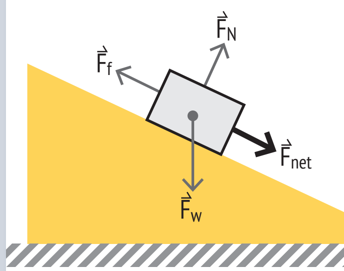
Physics | Forces

Newton's Laws of Motion

First law

FIGURE 1: Notes for the forces on a block of mass m on an inclined plane with base angle θ.



KEY

$\vec{F}_{net}$ = Net force

$\vec{F}_N$ = Normal force

$\vec{F}_w$ = Weight

$\vec{F}_f$ = Friction

Calculating various forces:

$$\vec{F}_{net} = \vec{F}_f + \vec{F}_N + \vec{F}_w$$

$$\vec{F}_N = \vec{F}_w \cos\theta$$

$$\vec{F}_w = m\vec{g}$$

$$\vec{F}_f = \mu\vec{F}_N = \mu\vec{F}_w \cos\theta$$

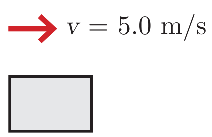
$$\vec{a} = \frac{\vec{F}_{net}}{m}$$

FIGURE 2: Notes for Newton's first law of motion.

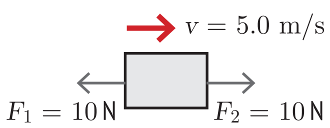
An object in motion will remain in motion at a constant velocity, and an object at rest will remain at rest unless acted on by an unbalanced force.

Newton's first law of motion clarifies that the velocity of an object will not change if the net force on it is zero. There will be no acceleration.

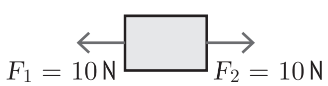
FIGURE 3



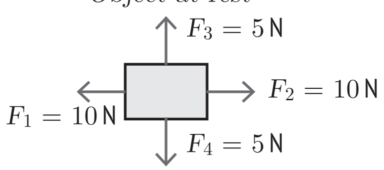
An object that is moving with a velocity of 5.0 m/s with no forces acting on it will continue in motion with a velocity of 5.0 m/s.



An object that is moving with a velocity of 5.0 m/s with balanced forces acting on it will continue in motion with a velocity of 5.0 m/s. The forces are balanced because the two forces acting on the block are equal in magnitude and opposite in direction.



An object at rest with balanced forces acting on it will remain at rest. The forces are balanced because the two forces acting on the block are equal in magnitude and opposite in direction.



An object at rest with balanced forces acting on it will remain at rest.

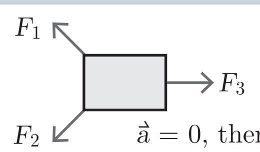
$\vec{F}_1 = -\vec{F}_2$

$\vec{F}_3 = -\vec{F}_4$

In each of the examples, the net force is zero, and so the acceleration is also zero.
The converse is also true: If the acceleration is zero, then the vector sum of the forces on the object must also be zero.

FIGURE 4

Object moving with a constant velocity



$\vec{a} = 0$, therefore, $\vec{F}_1 + \vec{F}_2 + \vec{F}_3 = 0$.

Second law

Newton's second law is known as the law of force. The acceleration of an object is dependent on the net force acting on the object and the object's mass. It is defined by the equation $F = ma$. If an object with a mass of 5 g is hit with the same force as an object with a mass of 10 g, the objects will travel at differing speeds and distances.

The acceleration is directly proportional to the net force and inversely proportional to the object's mass. A suitcase with a mass of 15 kg requires less force to lift than a suitcase with a mass of 30 kg.

Third law

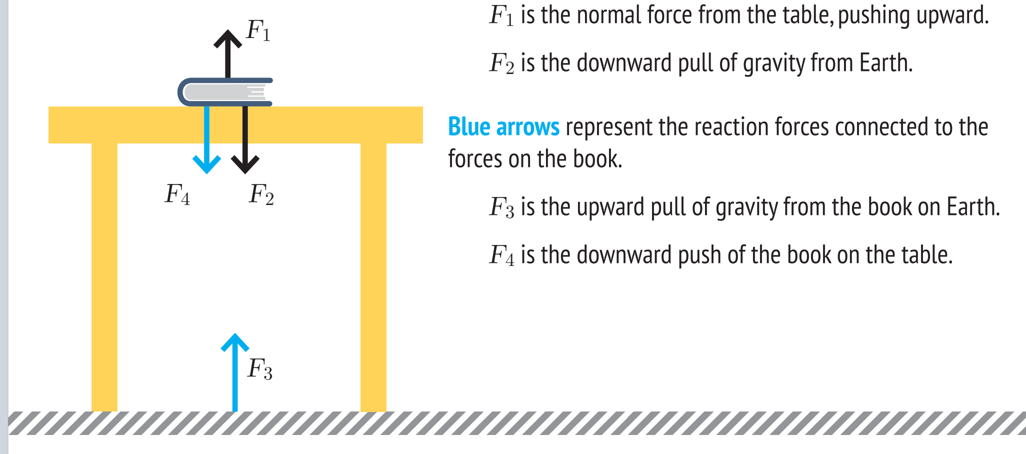
Handling misconceptions about Newton's third law of motion.

For every action, there is an equal and opposite reaction.

The third law refers to forces between pairs of objects that are interacting. The forces acting between the two objects will be equal in magnitude and opposite in direction.

The inclusion of the word "every" emphasizes that forces cannot occur in isolation. When forces are shown acting on an object, it is important to recall that every one of the forces comes from an object, and that object has an equal force acting on it in the opposite direction.

FIGURE 5



Black arrows represent forces acting on the book.

F_1 is the normal force from the table, pushing upward.

F_2 is the downward pull of gravity from Earth.

Blue arrows represent the reaction forces connected to the forces on the book.

F_3 is the upward pull of gravity from the book on Earth.

F_4 is the downward push of the book on the table.

F_1 and F_2 are equal and in opposite directions, but they are not a third law force pair. They are forces from two different objects (the table and Earth) acting on the book. Because the forces are balanced, the book will not move.

F_1 and F_4 are a third law force pair. The book and the table push against each other with equal force in opposite directions. It is difficult to imagine a table pushing, but it may help to think of a single wooden board with weight on it. It will bend in the middle and push back against the weight. The table will do this on a much smaller scale, but it does push back.

F_2 and F_4 are a third law force pair. Gravity from Earth pulls down on the book. Gravity from the book pulls up on Earth. The second note is difficult to imagine but all objects with mass attract each other with equal force. The way these forces affect the motion of the objects will be very different when the masses are very different, as in the case of the book and Earth.