Intro to Momentum Tutorial

9 April 2020

An important physical quantity, the name of which we'll give later, corresponds to the intuitive idea of *oomph*. The more oomph something has, the harder it is to stop, and the more ability it has to knock other things over. Let's figure out the formula for oomph.

A small pebble and a larger rock are thrown at the same speed.

- **Which one has more oomph?**

- **Why?**

The rock is twice as massive as the pebble.
Intuitively,

how does the rock's oomph compare to the pebble's oomph?

- **Is it twice as big? Half as big? Three times as big?**

Picture two identical bowling balls, one of which is rolling faster than the other.

- **Which ball, the faster or slower one, has more oomph?**

- **Why?**

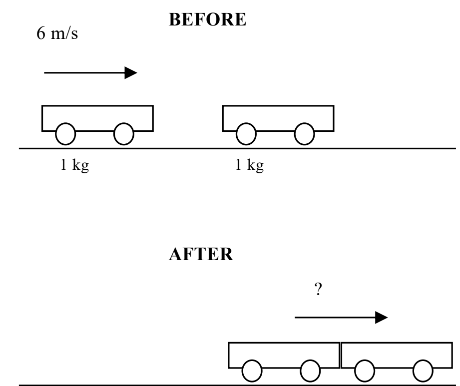
Picture two identical bowling balls, one of which is rolling faster than the other.
The faster ball is exactly 7 times as fast as the slower one.

- **Intuitively, how does the faster ball’s oomph compare to the slower ball’s oomph?**

The physics concept corresponding to oomph is *momentum*. Building on your above answers, figure out a formula for momentum (oomph) in terms of mass and velocity. Explain how the formula expresses your intuitions from prior slides. (For nutty historical reasons, physicists use the letter *p* for momentum.).

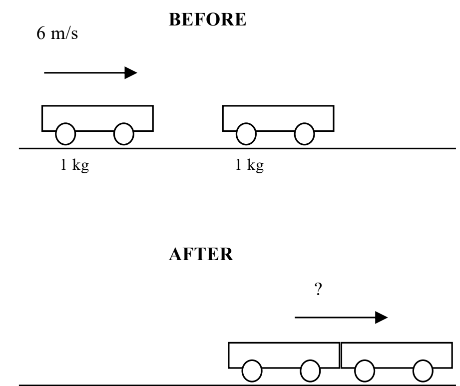
A 1 kg cart, rolling with negligible friction at 6 meters per second, collides with and sticks to an identical cart. So, after colliding, the carts roll together as a single unit.

- ***Using your intuitions*, guess the post-collision speed of the two carts. Briefly explain your reasoning.**



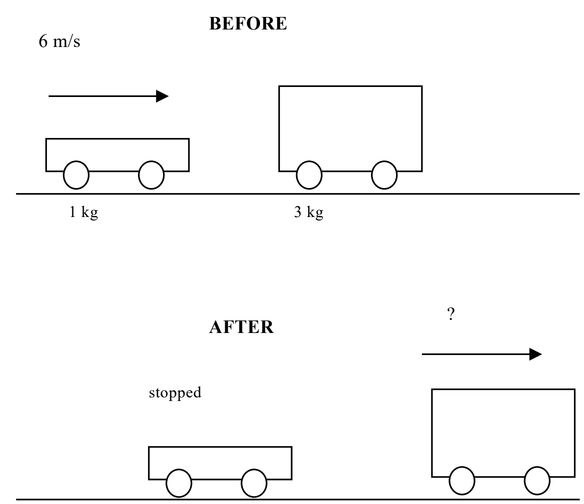
According to the intuitive guess you just made, is the overall momentum of the two-cart system after the collision greater than, less than, or equal to the overall momentum before the collision?

- **Work this out using the momentum formula you figured out above and plugging in the relevant numbers.**



In a similar experiment, the 1 kg cart collides with a 3 kg cart but doesn’t stick to it. Instead, the 3 kg cart gets knock forward by the 1 kg cart, which comes to rest after the collision.

