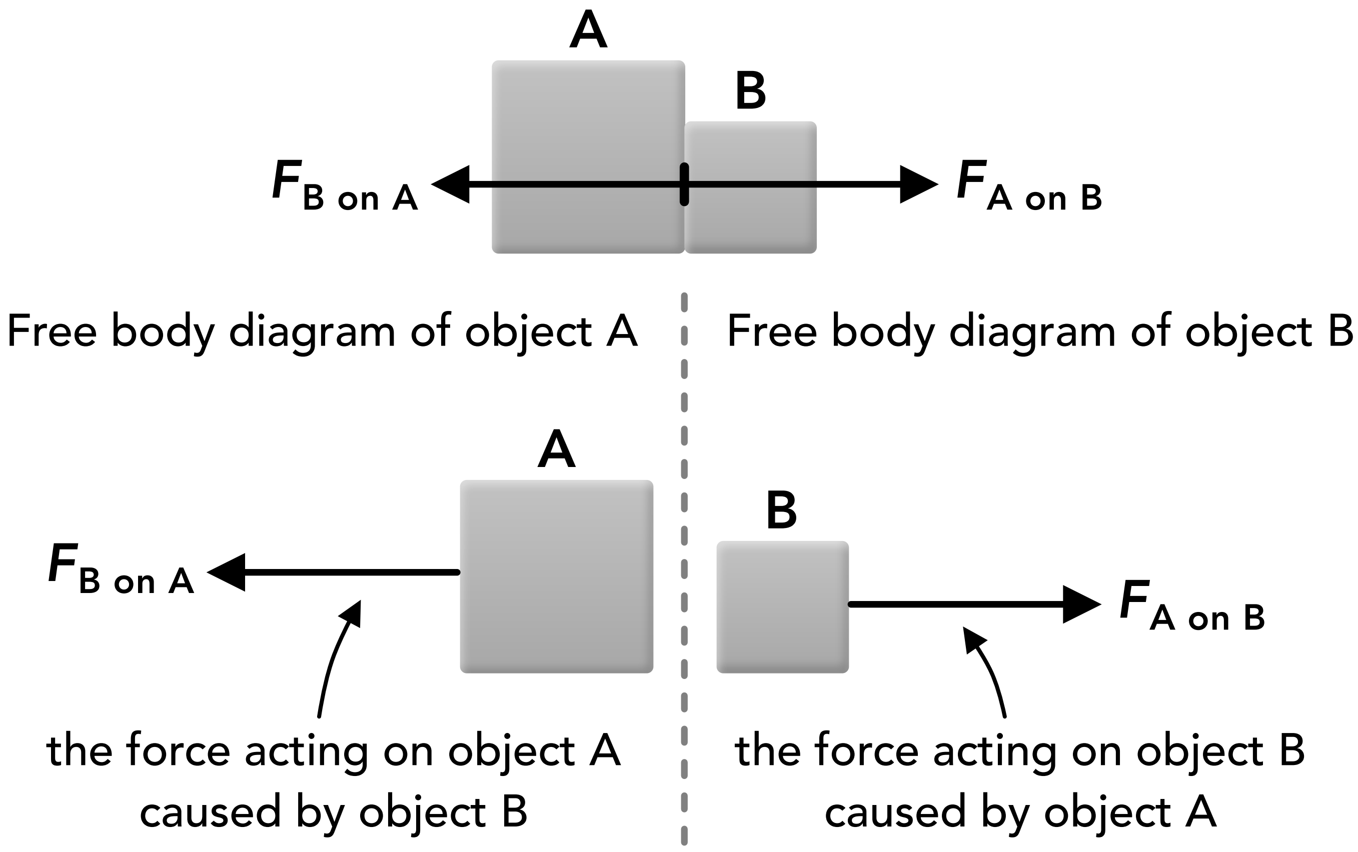
NEWTON'S 3RD LAW & NORMAL FORCE

Newton's 3rd Law of Motion

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

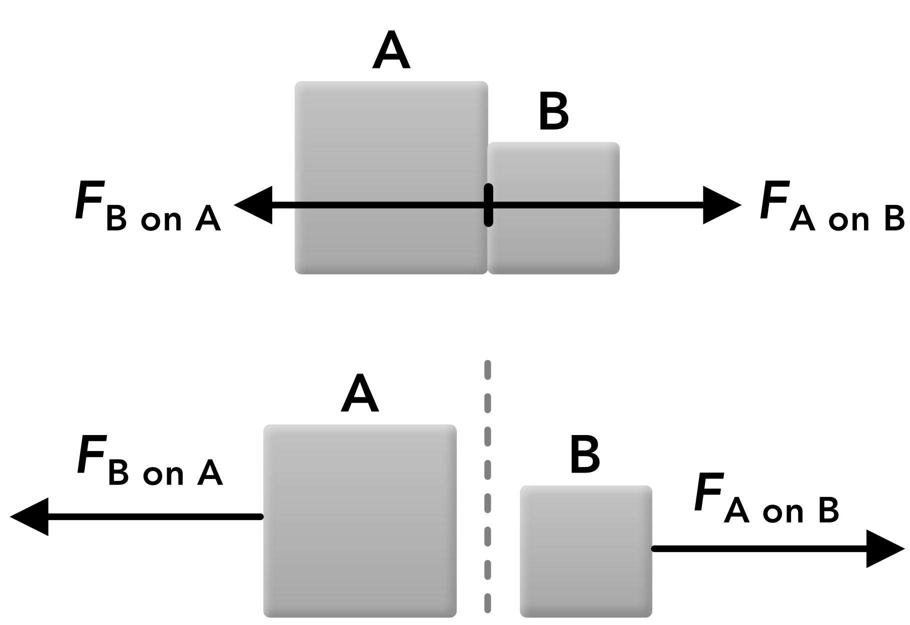


Variables		SI Unit
F	force	N
$F_{\text{A on B}}$	force of A acting on B	N
F_n	normal force	N
F_g	gravitional force	N

