Bumper Design Lab

Use momentum and contact time to evaluate a cart model

PHS.5.6 "Use an engineering design process and mathematical analysis to design and construct models to demonstrate the law of conservation of momentum (e.g., roller coasters, bicycle helmets, bumper systems)."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Circle the masses, speeds, and contact times needed for calculations, then underline the team's design goal.

A Softer Stop?

1. A team designs a bumper to protect a cargo cart from sudden contact. Their model uses two 0.50 kg carts on a low-friction track. Cart A moves right at 2.0 m/s, and cart B starts at rest. They compare foam and magnetic bumpers. The goal is to reduce the average force on B.

2. Momentum equals mass times velocity, and rightward velocity is positive here. To check conservation, add both carts' momenta before contact and again afterward. If external forces are negligible, these totals should match. The table records final speeds and contact times from idealized model trials. Each trial begins with the same masses and starting speeds.

RESULTS OF TWO BUMPER TRIALS

Bumper	A after (m/s)	B after (m/s)	Contact time (s)
Foam	0.4	1.6	0.20
Magnetic	0.0	2.0	0.05

3. A longer contact can lower average force, but the momentum change must also be considered. Average force magnitude equals the change in one cart's momentum divided by contact time. The team uses video to measure speed and a timer to estimate contact time. After comparing the bumpers, they can change the material or thickness and test again.

2 ANSWER WITH EVIDENCE

Use the passage

1. Calculate the total momentum of the two carts before contact.

2. Calculate the total momentum after contact with the foam bumper. Does it match the starting total?

3. Calculate the total momentum after contact with the magnetic bumper. Does it match the starting total?

4. Calculate the average force on cart B in each trial. Which bumper best meets the team's goal?

3 YOUR TURN

Your own words

Design a third bumper for the same carts. Name its material, predict both final speeds and a contact time, show that total momentum is conserved, calculate the average force on B, and explain how you would build and test it.

ANSWER KEY

Bumper Design Lab

HIGH SCHOOL · PHS.5.6

PART 1 · READ AND MARK

Circle the masses, speeds, and contact times needed for calculations, then underline the team's design goal. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	Calculate the total momentum of the two carts before contact.	**(0.50 kg)(2.0 m/s) + (0.50 kg)(0 m/s) = 1.0 kg·m/s rightward.**
2	Calculate the total momentum after contact with the foam bumper. Does it match the starting total?	**(0.50)(0.4) + (0.50)(1.6) = 1.0 kg·m/s rightward. It matches.**
3	Calculate the total momentum after contact with the magnetic bumper. Does it match the starting total?	**(0.50)(0.0) + (0.50)(2.0) = 1.0 kg·m/s rightward. It matches.**
4	Calculate the average force on cart B in each trial. Which bumper best meets the team's goal?	**Foam: (0.50 × 1.6)/0.20 = 4 N. Magnetic: (0.50 × 2.0)/0.05 = 20 N. Foam produces the lower average force.**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I would attach a thicker foam pad to cart A and test it on the same track. I predict A will move right at 0.6 m/s and B at 1.4 m/s after 0.35 s of contact. Their final momentum would be (0.50)(0.6) + (0.50)(1.4) = 1.0 kg·m/s, matching the starting total. B's average force would be (0.50 × 1.4)/0.35 = 2 N. I would use video to check both speeds and the contact time.

Accept correct calculations with consistent units and rightward direction. For the design task, accept other plausible bumpers and predictions if the final momentum totals 1.0 kg·m/s and the force calculation uses B's change in momentum.