“CRASH COURSE” ACTIVITY

Egg Crash!
Designing a Collision Safety Device

Key question(s)
• How do people survive major collisions?
• How does physics explain the effectiveness of seat belts and airbags?

Grade levels: 9–12
Time required: 50 minutes

Objectives
Students will:
• describe a collision in terms of momentum changes and impulse
• design, build, test, and evaluate a safety device to protect an egg during a collision

National Science Education Standards
Standard A: Science as Inquiry
• Identify questions and concepts that guide scientific investigations
• Design and conduct scientific investigations

Standard B: Physical Science
• Motion and forces

Standard E: Science and Technology
• Abilities of technological design
• Understanding about science and technology

Standard F: Science in Personal and Social Perspectives
• Natural and human-induced hazards

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 Lesson #2). Newton defined impulse as the quantity needed to change an object’s momentum.

To change an object’s momentum either the mass or the velocity or both change. If the mass remains constant, then the velocity changes and acceleration occurs. In his second law, Newton said in order to accelerate (or decelerate) a mass, a force must be applied. The way it’s often expressed is with the equation \( F = ma \). The force “\( F \)” is what’s needed to move mass “\( m \)” with an acceleration “\( a \)” The greater the force on an object, the greater its acceleration, or the greater its change in velocity, and therefore, the greater its change in momentum. How long the force acts is also important. Apply the brakes briefly to a coasting car and you produce a change in its momentum. Apply the same braking force over an extended period of time and you produce a greater change in the car’s momentum. So to change something’s momentum both force and time are important. The product of force and the time it is applied is called impulse.

\[ \text{impulse} = \text{force} \times \text{time interval} \]
The greater the impulse exerted on an object, the greater its change in momentum. The amount of damage in a collision is related to the time during which the force stopped the object. Seat belts and airbags stop occupants with less damage by applying a small force over a large time interval.

Materials needed
For each group:
• copier paper, 10 sheets (8 1/2"x11")
• masking tape, 1.0 meter
• scissors, one pair

For the Egg-Crash Tests:
• eggs, one raw, grade A, medium or large egg per team (1–2 dozen)
• newspaper, 15–20 sheets
• meter sticks, (2–3)
• ladder, 2 meters tall (approx. 6 ft.)
• hard-surfaced floor, walkway, or playing surface (e.g. basketball court)

Getting ready
Separate paper into stacks of 10 sheets each. Prepare a “crash site” to test students’ projects by spreading newspaper on the floor to cover an area approximately one square meter. Place a ladder next to the “crash site.”

Procedure
1. Ask students to think about how people survive major vehicle collisions. Explain that scientists and engineers apply the laws of physics to reduce damage to both cars and passengers. Explain that during this activity, students will be working in groups to design, build, test, and evaluate a “safety device” (in the form of a landing pad) to protect a raw egg during a collision with a hard surface (floor).
2. Divide students into groups of two or three and distribute paper (10 sheets per group), masking tape (1 meter per group) and scissors to each group.
3. Review “Collision Safety Device” or landing pad design, building, and testing parameters with students (see “Egg Crash!” Student Activity Sheet #3). Remind students that their device must protect the egg from repeated collisions, with each experiencing a greater change in momentum.
4. Allow students 20 minutes to build their devices. Distribute eggs to students after the time limit has expired. Do not allow any pre-testing of devices.
5. Determine the order in which teams are to drop or ask for teams to volunteer. Complete drops for round one before beginning round two with surviving eggs.  
*Suggested drop heights for rounds:* 1.0 m, 1.5 m, 2.0 m, 2.5 m.

6. Before beginning the final round, conduct a brief whole-class discussion addressing the following questions:

- **Which device do you predict to win and why?**
  
  *Answers will vary. Challenge students to relate the functioning of the devices to similar situation from their prior experience. Students may refer to interactions in which one object has more "give" than another. For example: falling on grass rather than concrete; or, when jumping from an elevated position down to the ground, bending your knees when your feet make contact with the ground instead of keeping your legs straight.*

- **Why does a surface with more “give,” like their Collision Safety Device, produce a safer fall?**
  
  *To bring the egg to a stop, the floor or the paper device must provide an impulse, which involves two variables—impact force and impact time. Since impact time is longer on the paper device, a smaller impact force results. The shorter impact time on the floor results in a greater impact force.*

7. After the superior Collision Safety Device has been determined, have students complete the Analysis and Crash Questions.

**Answers to crash questions**

1. Explain how your Collision Safety Device is similar to an airbag in preventing injuries. Use the terms momentum, impulse, impact force, and impact time in your response.

   *To bring the egg to a stop, the paper device must change the egg’s momentum by providing an impulse, which involves two variables—impact force and impact time. Since impact time is longer on the paper device, a smaller impact force results. The shorter impact time on the floor results in a greater impact force. Airbags stop occupants with less damage by applying a small force over a large time interval.*

2. Compare the impulses, impact forces, and impact times of the following: Race Car #1 crashes to a stop by hitting a wall head on; Race Car #2 crashes to a stop by skidding a great distance along a wall.