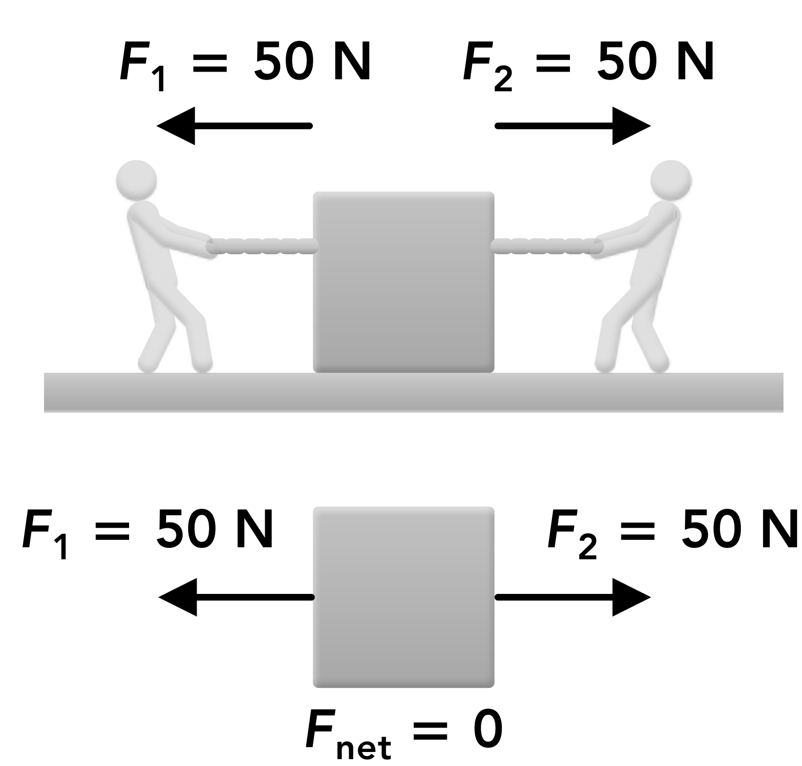
There is a pair of forces that exist when two objects interact with each other. Only one of these forces is included in the free body diagram for each object because the two forces are exerted on two different objects. We do not include both forces in the free body diagram of one object.

- **Newton's 3rd law of motion:** If object A exerts a force on object B, then object B exerts an equal and opposite force on object A (the force is equal in magnitude and opposite in direction).
- This law is sometimes stated as "every action has an equal and opposite reaction". This can be confusing because the words "action" and "reaction" may be misinterpreted as motion or something more complex, but they really just refer to a pair of forces that exist simultaneously (the "action" doesn't happen before the "reaction").
- Another common point of confusion is the phrase "equal and opposite forces". When used to describe the pair of forces from Newton's 3rd law of motion, it's accurate to say that two objects exert "equal and opposite forces" on each other when they interact (those two forces are inherently equal in magnitude and opposite in direction). The phrase is also sometimes used to describe two forces that are acting on an object that happen to have the same magnitude and opposite directions, resulting in zero net force and zero acceleration in that direction (due to Newton's 1st and 2nd laws). In that case, the two forces are entirely separate and have separate causes, and it's a coincidence that they are equal in magnitude and opposite in direction.
- It may help to remember that the pair of forces described in Newton's 3rd law must be the same type of force: two normal forces, two gravitational forces, two friction forces, two tension forces, etc.

These two forces are a pair of "equal and opposite" forces according to Newton's 3rd law, but the forces act on two separate objects

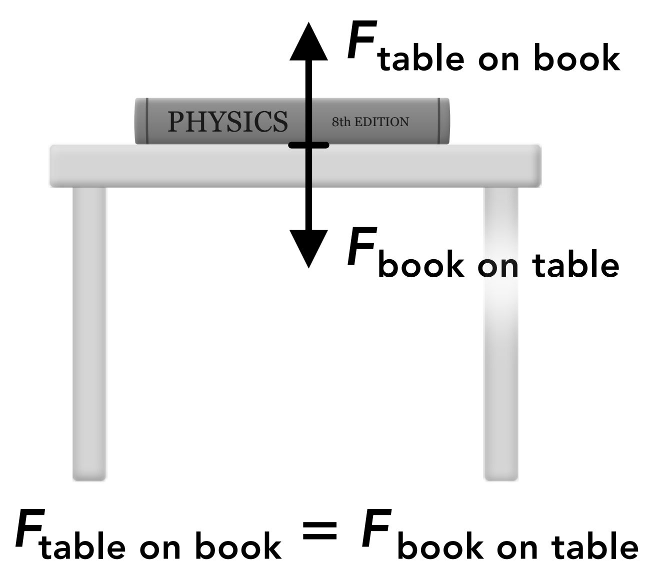


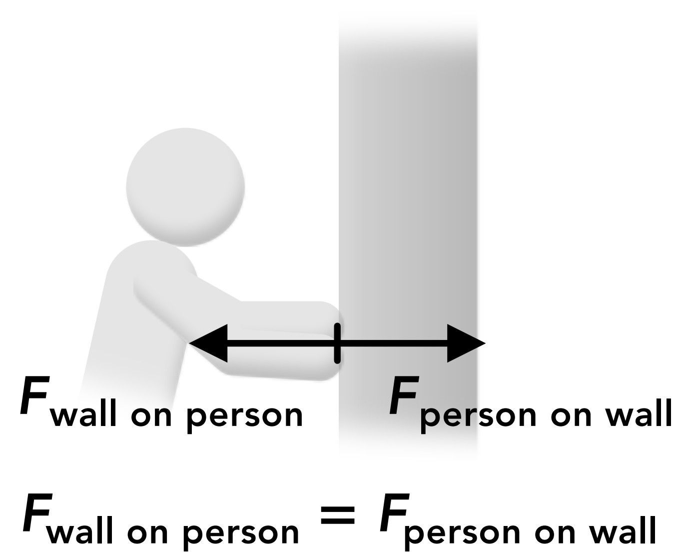
These two forces happen to be "equal and opposite" but they are separate forces that act on the same object (unrelated to Newton's 3rd law)

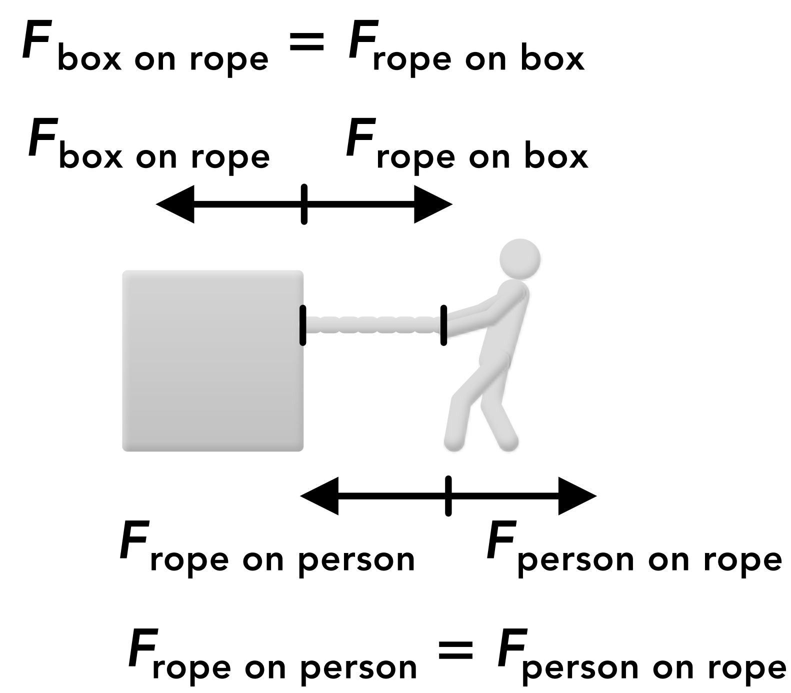


- A pair of forces can result from the physical contact between two objects (contact force pairs) or between two objects that are at a distance (non-contact force pairs).
- If two objects are in contact they each apply a force on the other object. This can be a pushing force (such as a normal force) or a pulling force (such as a tension force). This is sometimes referred to as a “reaction force” or simply a “contact force”.

