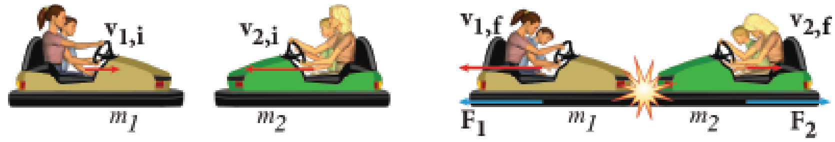
Figure 8
During the collision, the force exerted on each bumper car causes a change in momentum for each car. The total momentum is the same before and after the collision.



$\mathbf{F_1}$ is the force that m_2 exerts on m_1 during the collision, and $\mathbf{F_2}$ is the force that m_1 exerts on m_2 during the collision, as shown in **Figure 8.** Because the only forces acting in the collision are the forces the two bumper cars exert on each other, Newton's third law tells us that the force on m_1 is equal to and opposite the force on m_2 ($\mathbf{F_1} = -\mathbf{F_2}$). Additionally, the two forces act over the same time interval, Δt. Therefore, the force m_2 exerts on m_1 multiplied by the time interval is equal to the force m_1 exerts on m_2 multiplied by the time interval, or $\mathbf{F_1}\Delta t = -\mathbf{F_2}\Delta t$. That is, the impulse on m_1 is equal to and opposite the impulse on m_2. This relationship is true in every collision or interaction between two isolated objects.

Because impulse is equal to the change in momentum, and the impulse on m_1 is equal to and opposite the impulse on m_2, the change in momentum of m_1 is equal to and opposite the change in momentum of m_2. This means that in every interaction between two isolated objects, the change in momentum of the first object is equal to and opposite the change in momentum of the second object. In equation form, this is expressed by the following equation.

$$m_1\mathbf{v_{1,f}} - m_1\mathbf{v_{1,i}} = -(m_2\mathbf{v_{2,f}} - m_2\mathbf{v_{2,i}})$$

This equation means that if the momentum of one object increases after a collision, then the momentum of the other object in the situation must decrease by an equal amount. Rearranging this equation gives the following equation for the conservation of momentum.

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

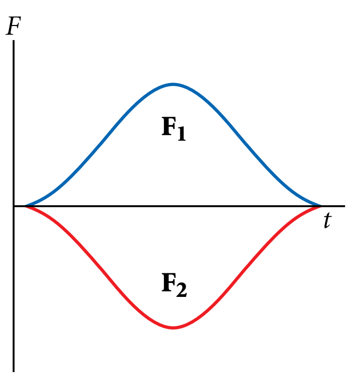


Figure 9
This graph shows the force on each bumper car during the collision. Although both forces vary with time, $\mathbf{F_1}$ and $\mathbf{F_2}$ are always equal in magnitude and opposite in direction.

Forces in real collisions are not constant during the collisions

As mentioned in Section 1, the forces involved in a collision are treated as though they are constant. In a real collision, however, the forces may vary in time in a complicated way. **Figure 9** shows the forces acting during the collision of the two bumper cars. At all times during the collision, the forces on the two cars at any instant during the collision are equal in magnitude and opposite in direction. However, the magnitudes of the forces change throughout the collision—increasing, reaching a maximum, and then decreasing.

When solving impulse problems, you should use the average force over the time of the collision as the value for force. Recall that the average velocity of an object undergoing a constant acceleration is equal to the constant velocity required for the object to travel the same displacement in the same time interval. The time-averaged force during a collision is equal to the constant force required to cause the same change in momentum as the real, changing force.