2 Newton's Laws of Motion

TEKS 4(A), 4(C), 4(D)

What You'll Learn

- how inertia is related to Newton's first law
- how acceleration is calculated using Newton's second law
- how forces relate to Newton's third law

Before You Read

Imagine stepping off the bed of a pick up truck onto a platform. As you step you push against the truck bed. Now imagine stepping off of a skateboard with the same effort. What happens to the truck and the skateboard as you step off of them?

Focus →
Highlight the main point in each paragraph. Use a different color to highlight examples of the main point.

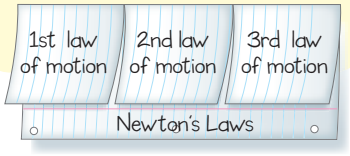
Read to Learn

Isaac Newton and the Laws of Motion

You have seen many examples of how forces change the motion of objects. Forces change the motion of objects in specific ways. The British scientist Sir Isaac Newton stated rules that describe the effects of forces on the motion of objects. These rules are known as Newton's laws of motion. They apply to all objects in motion, from billiard balls to planets orbiting the Sun.

FOLDABLES® Study Organizer

Find Main Ideas Make a three-tab book. Label it as shown. Use it to organize your notes as you read this section.



Newton's First Law of Motion

Newton's first law of motion states that an object moving at a constant velocity keeps moving at that velocity unless an unbalanced net force acts on it. An object at rest stays at rest unless a net force acts on it. Newton's first law of motion is sometimes called the law of inertia.

What is inertia?

Inertia is the tendency of an object to resist any change in its motion. If an object is moving, it will keep moving in a straight line at a constant speed until a force changes its direction or speed. Inertia causes an object to resist changes in direction and speed. A dirt bike will move in a straight line with a constant speed unless a force acts on it. A force can turn the wheel and change the direction. Another force, friction, can slow the speed of the bike. An object that is not moving also has inertia. It will remain motionless until an unbalanced force causes it to move.

Inertia and Mass The inertia of an object is related to its mass. The greater the mass is of an object, the greater its inertia is. A bowling ball has much greater mass than a table-tennis ball does. Therefore, a bowling ball has greater inertia than a table-tennis ball.

Imagine hitting a bowling ball with a table-tennis paddle. The bowling ball would not move very much. Imagine hitting a table-tennis ball with the same amount of force. The table-tennis ball would move quite easily.

Think it Over

1. **Compare** the inertia of a car to the inertia of a bicycle.

Newton's Second Law of Motion

Newton's second law of motion states that the net force acting on an object causes the object to accelerate in the direction of the net force. To find the acceleration of an object, you need to know its mass and the net force that is acting on it. The acceleration of an object can be found using the following equation.

$$\text{acceleration (in meters/second}^2) = \frac{\text{net force (in newtons)}}{\text{mass (in kilograms)}}$$

$$a = \frac{F_{net}}{m}$$

Suppose you are pushing a friend on a sled. The mass of your friend and the sled together is 70 kg. The net force on the sled is 35 N (kg m/s^2). Find the acceleration of the sled.

$$a = \frac{35\text{N}}{70\,\text{kg}} = 0.5\ \text{m/s}^2$$

The acceleration of the sled is 0.5 m/s^2.

Think it Over

2. **Define** What is Newton's second law of motion?

You read about Newton's first law of motion. The law says that the motion of an object changes only if an unbalanced force acts on it. Newton's second law of motion describes the relationship between the acceleration of an object, its mass, and the forces exerted on it.

How are force and acceleration related?

How are throwing a ball as hard as you can and tossing it gently different? When you throw the ball hard, you exert a much greater force on the ball than when gently tossing it. Therefore, the thrown ball has a greater velocity when it leaves your hand than it does when you toss it. The ball you throw hard has a greater change in velocity. And, the change in velocity happens over a shorter period of time.

Since acceleration is the change in velocity divided by the time it takes for the change to happen, throwing a ball harder has a greater acceleration because its velocity changes in a shorter time.

GET IT?

3. **Identify** You apply a force of 2 N to a toy car and to a real car. Which car has the greater acceleration? Why?

Apply Math

4. **Demonstrate** Show how multiplying both sides of the acceleration equation, $a = \frac{F_{net}}{m}$, by m results in the net force equation $F_{net} = ma$.

Are mass and acceleration related?

You would think that throwing a baseball and a softball as hard as you can, would give them the same speed. It does not because the softball has more mass. If the time to throw both balls is equal, the difference in mass affects the velocity, and therefore the acceleration. Thus mass and acceleration are related.

How can you find net force?

Using an object's mass and acceleration, you can use the formula for Newton's second law to calculate the net force. For example, a tennis ball touches the racket during a serve for only a few thousandths of a second. The ball accelerates in a very short time. Suppose the ball leaves the racket at a speed of 100 km/h and accelerates at 5,000 m/s^2. The ball's mass is 0.06 kg. Use this formula to find the force placed on the ball by the racket.

$$F_{net} = ma$$
$$F_{net} = (0.006 \text{ kg})(5{,}000 \text{ m/s}^2)$$
$$F_{net} = 300 \text{ kg m/s}^2 \quad F_{net} = 300 \text{ N}$$

Newton's Third Law of Motion

If you push against a wall while wearing in-line skates, you will roll backwards. The action of pushing against the wall produced a reaction—moving backward. This is an example of Newton's third law of motion.

Newton's third law of motion describes action and reaction. It states that when one object applies a force on a second object, the second object applies a force on the first object that is equal in strength and opposite in direction. In other words "to every action force there is an equal and opposite reaction force."

How do action and reaction happen?

When a force is applied in nature, a reaction force occurs at the same time. When you jump on a trampoline, you exert a downward force on the trampoline. At the same time, the trampoline exerts an equal upward force on you.

GET IT?

5. **Explain** why the action and reaction forces do not cancel.

How do action and reaction make you move?

The action and reaction forces are equal. So how do you move by walking if each time you push on the ground, Earth pushes back with an equal force? The forces are acting on objects that have different masses. Earth has more mass than you do. Even though the forces are equal, their net force is not equal. Unequal net forces determine the direction you move.

After You Read

Mini Glossary

inertia: the tendency of an object to resist any change in its motion

Newton's first law of motion: an object moving at a constant velocity keeps moving at that velocity until acted on by an unbalanced force

Newton's second law of motion: an object's acceleration is in the same direction as the net force and is equal to the net force divided by the mass

Newton's third law of motion: when an object exerts a force on a second object, the second object exerts an equal but opposite force on the first

Review

1. Review the terms and their definitions in the Mini Glossary. Choose two terms that are related and write a sentence using both terms.

2. Place the number of the law of motion in the blank next to the example of the law given.

   a. _____ $F_{net} = ma$

   b. _____ the seven ball is struck by the cue ball

   c. _____ an air-filled balloon is released

   d. _____ you push on a box of books

3. You highlighted the main parts of each paragraph as you read. How did you decide what the main points were?