Contact force pairs



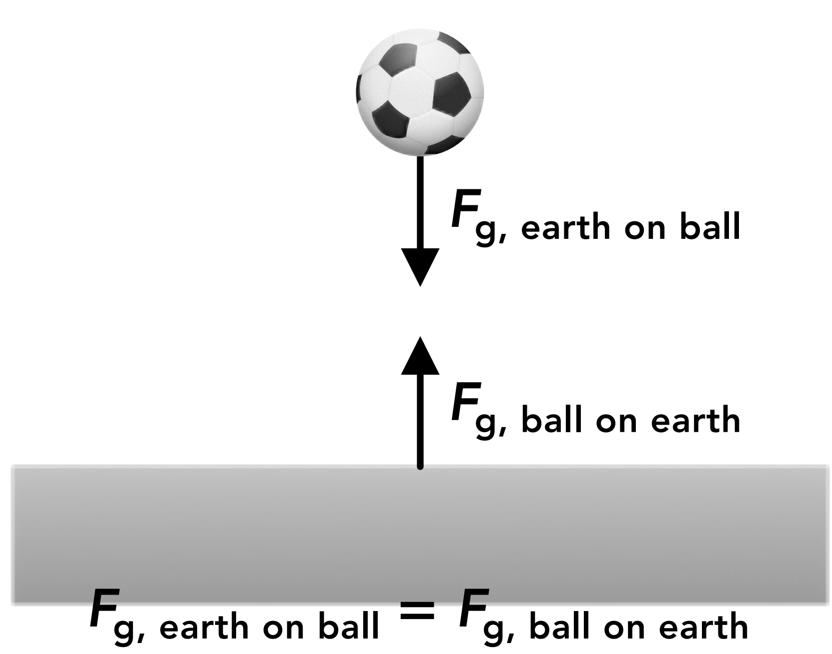




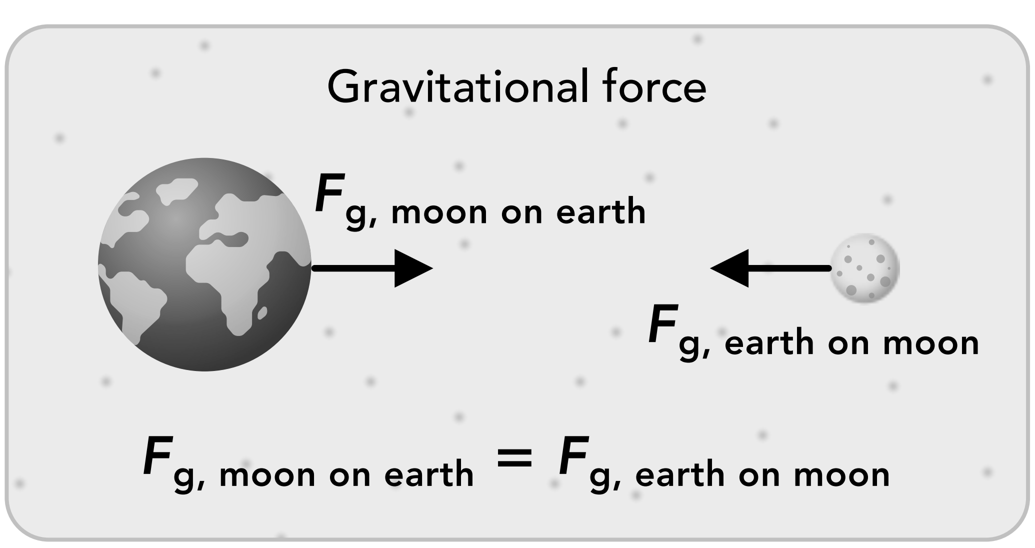
- There is an attractive gravitational force that acts between any two objects due to their mass.
- Although not covered in this course, there is an attractive magnetic force between opposite poles of a magnet and a repulsive force between similar poles. There is also an attractive electric force between two oppositely charged particles, and a repulsive force between two particles with the same charge.

