the winner. Follow the Safety Considerations for ladder use and remind students to wash their hands thoroughly after handling raw or broken eggs. (NOTE: Occasionally, especially at greater heights, all remaining groups will be eliminated in the same round. In this case, declare a tie for all of the groups who were successful at the PREVIOUS round's drop height and determine the winner based on the device that was made with the least amount of paper.)

The suggested drop heights for Rounds 1-4 are: 1.0 m, 1.5 m, 2.0 m, 2.5 m.

10. After the winning ~~Collision Safety Device~~ crash cushion has been determined, clean up the test area and have groups bring their landing pads back to the classroom for further analysis. Use the Background Information provided to discuss/review the key physics concepts and principles illustrated in this simulation (momentum, impulse, impact force, and impact time). Make sure students understand the relationships between these concepts and review formulas as needed. Optional: Show the activity's Conclusion video.

11. Instruct students to work collaboratively with their group members to answer the "Post-Testing" Analysis Questions and conduct a whole-class discussion of responses. Make sure students realize that, in addition to airbags and seat belts, other important vehicle collision safety features that have been developed by applying these same physics concepts and principles include: frontal crumple zones, padded dashboards, bumpers, and collapsible steering columns.

Answers to Analysis Questions

1. Overall, which types of ~~Collision Safety Device~~ Crash Cushion features were the <u>most</u> and <u>least</u> effective in this simulation and why?

Answers will vary, but typically, the most successful devices have one or more of the following key design features:

- *Wide landing pad area to compensate for errors in aiming/sighting eggs*
- *High sides to keep eggs from bouncing or rolling out. Wide-mouthed "funnel" designs often work especially well.*
- *Increased distance between the top landing pad surface and the floor to make sure the egg does not fall or push all the way through the landing pad and make contact with the floor, especially when dropped from greater heights.*
- *Sturdy support structures to withstand multiple drops*
- *Layers of crumpled paper, rolled paper tubes, or other air-filled areas to increase impact time.*
- *Flexible landing pads that have some "give" when struck by the falling egg (similar to falling on soft grass rather than hard concrete).*

2. As the drop height increased with each round, the amount of momentum the eggs experienced in their collisions with the landing devices also increased. Identify at least 2 ~~Collision Safety Device~~ crash cushions design features that were especially important/useful for successful drops of eggs from greater heights (i.e., collisions with greater momentum).

Answers will vary, but any design feature that helped increase impact time (slow the egg down gradually) and reduce the impact force would reduce the egg's momentum.

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Answers to Analysis Questions (continued)

3. **Often, even groups with well-designed and soundly-constructed Collision Safety Devices are not successful when eggs are dropped from greater heights. Identify at least 2 other reasons egg drops from greater heights are more challenging regardless of the quality of the landing pad.**

   "Operator error" increases dramatically as drop heights increase. Smaller "targets" are harder to line up with the eggs as the distance between the egg and the landing pad increases and it is harder to hold/release eggs so that they drop straight down from greater heights.

4. **After your class discussion/review of the concepts of momentum, impulse, impact force, and impact time, use all four of these terms to explain how your group's ~~Collision Safety Device~~ Crash Cushion could be modified to better simulate the safety benefits of vehicle airbags.**

   To safely bring the egg to a stop, the device must decrease the egg's momentum during the collision by providing an impulse, which is the product of two variables —impact force x impact time. The more the device "slows down" (i.e., increases the impact time of) the collision, the smaller the final impact force on the egg will be. Airbags increase impact time and result in less injury because they stop occupants by applying a smaller impact force over a larger time interval compared to the large impact force experienced by vehicle occupants who have nothing to slow down the time between the initial crash of the vehicle and their body's crash into the steering wheel, dashboard, window, or other component inside the vehicle.

5. **Compare the impulses, impact forces, and impact times in the following two scenarios:**
   A. Speeding Race Car #1 comes to a stop by hitting the wall of the track head on.
   B. Speeding Race Car #2 comes to a stop by skidding a great distance and scraping its side along the wall of the track

   Assuming both cars have equal momentum before the crash, both race cars experience the SAME impulse or change in momentum when they come to a stop. Race Car #1 experiences a big impact force ("big" F) over a short impact time ("little" t) while Race Car #2 experiences a small impact force (little" f) over a longer time of impact ("big" T).

6. **According to the National Highway Traffic Safety Administration, thousands of people are alive today because of the addition of airbags to vehicles that contain seat belts. Explain why airbags alone are NOT safe alternatives to seat belts, but instead are to be used along WITH seat belts to prevent or reduce injury.**

   Designed to work with seat belts, airbags provide additional protection, especially to people's heads and chests, in serious crashes. In cases of sudden, hard braking or other violent maneuvers before a crash, the seat belts keep people in an upright position against the seat back which allows space for the airbags to inflate between the occupants and the hard interior surfaces.

Extension

Have students visit the IIHS.org website to investigate how air bags work and how automakers are finding new ways to integrate airbags into vehicles. To find information on airbags, ask students to select "Airbags" from the TOPICS drop-down menu located at the top of the IIHS.org site.