- **Again using intuitions, guess the post-collision speed of the 3 kg cart.**



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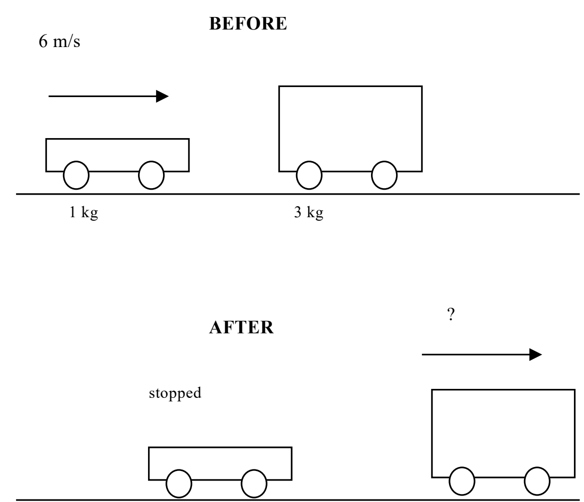
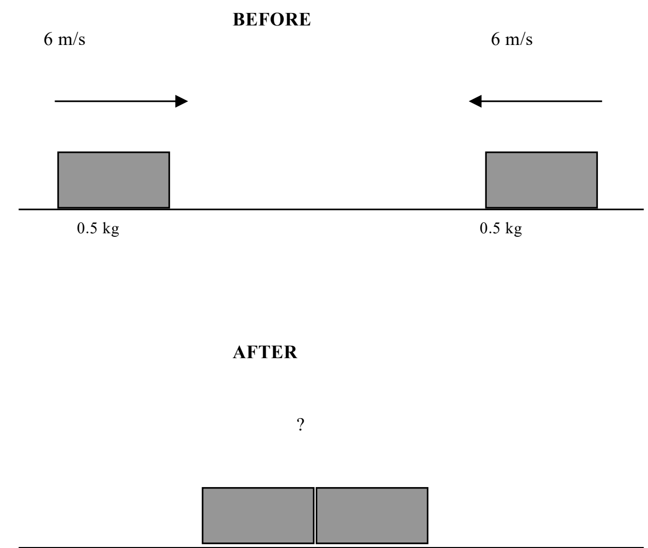


Based on your work above, state a general rule about how the total momentum of a system changes during a collision.

Two identical blocks, both of mass 0.5 kg and covered with Velcro™, slide toward each other at equal speeds, 6 m/s. The blocks stick together.

- ***Intuitively*, after the collision, how fast do the blocks move and in what direction?**



Does direction of motion matter?

- Can we create a “conservation of momentum” statement?

- *Conservation of momentum* is a fundamental physical law. Among other things, it says that when two objects collide, the total momentum of the system immediately after the collision equals the total momentum of the system immediately before the collision:

$$\Sigma\overrightarrow{p_i} = \Sigma\overrightarrow{p_f}$$

- Since momentum is proportional to mass times velocity, and velocity depends on direction, momentum is also a vector with a direction – the same one as the velocity direction.
- Therefore, a negative "oomph" can partially or fully cancel a positive "oomph", like the Velcro block example.

On a safety test course, a 1000 kg car heading north at 5 m/s collides head-on with an 800 kg car heading south at 4 m/s. At these low speeds, the new high-tech bumpers prevent the cars from crumpling; they bounce off each other. After the bounce, the 1000 kg car is heading southward at 1 m/s. We're going to ask you for the post-collision speed and direction of motion of the other car.

- What's a good first step, after drawing a sketch and writing down the known and unknown variables?
- Before doing the math, what is your "guess" for the final direction of motion of the lighter car?

Now calculate the lighter car’s speed and direction of motion after the collision.

When is momentum conserved?

- This is discussed in the book, or in the pre-lecture video.

When is momentum conserved?

- Define the system.
- What forces are acting on the system?
  - What forces are internal?
  - What forces are external?
- If forces are internal, then total momentum of the system is conserved.
- If forces are external, total momentum of the system is not conserved.

Projectile motion: is momentum conserved?

- We shoot a cannon that is aimed 30 degrees above horizontal.
- As the cannonball flies through the air (after being shot) is momentum conserved:
  - In the x-direction?
    - How do we know?
  - In the y-direction?
    - How do we know?

- What about while the cannon is shooting the cannonball?