Non-contact force pairs

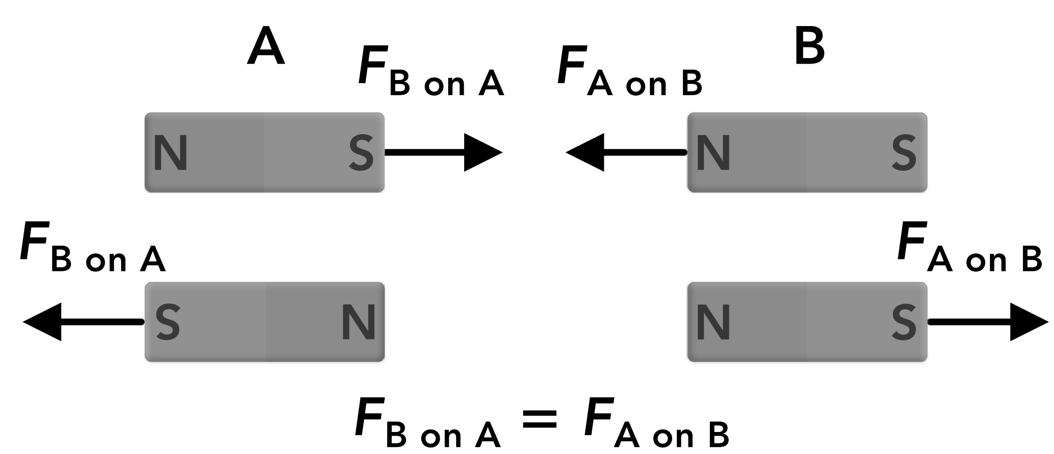
Gravitational force



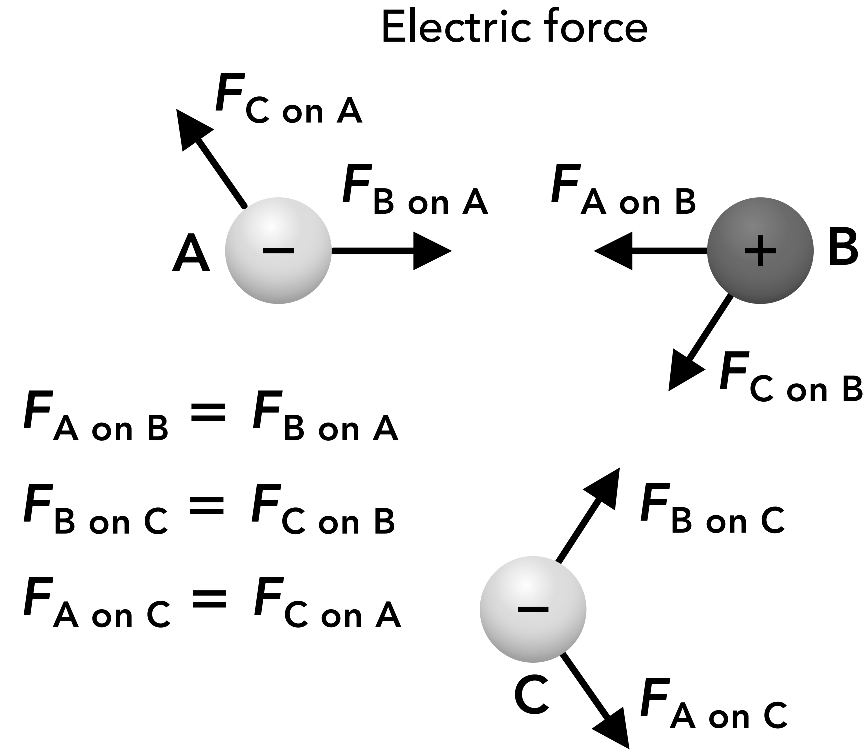
Gravitational force



Magnetic force

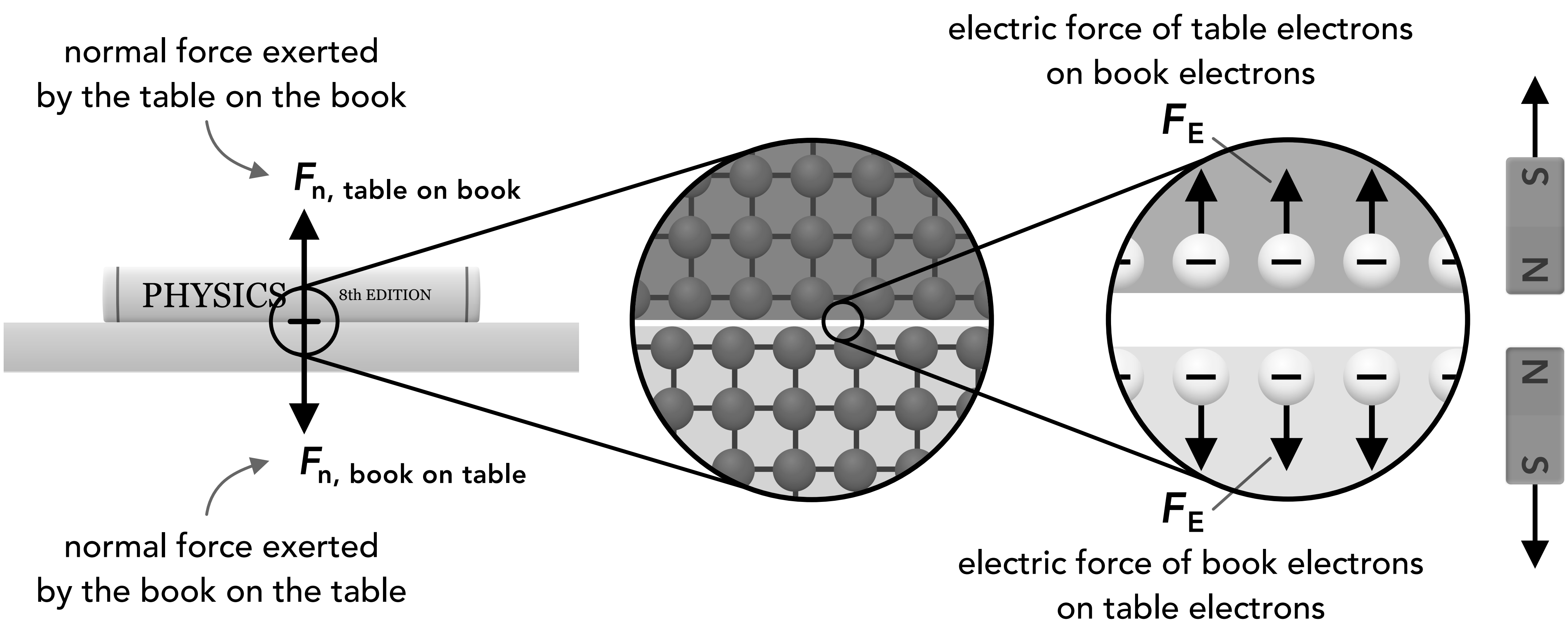


Electric force

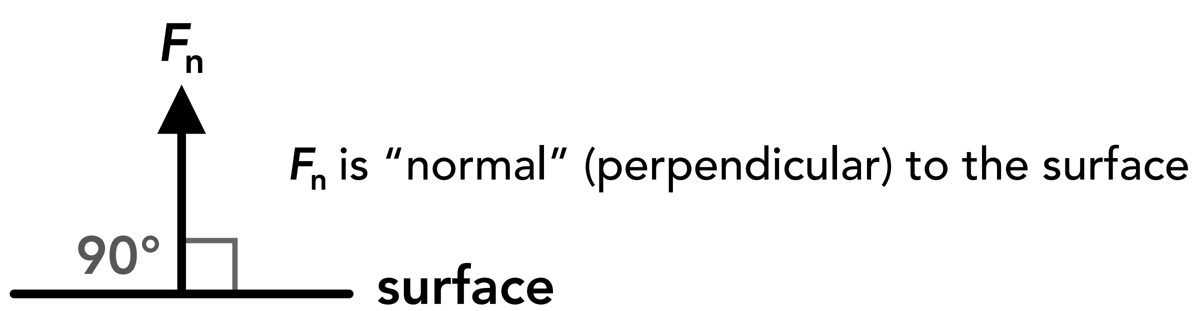


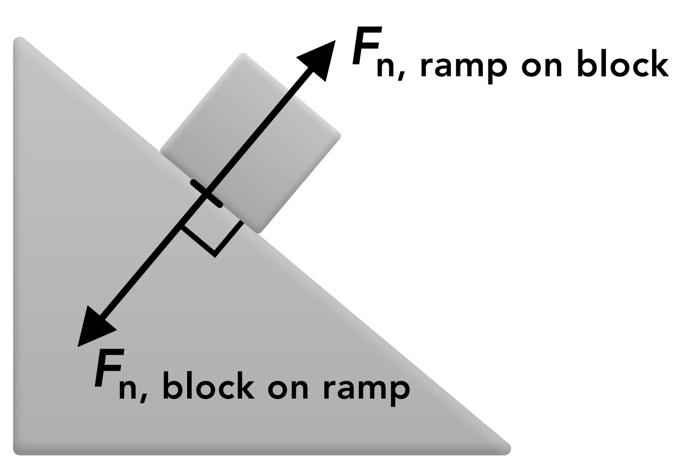
Normal Force

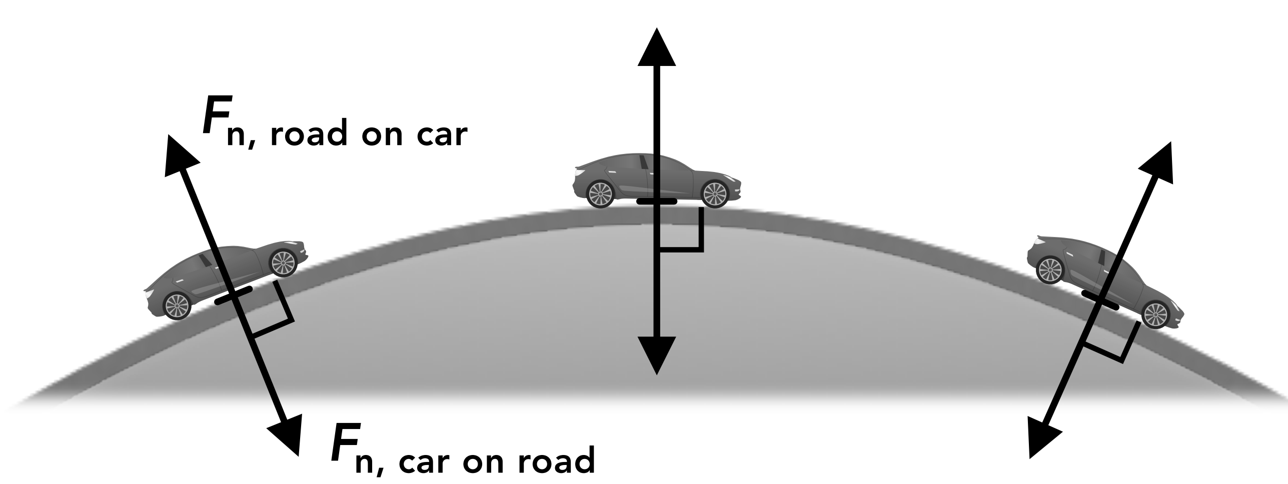
- A **normal force** is just a term for the pushing force that arises when two objects are in contact.
- Normal force is represented as "F_n" or "$\boldsymbol{N}$" which should not be confused with a Newton (N), the unit of force.