   *Assuming both cars have equal momentum before the crash, both race cars experience the SAME impulse or change in momentum since they both crash to a stop. Race Car #1 experiences a big impact force over a short impact time. Race Car #2 experiences small impact force over a longer time of impact.*

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3. List other vehicle safety devices that reduce the impact force by increasing the time of impact.
   frontal crumple zones, padded dashboards, bumpers, collapsible steering columns

4. According to the National Highway Traffic Safety Administration thousands of people are alive today because of their airbags. Explain why airbags are NOT alternatives to seat belts but rather are intended to be used WITH seat belts to increase safety.
   Designed to work with seat belts, airbags provide additional protection, especially to people’s heads and chests, in serious crashes. If there is hard braking or other violent maneuvers before the crash, the lap/shoulder belts keep people in position where there is still space for the airbags to inflate between the occupants and the hard interior surfaces. Belts also provide important protection in nonfrontal crashes. According to the Insurance Institute for Highway Safety, deaths in frontal crashes of cars with airbags are reduced by about 26 percent among drivers and 14 percent among passengers.

Extension(s)
1. Have students explore the Insurance Institute for Highway Safety’s website (www.highwaysafety.org) to answer the following questions about airbags:
   • How serious does a frontal crash have to be for an airbag to inflate?
   • Are there any problems with airbags?
   • Can they injure people? How? Who is at greatest risk?
   • Should people at risk get an on/off switch for their airbags?
2. Have students videotape (either live or from television), explain, and present sequences that illustrate various interactions that effectively reduce the force by increasing the time.

Possible interactions:
   • bungee jumping
   • circus trapeze safety net
   • boxing match (see Figure 1)
   • egg toss into a bed sheet (see video, have two students hold a sagging bed sheet while another student throws an egg into the sheet)
   • egg toss game (wearing lab aprons and safety goggles, pairs of students toss eggs back and forth at successively greater distances; unbroken egg caught at greatest distance wins. Note: record for Mr. Jones’ classes is 31 m.)
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Crash test question(s)
• How do people survive major collisions?
• How does physics explain the effectiveness of seat belts and airbags?

Purpose
• To design, build, test, and evaluate a landing pad or "safety device" to protect an egg during a collision with a hard surface
• To describe a collision in terms of changing momentum, impulse, impact force, and impact time

Materials needed
For each group of two or three students:
• copier paper, 10 sheets (8 1/2" x 11")
• masking tape, 1.0 meter
• scissors, one pair

Discussion
How do people survive major vehicle collisions? Scientists and engineers apply the laws of physics to reduce damage to both cars and passengers. During this activity, you will work in groups to design, build, test, and evaluate a "collision safety device" (in the form of a landing pad) to protect a raw egg during a collision with a hard surface. Hopefully, this process will help you discover the physics underlying some of the "EGGcellent" safety devices in a car!

Procedure
Using no more than 10 sheets of paper, one meter of masking tape and following the parameters listed on the back of this sheet, design, build, and test a landing pad/"collision safety device" that will protect an egg when dropped from ever increasing heights.
EGG “Collision Safety Device” Parameters

1. Groups may use less, but no more than 10 sheets of paper.
   - Report to the teacher the amount of paper used to build your safety device. In the event of a tie, the device constructed with fewest sheets of paper will be declared the superior safety device.

2. Collision Safety Devices must be free-standing. Teams cannot support their devices by holding them or taping them to another structure.

3. Nothing may be attached to the egg.

4. Scissors may not be part of the Collision Safety Device.

5. Dropping height is measured from the bottom of the egg, at the release point, to the top of the Collision Safety Device.

6. Eggs will be dropped by a member of the Device’s design team.

7. Eggs that miss the Collision Safety Device when dropped are eliminated.

8. Eggs will be inspected before and after each drop and must not show any cracks.
   - Eggs that survive the initial impact but roll off their device and break are eliminated.
   - Teams that break their egg by accident or carelessness are eliminated.

9. In order to simulate car collisions with greater momentum the eggs will be dropped from successively greater heights (1.0 m, 1.5 m, 2.0 m, 2.5 m)

10. Devices must be completed within the time limit of 20 minutes.
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Analysis

1. Draw a large diagram of your Collision Safety Device in the space below.

2. Describe your team’s Collision Safety Device, the reasoning behind your design, and its performance during the various collisions. Refer to your diagram.

Crash questions

1. Explain how your Collision Safety Device is similar to an airbag in preventing injuries. Use the terms momentum, impulse, impact force, and impact time in your response.
More crash questions

2. Compare the impulses, impact forces, and impact times of the following: Race Car #1 crashes to a stop by hitting a wall head on; Race Car #2 crashes to a stop by skidding a great distance along a wall.

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4. Explain why airbags are not alternatives to seat belts but are intended to be used with seat belts to increase safety.

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