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Topic: Rocketry
Code: HF61324

other words, the momentum of ball A plus the momentum of ball B before the collision is equal to the momentum of ball A plus the momentum of ball B after the collision.

$$\mathbf{p}_{A,i} + \mathbf{p}_{B,i} = \mathbf{p}_{A,f} + \mathbf{p}_{B,f}$$

This relationship is true for all interactions between isolated objects and is known as the *law of conservation of momentum.*

CONSERVATION OF MOMENTUM

$$m_1\mathbf{v}_{1,i} + m_2\mathbf{v}_{2,i} = m_1\mathbf{v}_{1,f} + m_2\mathbf{v}_{2,f}$$

total initial momentum = total final momentum

For an isolated system, the law of conservation of momentum can be stated as follows:

The total momentum of all objects interacting with one another remains constant regardless of the nature of the forces between the objects.

Momentum is conserved in collisions

In the billiard ball example, we found that the momentum of ball A does not remain constant and the momentum of ball B does not remain constant, but the total momentum of ball A and ball B does remain constant. In general, the total momentum remains constant for a system of objects that interact with one another. In this case, in which the table is assumed to be frictionless, the billiard balls are the only two objects interacting. If a third object exerted a force on either ball A or ball B during the collision, the total momentum of ball A, ball B, and the third object would remain constant.

In this book, most conservation-of-momentum problems deal with only two isolated objects. However, when you use conservation of momentum to solve a problem or investigate a situation, it is important to include all objects that are involved in the interaction. Frictional forces—such as the frictional force between the billiard balls and the table—will be disregarded in most conservation-of-momentum problems in this book.

Momentum is conserved for objects pushing away from each other

Another example of conservation of momentum occurs when two or more interacting objects that initially have no momentum begin moving away from each other. Imagine that you initially stand at rest and then jump up, leaving the ground with a velocity **v.** Obviously, *your* momentum is not conserved; before the jump, it was zero, and it became $m\mathbf{v}$ as you began to rise. However, the total momentum remains constant if you include Earth in your analysis. The total momentum for you and Earth remains constant.

If your momentum after you jump is 60 kg•m/s upward, then Earth must have a corresponding momentum of 60 kg•m/s downward, because total

Why it Matters

Conceptual Challenge

1. Ice Skating

If a reckless ice skater collides with another skater who is standing on the ice, is it possible for both skaters to be at rest after the collision?

2. Space Travel

A spacecraft undergoes a change of velocity when its rockets are fired. How does the spacecraft change velocity in empty space, where there is nothing for the gases emitted by the rockets to push against?