# Laws of Motion

## Newton's Laws of Motion

In the mid 1660s, Sir Isaac Newton formulated the three laws of motion. These laws explain how forces affect the motion of all objects. Even today, Newton's laws of motion remain the basis for understanding the motion of objects.

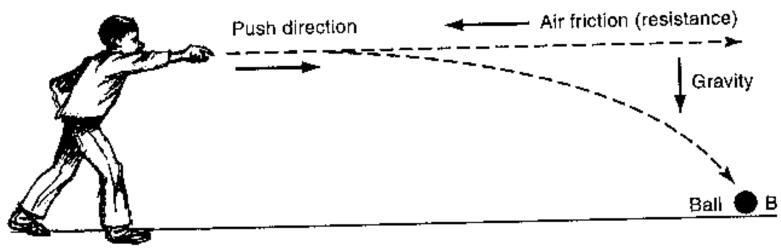


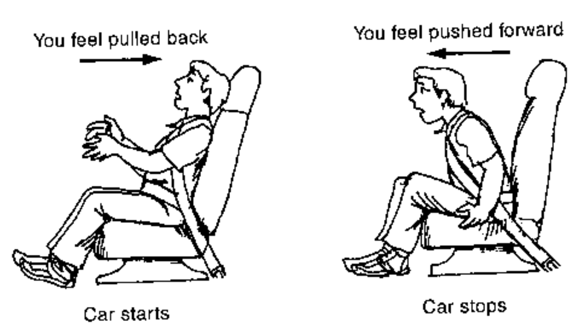

***Figure 10-4.*** *Air friction is the force that slows the ball and gravity pulls the ball back to Earth.*

## First Law of Motion

The ***first law of motion*** states that **an object at rest will remain at rest and an object in motion will remain in motion, unless an outside force acts on the object.** There are two parts to this law. First, any object at rest will not move unless some force acts on it. An empty garbage can will remain at the curb or a dead leaf will remain on the front lawn until some force moves it. The force that moves the garbage can may be a person, and the wind may be the force that blows the leaf away. Second, any moving object will continue to move in the same direction, at the same speed, until a force acts on the object to change its speed or direction. A thrown baseball will move in a straight line at a constant speed until another force affects it. The force of air friction will decrease the speed of the ball, and the force of gravity will change the direction of the ball by pulling it down toward Earth (see Figure 10-4).

The tendency of an object at rest to remain at rest or an object in motion to remain in motion is called ***inertia***. In other words, inertia is the tendency of an object to resist any change in its motion. The more massive an object is, the greater its inertia, or the greater it will resist a change in motion. When you are riding in a moving car that stops suddenly, your body continues to move forward. Also, when you are seated in a parked car that suddenly accelerates, you feel your body move backward. When a car stops, your moving body resists the stopping action. When a car accelerates, your body resists being put in motion (see Figure 10-5).

***Figure 10-5.*** *The first law of motion: Objects resist a change in motion—an effect you can feel in a starting or stopping car.*



## *Second Law of Motion*

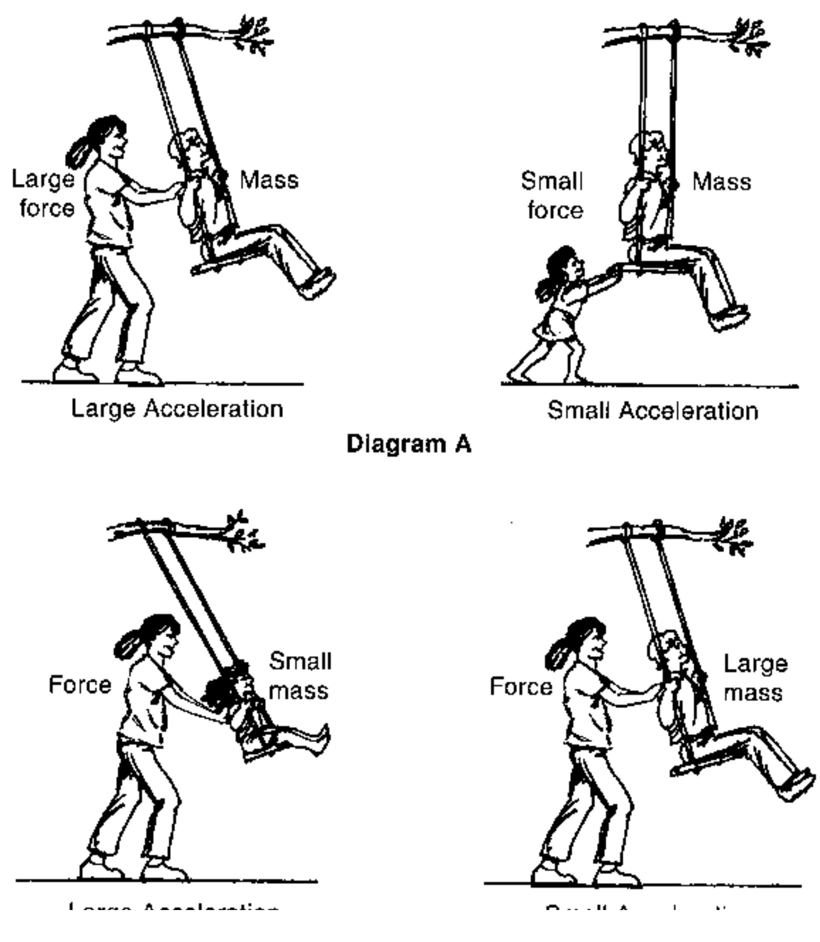
The ***second law of motion*** states **the relationship among force, mass, and acceleration**. The law is commonly expressed by the formula:

$$\text{acceleration} = \frac{\text{Force}}{\text{mass}}, \text{ or } a = \frac{F}{m}$$

A large force acting on a given mass will cause a greater acceleration on that mass than a small force. For example, a mother (large force) pushing her husband (given mass) on a swing will cause a greater acceleration than their daughter (small force) pushing her father. (Figure 10-6A)

Also, a small mass acted on by a given force will have a greater acceleration than a large mass. A mother (given force) pushing her daughter (small mass) will cause a greater acceleration than the mother pushing the husband (large mass). (Figure 10-6B)

***Figure 10-6.*** *(A) A large force pushing a given mass will cause a greater acceleration than a small force. (B) A small mass pushed by a given force will experience a greater acceleration than a large mass.*



# Laboratory Skill

## Using Math to Analyze Data

Newton's second law of motion states the relationship among force, mass, and acceleration. This relationship is expressed by the following formula:

$$\text{Force} = \text{mass} \times \text{acceleration, or } F = m \times a$$

The following chart shows six mathematical examples of how the formula is applied.

| | *Acceleration (meters/second/second)* | *Force (newtons)* | *Mass (kilograms)* |
|---|---|---|---|
| Example 1 | 1 | 1 | 1 |
| Example 2 | 2 | 20 | 10 |
| Example 3 | 1 | 10 | 10 |
| Example 4 | 1 | 20 | 20 |
| Example 5 | 0.5 | 10 | 20 |
| Example 6 | 2 | *X* | 50 |

***QUESTIONS***

1. If the mass of a body remains the same and the force moving it is doubled, then the body's acceleration is doubled. Which two examples in the chart above demonstrate this?
2. If the force remains the same but the body is replaced with an object whose mass is twice that of the body, then the acceleration
   (1) is doubled
   (2) is halved
   (3) remains the same
   (4) is equal to mass
3. In Example 6 in the chart, the unknown force *X* would be
   (1) 50 newtons
   (2) 100 newtons
   (3) 150 newtons
   (4) 52 newtons
4. According to the chart, a newton is
   (1) a force that will move 1 kg at 1 meter/second/second
   (2) a force that will move 20 kg at 10 meters/second/second
   (3) a force that will move 10 kg at 20 meters/second/second
   (4) a measure of mass

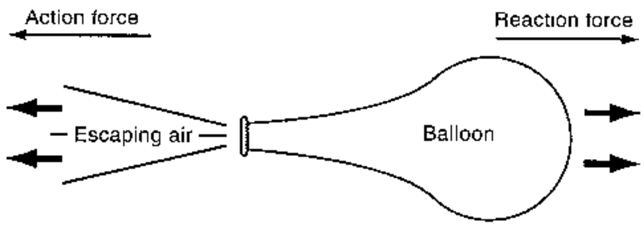



***Figure 10-7.*** *The third law of motion: every action has an equal and opposite reaction.*

## Third Law of Motion

The ***third law of motion*** states that **for every action there is an equal and opposite reaction**. A simple demonstration of blowing up a balloon and letting it go shows how this law works. When the air is released from the balloon, the balloon moves in the opposite direction (see Figure 10-7). Kicking a soccer ball, hot gases shooting out of a rocket engine, and walking are all actions that produce an equal and opposite reactive force.