- At a macroscopic level, a normal force is a contact force that prevents two solid objects from passing through each other. The surfaces of each object may appear to be touching, but at the atomic level the electrons in one object are repelling the electrons in the other object with an electric force (to put it simply). In a way, pushing two objects together is similar to pushing two extremely strong repelling magnets together.



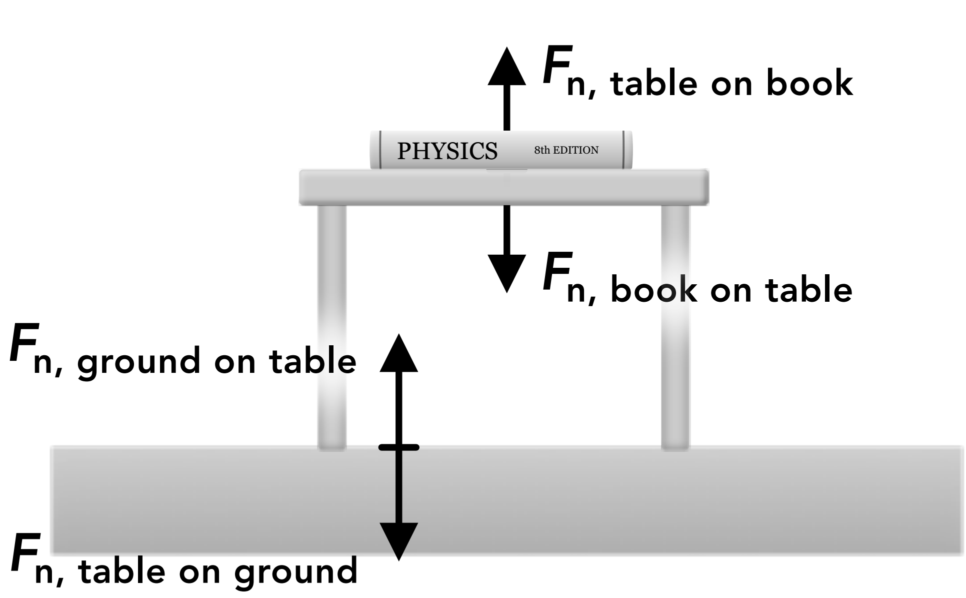
- This is called a normal force because "normal" means **perpendicular** in geometry, and a normal force always acts perpendicular to the surface that the object is contacting.

