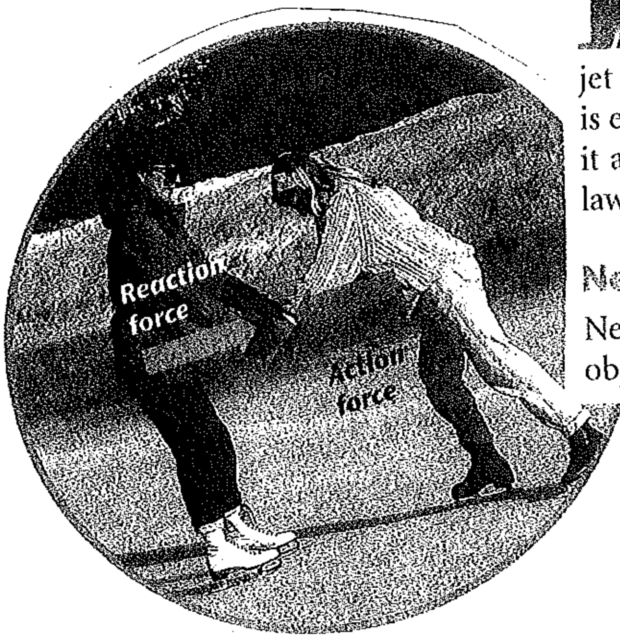
Action and Reaction



Imagine that you are an astronaut making a space walk outside your space station. In your excitement about your walk, you lose track of time and use up all the fuel in your jet pack. How do you get back to the station? Your jet pack is empty, but it can still get you back to the station if you thr... it away. To understand how, you need to know Newton's thi... law of motion.

Newton's Third Law of Motion

Newton realized that forces are not "one-sided." Whenever one object exerts a force on a second object, the second object exerts a force back on the first object. The force exerted by the second object is equal in strength and opposite in direction to the first force. Newton called one force the "action" and the other force the "reaction." **Newton's third law of motion states that if one object exerts a force on another object, then the second object exerts a force of equal strength in the opposite direction on the first object.**

Equal but Opposite You may already be familiar with examples of Newton's third law of motion. Perhaps you have watched figure skaters and have seen one skater push on the other. As a result, both skaters move—not only the skater who was pushed. The skater who pushed is pushed back with an equal force, but in the opposite direction.

The speeds with which the two skaters move depend on their masses. If they have the same mass, they will move at the same speed. But if one skater has a greater mass than the other, she will move backward more slowly. Although the action and reaction forces will be equal and opposite, the same force acting on a greater mass results in a smaller acceleration. Recall that this is Newton's second law of motion.

Now can you figure out how to return from your space walk? In order to get a push back to the space station, you need to push on some object. You can remove your empty jet pack and push it away from you. In return, the jet pack will exert an equal force on you, sending you back to the safety of the space station.

Action-Reaction in Action Newton's third law is in action all around you. When you walk, you push the ground with your feet. The ground pushes back on your feet with an equal and opposite force. You go forward when you walk because the ground is pushing you! A bird flies forward by exerting a force on the air with its wings. The air pushes back on those wings with an equal force that propels the bird forward.

Integrating Life Science A squid applies Newton's third law of motion to move itself through the water. The squid exerts a force on the water that it expels from its body cavity. At the same time, the water exerts an equal and opposite force on the squid, causing it to move.

On a sunny afternoon you are baby-sitting for two boys who love wagon rides. You soon find that they enjoy the ride most if you accelerate quickly. They shout "Faster, faster!" and after a few minutes you sit down in the wagon to catch your breath. The smaller boy takes a turn pulling, but finds that he can't make the wagon accelerate nearly as fast as you can. How is the acceleration of the wagon related to the force pulling it? How is the acceleration related to the mass of the wagon?

Newton's Second Law of Motion

Newton's second law of motion explains how force, mass, and acceleration are related. **The net force on an object is equal to the product of its acceleration and its mass.** The relationship among the quantities force, mass, and acceleration can be written in one equation.

$$Force = Mass \times Acceleration$$

People often refer to this equation itself as Newton's second law of motion.

As with any equation, you must pay attention to the units of measurement. When acceleration is measured in meters per second per second (m/s^2) and mass is measured in kilograms, force is measured in kilograms × meters per second per second ($kg \cdot m/s^2$). This long unit is called the newton (N), in honor of Isaac Newton. One **newton** equals the force required to accelerate one kilogram of mass at 1 meter per second per second.

$$1\ N = 1\ kg \times 1\ m/s^2$$

A student might have a mass of 40 kilograms. Suppose she is walking, and accelerates at $1\ m/s^2$. You can easily find the force she exerts by substituting mass and acceleration into the equation. You find that 40 kilograms × $1\ m/s^2$ is 40 newtons.

Sometimes you may want to write the relationship among acceleration, force, and mass in a different form.

$$Acceleration = \frac{Force}{Mass}$$

This form is found by rearranging the equation for Newton's second law.