Family edition

Robot Soccer Lab: Head-On, Momentum Before and After a Collision

Ages 14-18 · about 45 minutes, in one sitting

In Robot Soccer Lab your child crashes a soccer robot into a ball, on purpose, and shows with the numbers that momentum is the same before and after.

What you need

- A computer or Chromebook with a current browser.
- The link: mytekdev.com/try/robotsoccerlab?lesson=head-on-momentum-before-and-after-a-collision&ref=fam-robotsoccerlab-4. No account, no email and nothing to install.
- A calculator.

Before you start: try it once yourself

Open mytekdev.com/try/robotsoccerlab?lesson=head-on-momentum-before-and-after-a-collision&ref=fam-robotsoccerlab-4. A short guide opens over Level 12, Head-on, with the program in the Python tab.

1. **The rounds.** Three rounds of 3 seconds. Each puts the robot 35 cm (center to center) behind a resting ball and lets it drive. Rounds 1 and 2 use the golf-size ball, 0.046 kg; round 3 the big ball, about 0.14 kg. robot.time() says which round it is: under 3 seconds is round 1.
2. **The table.** In the box, one row a round: the robot's speed before and just after the hit, the ball's speed after, and the momentum before and after, in kg m/s. Under it, the robot's mass: 1.387 kg for the starter robot.
3. **The program.** If the time is under 3, move at angle 0 speed 40; else move at angle 0 speed 40. Speed 40 is 0.40 m/s. The referee wants rounds 1 and 2 at least 0.2 m/s apart, so the starter fails with "the same speed twice" and still shows the table.
4. **Speed.** Each level starts in real time. Speed up and Slower, under the field, change the speed; the round play button starts the level again from the beginning, with the program as it is now.
5. **Numbers to expect.** 40 then 80: round 1, 0.40 to 0.38, ball 0.58, momentum 0.55 and 0.55. Round 2, 0.80 to 0.76, ball 1.16, 1.11 and 1.11. Round 3, the big ball, 0.80 to 0.69, ball 1.09, 1.11 and 1.11. 30 then 60: 0.42, then 0.83 and 0.83. 50 then 100: 0.69, then 1.39 and 1.39. These do not change from run to run.

> The numbers depend on the robot's mass, which comes from its parts in Robot, Configurator. A robot with the kicker taken off weighs 1.227 kg (40 then 80: 0.49, 0.98, 0.98); with a dribbler added, 1.457 kg (0.58, 1.17, 1.17). Before and after still match. If one child's numbers differ from a neighbor's, check the mass under the table first. After each hit the robot keeps driving and may touch the ball again; only the first hit of each round goes in the table.

The ideas, in plain words

In a collision the two objects push on each other with equal and opposite forces for the same short time, so the momentum one loses the other gains. With no net force from outside the system, the total momentum is conserved. The robot's wheels push on the carpet too, but over the instant of the hit that push is tiny next to the collision, so robot plus ball is a system with no net force for that moment.

The collision is not elastic: in the app the ball leaves faster than the robot by half the robot's speed before the hit (a coefficient of restitution of 0.5, a classroom value, not a measurement). Momentum is conserved; kinetic energy is not. The golf-size ball's 46 g is the weight of a golf ball of its size; the big ball's 141 g, with its batteries, is our estimate.

Robot soccer has led to real companies: Raffaello D'Andrea, who coached Cornell's robot soccer team, went on to co-found Kiva Systems, whose warehouse robots Amazon bought in 2012. Robotics, mechanical, electrical and software engineers all work on robots like these.

Do it together

1. Open mytekdev.com/try/robotsoccerlab?lesson=head-on-momentum-before-and-after-a-collision&ref=fam-robotsoccerlab-4 and press play. Read the box on the field.

   > **You'll know it worked when:** "The same speed twice": the level wants two different speeds. A table shows the three hits.

2. Open `Python`, change the second 40 to 80, go back to `Simulator` and press play.

   > **You'll know it worked when:** Three head-on hits, and a table of speeds before and after.

3. Work out round 1 yourself: momentum before = 1.387 x 0.40; after = 1.387 x 0.38 + 0.046 x 0.58.

   > **You'll know it worked when:** Both about 0.55 kg m/s, as the table says.

4. Compare rounds 2 and 3: how much did the robot slow down for each ball?

   > **You'll know it worked when:** From 0.80 to 0.76 for the small ball, and to 0.69 for the big one: about three times as much, for a ball about three times as heavy.