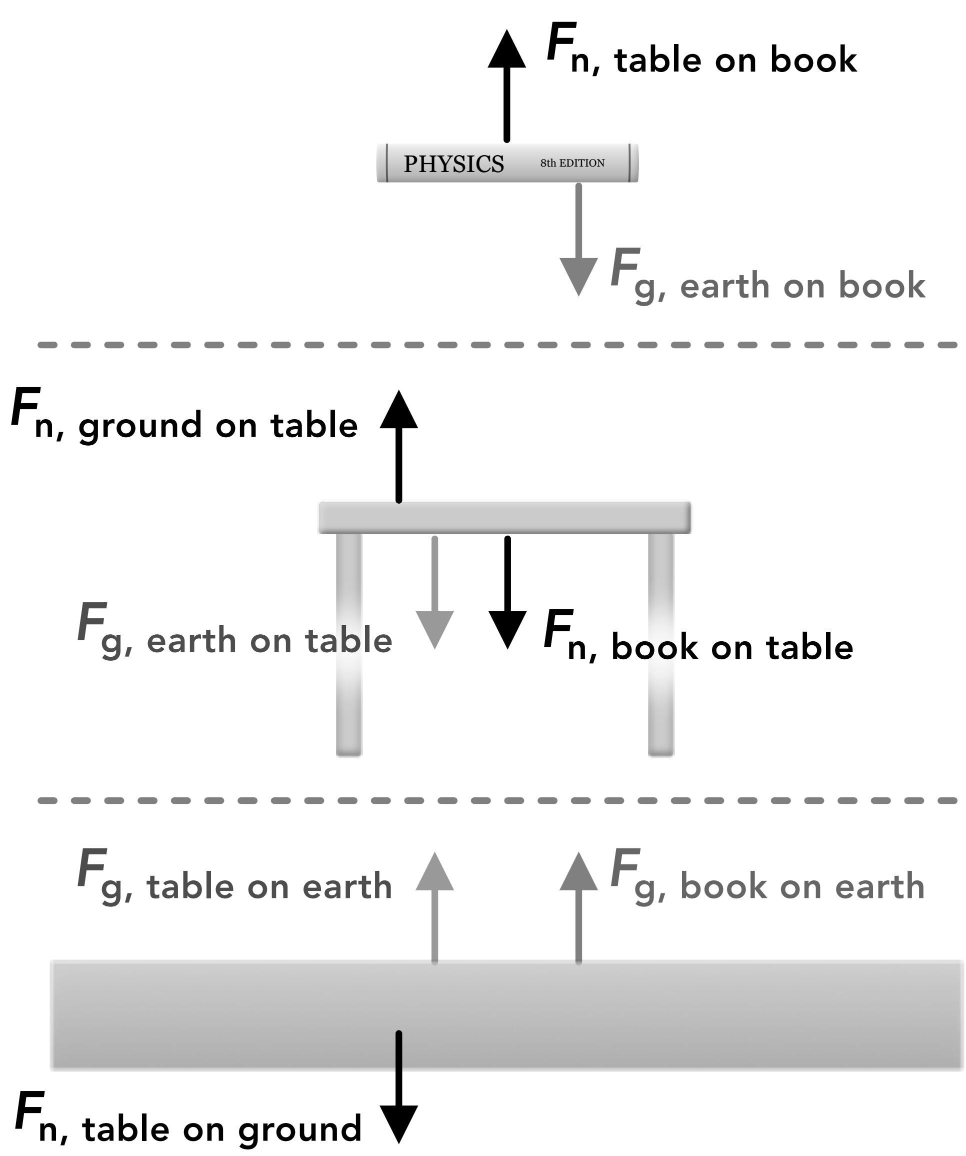




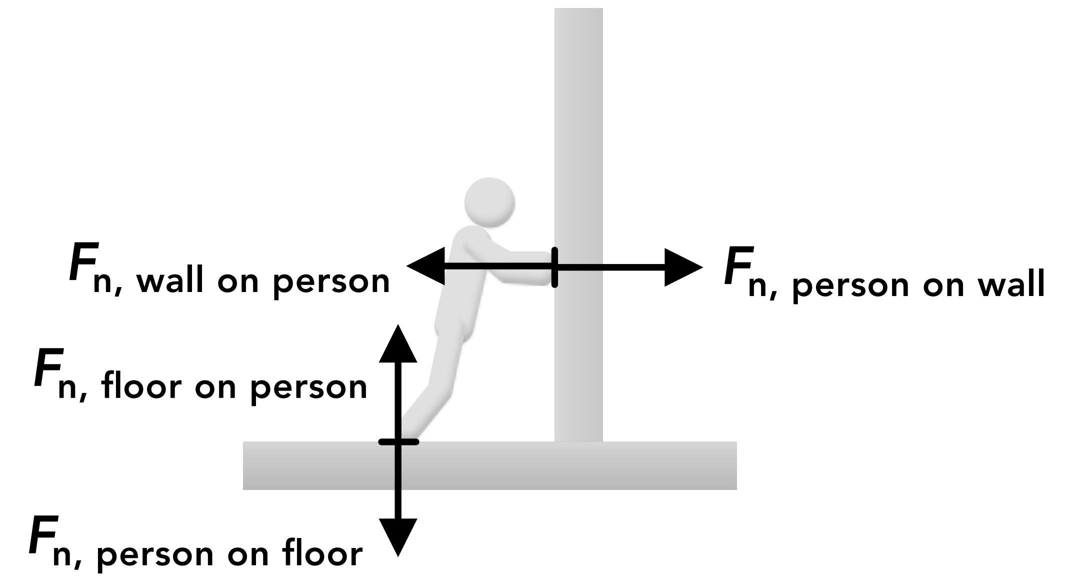


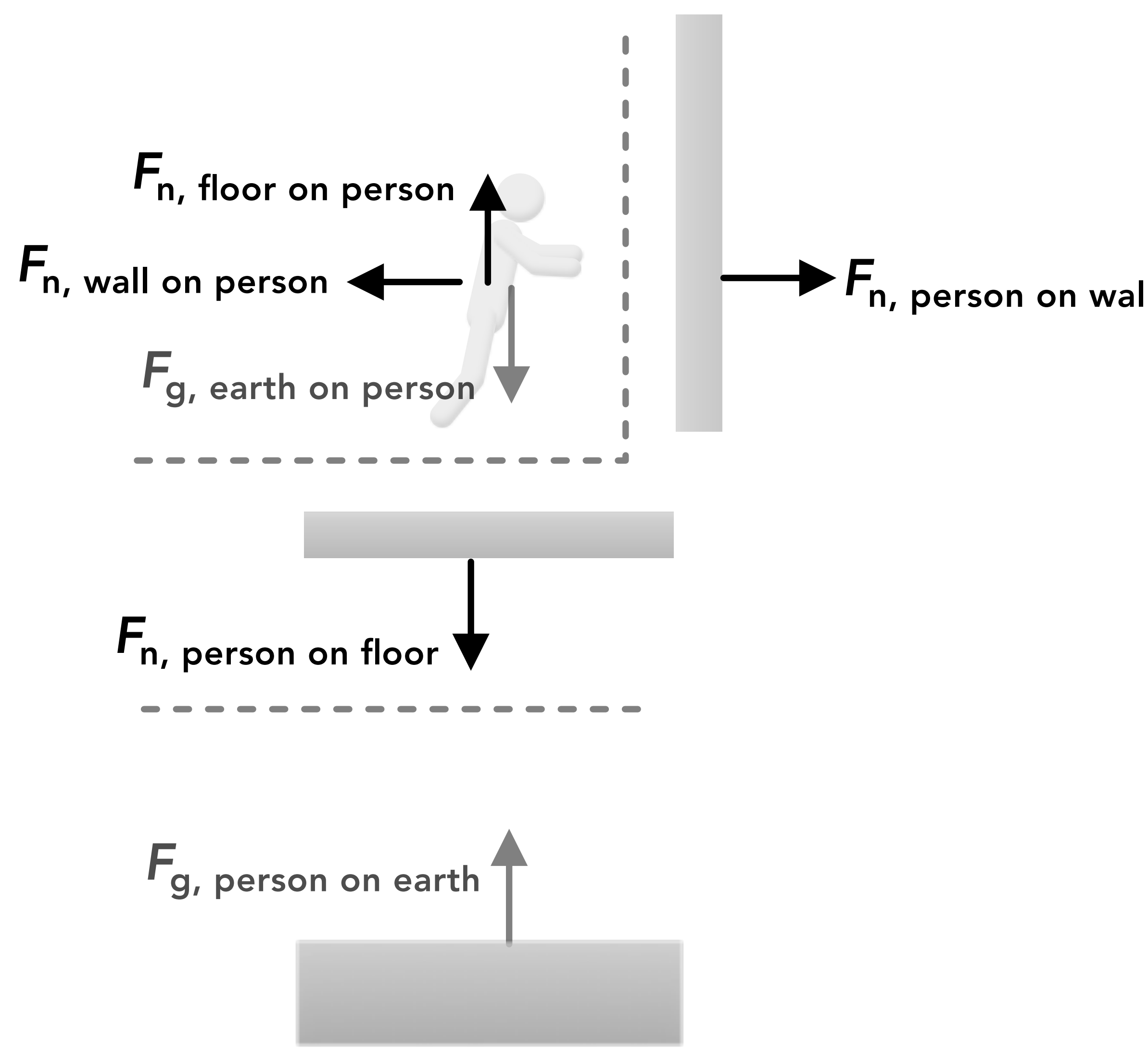
- If a book is resting on a table, the book exerts a downwards normal force on the table and the table exerts an upwards normal force on the book with the same magnitude. Separately, the table exerts a downwards normal force on the ground and the ground exerts an upwards normal force on the table. Note that there are also gravitational force pairs between the earth and the book, and between the earth and the table. Technically there is a gravitational force acting between the book and the table, but it's so weak that it's usually ignored.





