Name _____ **period** _____ **date** _____

POGIL: Conservation of Momentum

Purpose

To explore the cause of conservation of momentum and its role in collisions.

Part 1: Impulse and Momentum

We'll start with a few reminders about forces, impulse, and momentum. The momentum of an object is simply its mass times its velocity. We can write this as an equation:

$$\textbf{momentum} = \textbf{mass} \times \textbf{velocity or } p = mv,$$

where m is the object's mass and v is its velocity. Remember that momentum also includes the direction of motion of the object.

The impulse that acts on an object is the average force times the time that the average force acts on the object. We can write this as an equation:

$$\textbf{impulse} = \textbf{average force} \times \textbf{time or } J = Ft,$$

where F is the average force and t is the time. Impulse also includes the direction that the object is pushed by the average force.

The *impulse-momentum* theorem tells us that the impulse acting on an object is equal to its change in momentum:

$$\textbf{impulse} = \textbf{change in momentum or } Ft = \Delta mv = mv_{final} - mv_{initial}.$$

Remember that the change in a quantity is always the final amount minus the initial amount. The impulse-momentum theorem also tells us that the direction of the impulse is the same as the direction of the change in momentum.

Critical Thinking Questions, part 1

The picture below shows a collision about to happen between two railroad cars. Car #1 has a mass of 2000 kg and is traveling to the right at 4 m/s, while the car #2 has a mass of 1000 kg and is traveling to the left at 2 m/s. Assume friction is negligible.

1. What is the initial magnitude and direction of the momentum of car #1?

2. What is the initial magnitude and direction of the momentum of car #2?

3. What is the magnitude and direction of the momenta of both cars combined?

Now the cars collide and stick together after the collision, as shown in the picture below.

4. As the cars collide, suppose car #1 experiences an average force of impact of 40,000 N for 0.1 s.
    a. What is the direction of this force?

    b. What is the magnitude and direction of the impulse on car #1?

    c. What is the magnitude and direction of the change in momentum of car #1?

    d. What is the magnitude and direction of the force of impact on car #2?

    e. What is the magnitude and direction of the impulse on car #2?

    f. What is the magnitude and direction of the change in momentum of car #2?

5. Use your answer to questions 4c to determine the momentum of car #1 after the collision.

6. Use your answer to questions 4f to determine the momentum of car #2 after the collision.

7. What is the magnitude and direction of both cars combined after the collision? Compare your answer to the one you obtained in question 3.

Part 2: Conservation of Momentum

A *system* is a collection of objects that interact with each other. For example, in part 1 we worked with a system that consisted of two railroad cars. Objects within a system may exert forces on each other; since these forces are due to objects that are part of the system, we refer to them as *internal forces*. If forces are exerted on the system by objects outside of it, we refer to those forces as *external forces*. Notice that in part 1 there were no *net* external forces on the system, and we discovered a very special result.

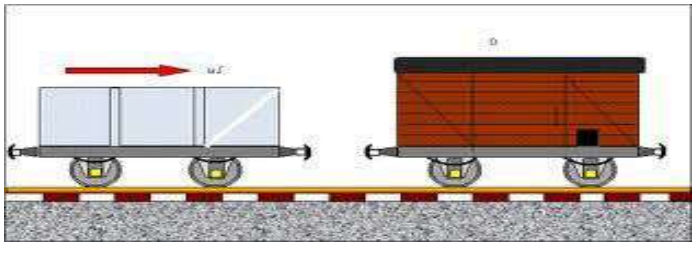
The Law of Conservation of Momentum states the following:

If there are no net external forces on a system, then the total momentum of that system is constant.

This means that for collections of objects colliding with each other, as long as there is no net external force, the objects may exchange momentum with each other but the total momentum will remain constant.

Critical Thinking Questions, part 2

Here is another picture of two railroad cars colliding. Car #1 has a mass of 1500 kg and is moving to the right with a speed of 3 m/s. Car #2 has a mass of 1000 kg and is at rest.



8. What is the initial magnitude and direction of the momentum of car #1?

9. What is the initial magnitude and direction of the momentum of car #2?

10. What is the magnitude and direction of the total momentum of the system consisting of both railroad cars?

Now the railroad cars collide and stick together after the collision, as shown in the picture below.

11. What is the magnitude and direction of the total momentum of the system *after* the collision?

12. What is the speed of the railroad cars after the collision?

13. Which car experienced the greater change in velocity? What property of the car explains why it experienced the greater change?

Conclusions

Write a paragraph in clear, complete sentences that addresses the following questions:

- During a collision between two objects of equal mass:
  - which one experiences the greater force of impact? Justify your answer.
  - which one experiences a greater impulse? Justify your answer.
  - which one experiences a greater change in momentum? Justify your answer.
  - which one experiences a greater change in velocity? Justify your answer.
- How can momentum be conserved during a collision between two objects when one of the objects is clearly changing its momentum?