5. Change 40 and 80 to 30 and 60. Before pressing play, work out the momentum before each hit.

   > **You'll know it worked when:** 1.387 x 0.30 is 0.42 and 1.387 x 0.60 is 0.83, and the table agrees, before and after.

Talk about it

Ask these while you work together. A child who has understood it can answer them without help:

- Why is all the momentum before the hit the robot's?
- In round 2, how much momentum did the robot lose, and where did it go?
- Why did the big ball slow the robot more than the small one?
- Why are the robot's speeds the same in rounds 2 and 3 before the hit, but different after?
- If the robot were heavier, what would change in the table, and what would not?

> The second question is the one that matters. A child who says "1.387 x 0.04 is about 0.054, and the ball gained 0.046 x 1.16, about 0.053" has supported the claim with numbers. A child who says "they match" has the result but not the idea.

For younger and older kids

Younger: For a younger child, read the momentum columns in the table instead of calculating, and talk about why the totals match.

Older: For an older child, work out the energy, half m v squared, before and after, and see that it is not kept.

Keep going

- Open Robot, Configurator and take the kicker off (the robot becomes 1.227 kg). Predict the momentum before the 80 hit, then run it.
- Calculate the kinetic energy (half m v squared) before and after round 2. Is it conserved? What does that say about this collision?
- The ball always leaves faster than the robot by half the robot's speed before the hit. Use that and momentum to predict both speeds after a hit at 60.

Bring it into other subjects

- Math: graph the ball's speed after the hit against the robot's speed before, for four speeds. What is the slope?
- Engineering: why do real teams keep their robots under the 1.5 kg limit, and what would a heavier robot gain in a push?
- Sports: find how a golf club's mass and speed affect the ball's speed off the tee.
- Careers: look up crash testing for cars, where engineers measure momentum and forces in collisions.

For your records

Ready to copy into an hour log, a portfolio or a transcript.

LESSON	Robot Soccer Lab: Head-On, Momentum Before and After a Collision
SUBJECTS	Physical science
TIME	45 minutes
WHAT WE DID	Ran simulated head-on collisions between a robot and two balls, calculated momentum before and after each, and used the data to show that total momentum is conserved.
SKILLS PRACTICED	Momentum; Using data to support a claim; Making and testing a prediction

Activity sheet (optional)

Name: _____ Date: _____

Open the app: scan the QR code, or go to mytekdev.com/try/robotsoccerlab?lesson=head-on-momentum-before-and-after-a-collision

Essential question: When a robot hits a ball, what stays the same?

Warm-up: A bowling ball hits a ping-pong ball, then a soccer ball. Which slows it more?

_____

1. **Vocabulary.** Momentum, system, conserved, collision, head-on, mass: write each in your own words.

2. **Masses.** Robot: _____ kg. Golf-size ball: 0.046 kg. Big ball: about 0.14 kg (an estimate).
3. **Data.** Round 1: robot before ____ after ____, ball after ____. Round 2: ____ ____ ____. Round 3 (big ball): ____ ____ ____.

4. **My calculations.** Momentum before and after, in kg m/s. Round 1: _____ and _____. Round 2: _____ and _____. Round 3: _____ and _____. The robot slowed by _____ in round 2 and _____ in round 3.

5. **My prediction.** New speeds ____ and ____. Predicted momentum before each hit: _____ and _____. The table said: _____ and _____.

1. What stayed the same in every hit, and how do your numbers show it?

2. Why did the big ball slow the robot about three times as much?

Quick check

Name: _____

1. A 2 kg cart moving at 0.5 m/s has a momentum of: (A) 0.25 kg m/s (B) 1 kg m/s (C) 2.5 kg m/s

2. Before a hit the robot has 1.11 kg m/s and the ball is at rest. After the hit the total momentum is: (A) 0 (B) 1.11 kg m/s (C) more than 1.11

3. A friend says the robot lost momentum in the hit, so momentum was not conserved. Use what you learned today to answer.

Answers

QUESTION	ANSWER	WHY
1	B	2 x 0.5 = 1 kg m/s.
2	B	With no net force on the robot and the ball, the total is the same before and after.
3	Open answer	The robot lost momentum, but the ball gained exactly that much: the total for the system is the same, 1.11 before and after.

If your state or umbrella school asks, this lesson covers NGSS HS-PS2-2.

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The app this lesson uses is free and runs in the browser, with nothing to install and no account needed. It is at mytekdev.com.

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