

**Chapter 12 Forces and Motion****Summary****12.1 Forces**

A force is a push or a pull that acts on an object. A force can cause a resting object to move, or it can accelerate a moving object by changing the object's speed or direction.

Force is measured in newtons (N). One newton is the force that causes a 1-kilogram mass to accelerate at a rate of 1 meter per second each second ( $\text{m/s}^2$ ).

Forces can be combined. Forces in the same direction add together. Forces in opposite directions subtract from one another. The net force is the overall force acting on an object.

Balanced forces are forces that combine to produce a net force of zero. When the forces on an object are balanced, the net force is zero and there is no change in the object's motion.

An unbalanced force is a force that results when the net force acting on an object is not equal to zero. When an unbalanced force acts on an object, the object accelerates.

All moving objects are subject to friction. Friction is a force that opposes the motion of objects that touch as they move past each other. Friction acts at the surface where objects are in contact.

There are four main types of friction: static friction, sliding friction, rolling friction, and fluid friction.

- Static friction is the friction force that acts on objects that are not moving.
- Sliding friction is a force that opposes the motion of an object as it slides over a surface.
- Rolling friction is the friction force that acts on rolling objects.
- Fluid friction is the friction force that opposes the motion of an object through a fluid.

Gravity is a force that acts between any two masses. Gravity is an attractive force, that is, it pulls objects together.

Earth's gravity acts downward toward the center of Earth.

Both gravity and air resistance affect the motion of a falling object. Gravity causes an object to accelerate downward, whereas air resistance acts in the direction opposite to the motion and reduces acceleration. Terminal velocity is the constant velocity of a falling object when the force of air resistance equals the force of gravity.

Projectile motion is the curved path of an object in free fall after it is given an initial forward velocity (for example, a thrown ball).

**12.2 Newton's First and Second Laws of Motion**

The ancient Greek philosopher Aristotle incorrectly proposed that force is required to keep an object moving at constant speed. The Italian scientist Galileo Galilei concluded that moving objects not subjected to friction or any other force would continue to move indefinitely.

The English scientist Isaac Newton summarized his study of force and motion in several laws of motion. According to Newton's first law of motion, the state of motion of an object does not change as long as the net force acting on the object is zero. Thus, unless an unbalanced force acts, an object at rest remains at rest, and an object in motion remains in motion with the same speed and direction.

Newton's first law of motion is sometimes called the law of inertia. Inertia is the tendency of an object to resist change in its motion.

An unbalanced force causes an object's velocity to change. In other words, the object accelerates. The acceleration of an object also depends on its mass. Mass depends on the amount of matter the object contains.

**Chapter 12 Forces and Motion**

According to Newton's second law of motion, the acceleration of an object is equal to the net force acting on it divided by the object's mass. Newton was able to put these ideas into a single formula.

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}, \text{ or } a = \frac{F}{m}$$

The acceleration of an object is always in the same direction as the net force. In using the formula for Newton's second law, it is helpful to realize that the units N/kg and m/s<sup>2</sup> are the same.

Weight (*W*) is the force of gravity acting on an object. An object's weight is the product of the object's mass (*m*) and acceleration due to gravity acting on it (*g*).

$$W = mg$$

**12.3 Newton's Third Law of Motion and Momentum**

According to Newton's third law of motion, whenever one object exerts a force on a second object, the second object exerts an equal and opposite force on the first object. The two forces are called action and reaction forces.

Momentum is the product of an object's mass and its velocity. An object with large momentum is hard to stop. The momentum for any object at rest is zero.

You can calculate momentum by multiplying an object's mass (in kilograms) and its velocity (in meters per second).

$$\text{Momentum} = \text{Mass} \times \text{Velocity}$$

Momentum is measured in units of kilogram-meters per second (kg•m/s).

Under certain conditions, collisions of objects obey the law of conservation of momentum. In physics, the word *conservation* means that something has constant value. That is, conservation of momentum means that momentum does not increase or decrease.

According to the law of conservation of momentum, if no net force acts on a system, then the total momentum of the system does not change. In a closed system, the loss of momentum of one object equals the gain in momentum of another object—momentum is conserved.

**12.4 Universal Forces**

Electric force and magnetic force are two different aspects of the electromagnetic force. Electromagnetic force is associated with charged particles. Electric force and magnetic force are the only forces that can both attract and repel. Electric forces act between charged objects or particles such as electrons and protons. Magnetic forces act on certain metals, on the poles of magnets, and on moving charges.

Two forces, the strong nuclear force and the weak nuclear force, act within the nucleus of an atom to hold it together. These forces are strong enough to overcome the electric force of repulsion that acts among the protons.

Gravity is the weakest universal force. Gravitational force is an attractive force that acts between any two masses. Newton's law of universal gravitation states that every object in the universe attracts every other object.

The gravitational force between two objects is proportional to their masses and decreases rapidly as the distance between the masses increases. The greater the mass of the objects, the greater is the gravitational force. Gravitational force decreases with the square of the distance between objects.

Gravity keeps the moon in orbit around Earth, the planets in orbit around the sun, and the stars in orbit around their galaxies. Earth's gravitational force keeps the moon in a nearly circular orbit around Earth. A centripetal force is a center-directed force that continuously