Newton's Laws of Motion

Newton's Third Law
If object A exerts a force on object B (called the action force), then object B exerts a force on object A (called the reaction force) that is equal in magnitude but opposite in direction.

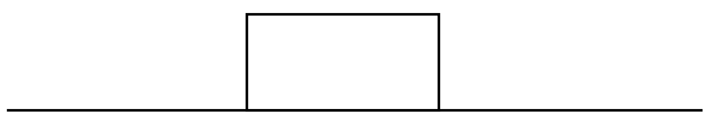
$$F_{A\ on\ B} = -F_{B\ on\ A}$$

Note: Although the action and reaction forces are equal in magnitude and opposite in direction, they can never cancel each other because they act on different objects. In order for two forces to cancel, they must act on the same object.

A simple example of Newton's third law involves a book at rest on a table. Gravity pulls down on the book, causing the book to exert a downward force on the table. At the same time, the table exerts an upward force on the book, called the **normal force**. As hard as the book pushes down on the table (action force), the table pushed up on the book (reaction force).

$$F_{Book\ on\ Table} = -F_{Table\ on\ Book}$$

The Normal Force
Consider a book at rest on a table, as shown:



The following facts are apparent:

- gravity acts on the book
- the book is not accelerating (thus, $\sum F = 0$)

According to Newton's laws, there must be a force acting on the book that is cancelling the gravitational force. This force, provided by the table pushing up on the book, is called the normal force.

The normal force:
- always exists between two surfaces that are in contact
- is always perpendicular to the surface

Newton's Laws Worksheet

Newton's Third Law

1. State the reaction force for each of the following forces.
   a. the southward force of a field goal kicker's toe on a football
   b. the backward force of a jogger's shoe on the ground
   c. the downward force of a book on a desk
   d. the backward force of a jet's engines on its exhaust gases
   e. the backward pull of a swimmer's hands on the water in the butterfly stroke

2. A beginning physics student, confused by a seeming contradiction in Newton's laws, asks her teacher the following question: "If, for every force there is an equal and opposite reaction force, then all forces in nature come in equal and opposite pairs, and are therefore balanced. Thus, since there can never be such a thing as an unbalanced force, how can any object ever accelerate?" Explain the fault in this common misconception.

3. A fireman at the scene of a fire is holding a heavy hose out of which water is gushing. To keep his balance, he often has to lean. Which way does he lean, forward or backward, and why?

4. A squirrel with an armful of nuts is sliding helplessly across a flat, icy roof, getting dangerously close to the edge. He understands Newton's Third Law, and is able to save himself. Explain how he does it.

5. A large 500 kg magnet exerts a constant force of 3.00 N on a 0.250 kg bar magnet. What magnitude force does the bar magnet exert on the large magnet?

Newton's Second Law

6. A person with a black-belt in karate has a fist that has a mass of 0.70 kg. Starting from rest, this fist attains a velocity of 8.0 m/s in 0.15 s. What is the magnitude of the average net force applied to the fist to achieve this level of performance? (37 N)

7. A bicycle has a mass of 13.1 kg, and its rider has a mass of 81.7 kg. The rider is pumping hard, so that a horizontal net force of 9.78 N accelerates them. What is the acceleration? ($0.103\ \text{m/s}^2$)

8. An airplane has a mass of 31 000 kg and takes off under the influence of a constant net force of 37 000 N. What is the net force that acts on the plane's 78 kg pilot, assuming that he has the same acceleration as the plane? (93 N)

9. Scientists are experimenting with a kind of gun that may eventually be used to fire payloads directly into orbit. In one test, this gun accelerates a 5.0 kg projectile from rest to a speed of $4.0\times10^3\ \text{m/s}$. The net force accelerating the projectile is $4.9\times10^5\ \text{N}$. How much time is required for the projectile to come up to speed? (0.041 s)

10. When a 0.058 kg tennis ball is served, it accelerates from rest to a speed of 45 m/s. The impact with the racket gives the ball a constant acceleration over a distance of 0.44 m. What is the magnitude of the net force acting on the ball? (130 N)

11. During a circus performance, a 72 kg human cannonball is shot out of an 18 m long cannon. If the human cannonball spends 0.95 s in the cannon, determine the average net force exerted on him in the barrel of the cannon. (2872 N)

12. A catapult on an aircraft carrier is capable of accelerating a plane from 0 to 56.0 m/s in a distance of 80.0 m. Find the average net force that the catapult exerts on a 13 300 kg jet. (2.61×10^{5} N)