Stretch the Stop

Use test evidence to refine a collision bumper.

HS-PS2-3 "Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision..."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline the variables held constant, circle features that lengthen the collision, and write E beside evidence used to evaluate or refine the bumper.

A Bumper for a Camera Crate

1. A robotics team needed to protect a 4.0 kg camera crate when its delivery cart accidentally struck a rigid stop. The cart approached at 2.0 m/s and stopped, so the crate's momentum changed by 8.0 kg·m/s. Because average force equals change in momentum divided by collision time, the team focused on making the stop take longer. Their first bumper used a thin foam pad. It compressed quickly, and high-speed video showed that the collision lasted 0.018 s. A force sensor recorded a sharp peak, while the crate remained attached to the cart during impact.

2. To make a fair comparison, the team kept the crate mass, approach speed, rigid stop, and cart path the same. They replaced the thin pad with a bumper containing foldable cardboard honeycomb cells behind a thicker foam face. The foam began the contact gently, and the cells crushed in stages instead of stopping the cart at once. In the second trial, video showed a 0.052 s collision. Since both trials had the same momentum change, a longer stopping time should produce a smaller average force. The sensor trace also had a lower, broader peak.

3. The revised bumper reduced force, but the team still evaluated whether it protected the crate under realistic conditions. After five trials at the planned speed, the camera stayed aligned and the crate showed no cracks. However, one honeycomb section did not fully recover after a collision. The team chose a refinement, not a final claim: test several cell-wall thicknesses and replaceable inserts. A successful version must keep the collision time long, limit damage, and be practical for repeated use. Testing at a higher speed would be a separate condition, because it would change the momentum that the bumper must manage.

2 ANSWER WITH EVIDENCE

Use the passage

1. What four variables did the team keep the same to make the bumper comparison fair?

2. Use Favg = Δp/Δt to calculate the average force magnitude for each trial. The momentum change was 8.0 kg·m/s in both trials.

3. How did the thicker foam face and honeycomb cells help minimize force on the crate?

4. What evidence showed that the revised bumper was promising, and what evidence showed that it still needed refinement?

3 YOUR TURN

Your own words

A 6.0 kg model satellite rides on a cart that stops after hitting a wall at 1.5 m/s. Propose a device that could minimize the force, describe a fair test against a basic foam pad, state what evidence you would collect, and name one refinement you would make if the first design has a problem.

ANSWER KEY

Stretch the Stop

HIGH SCHOOL · HS-PS2-3

PART 1 · READ AND MARK

Underline the variables held constant, circle features that lengthen the collision, and write E beside evidence used to evaluate or refine the bumper. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	What four variables did the team keep the same to make the bumper comparison fair?	**They kept the crate mass, approach speed, rigid stop, and cart path the same.**
2	Use Favg = Δp/Δt to calculate the average force magnitude for each trial. The momentum change was 8.0 kg·m/s in both trials.	**First bumper: 8.0 ÷ 0.018 ≈ 440 N. Revised bumper: 8.0 ÷ 0.052 ≈ 154 N.**
3	How did the thicker foam face and honeycomb cells help minimize force on the crate?	**They made the collision last longer. The foam started contact gently, and the honeycomb cells crushed in stages, reducing the average force.**
4	What evidence showed that the revised bumper was promising, and what evidence showed that it still needed refinement?	**The camera stayed aligned, the crate had no cracks, and the sensor trace had a lower, broader peak. One honeycomb section did not fully recover after a collision.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I would mount the satellite on a sliding tray with a controlled friction brake and a foam end stop. For a fair test, I would send the same 6.0 kg cart into the same wall at 1.5 m/s and compare the tray with a basic foam pad using video and a force sensor. If the cart stops, its momentum change is 9.0 kg·m/s, so a longer stopping time should lower average force. I would look for a lower peak force, longer collision time, and no satellite damage. If the tray reaches its end stop too sharply, I would increase its sliding distance and test again.

Accept equivalent controlled variables, force calculations rounded reasonably, and explanations that connect a longer collision time to lower average force when momentum change is the same. For the open task, accept varied devices if the student includes a fair comparison, measurable evidence, and a refinement linked to a test result.