$$F_{\text{n, book on table}} = F_{\text{n, table on book}}$$
$$F_{\text{n, table on ground}} = F_{\text{n, ground on table}}$$



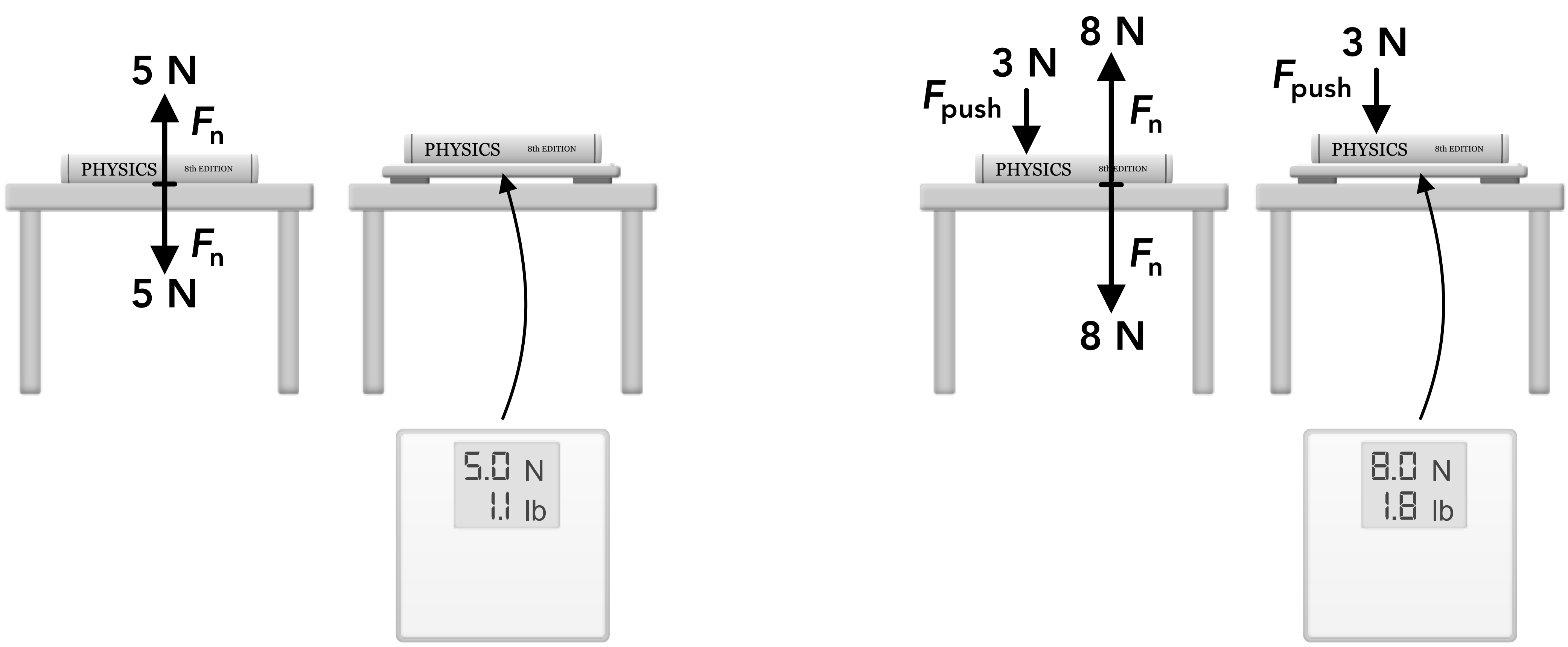


*gravitational force pairs between the floor, the wall and the earth not shown

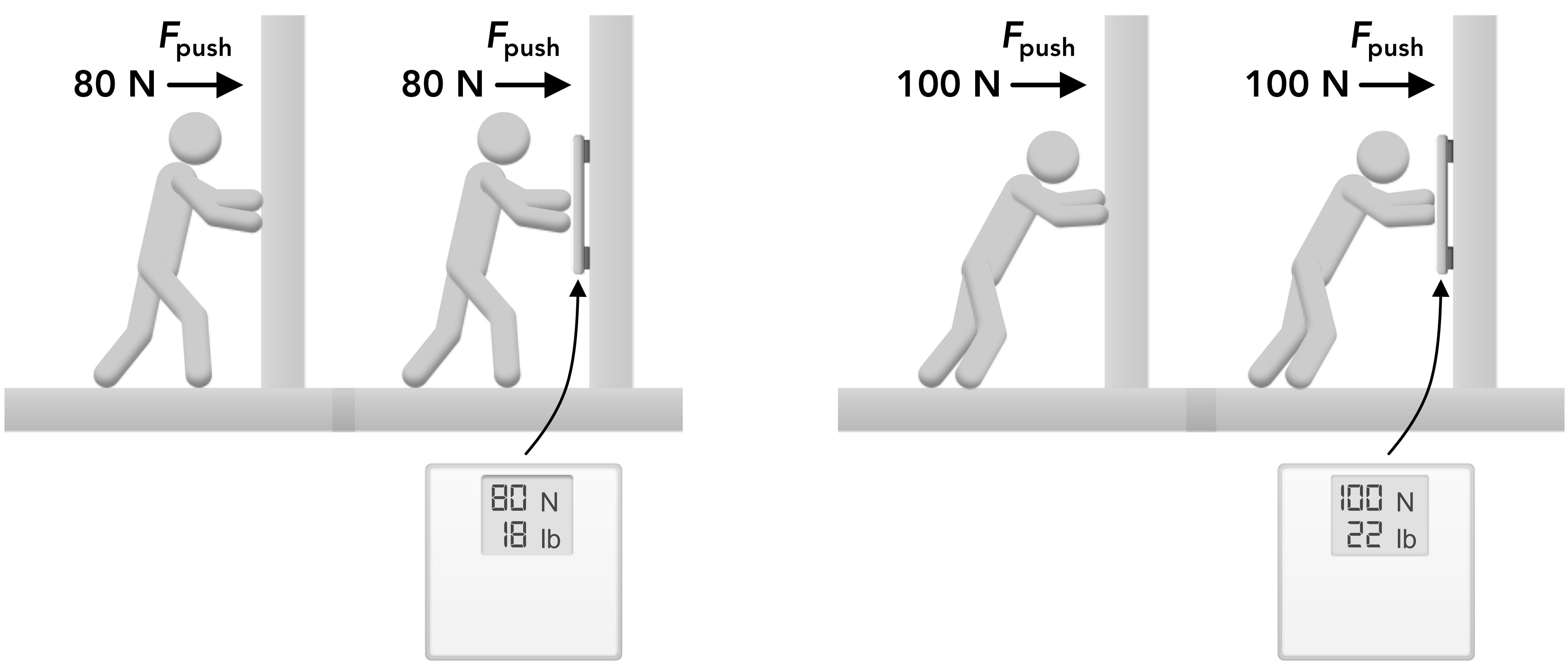
$$F_{\text{n, person on wall}} = F_{\text{n, wall on person}}$$
$$F_{\text{n, person on floor}} = F_{\text{n, floor on person}}$$

- The normal force may be less intuitive at first because its magnitude can change based on the other forces being exerted on the object. We usually can't visualize a change in the normal force because the object and the surface don't appear to get closer or farther from each other.
- When thinking about the normal force, we can imagine placing a flat scale or a spring between the object and the surface to visualize the normal force. A scale measures the force acting on both sides (which are equal in magnitude if the scale is not accelerating). A spring will change length when a force is applied to both ends (which are also equal in magnitude if the spring is not accelerating).

A scale would measure the normal force between the book and the table

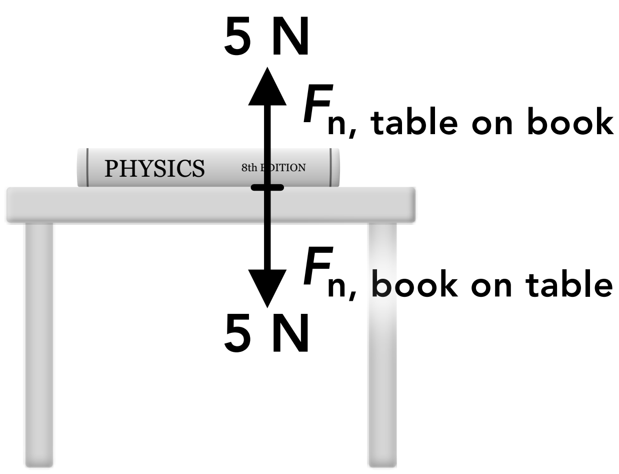


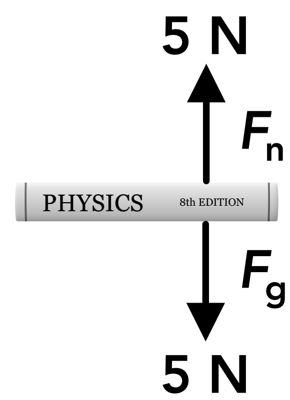
A scale would measure the normal force between the person and the wall



- It's worth noting that the normal force acting upwards on an object is sometimes equal in magnitude to the gravitational force (weight) acting downwards on the object, but not always. This is only true if those are the only two forces acting on the object in those directions and the object is not accelerating, but the normal force depends on other forces being exerted on the object along the same axis.

A book is sitting at rest on a table. The only forces acting on the book are the gravitational force (weight) and the normal force from the table. The net force on the book is zero (it is not accelerating) so the normal force is equal in magnitude to the gravitational force.

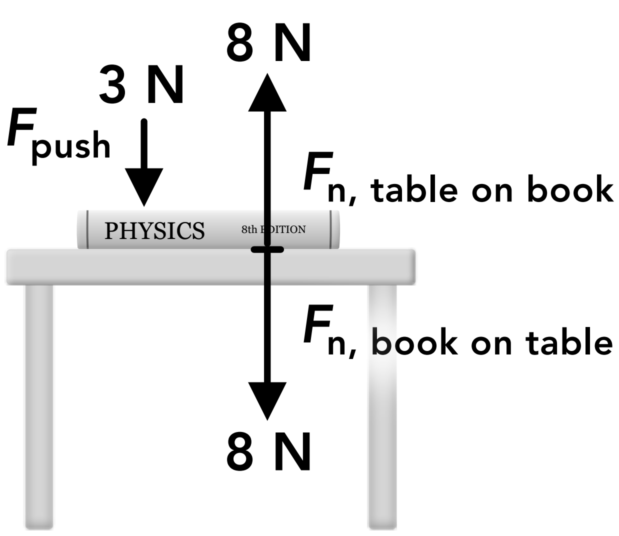


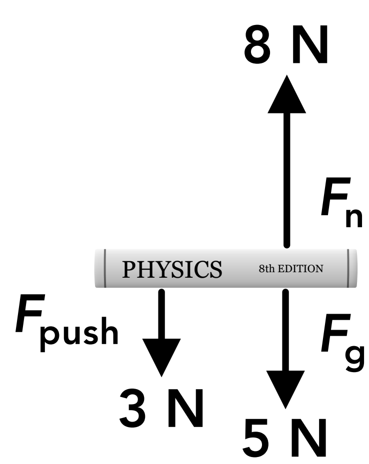


$a_y = 0$

$$\sum F_y = ma_y$$
$$\sum F_y = F_n - F_g = m(0)$$
$$F_n = F_g$$
$$F_n = 5\text{ N}$$

A book is sitting at rest on a table and someone pushes down on the book with a force of 3 N. The net force on the book is still zero (it is not accelerating) so the normal force increases and is equal in magnitude to the gravitational force plus the push force.

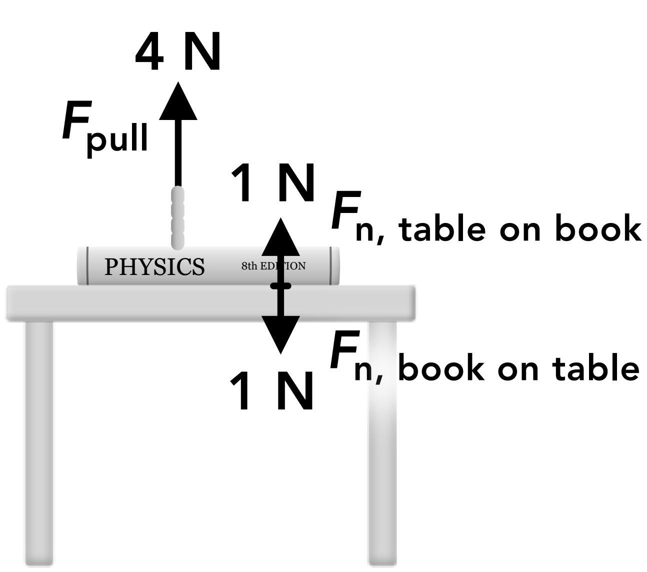


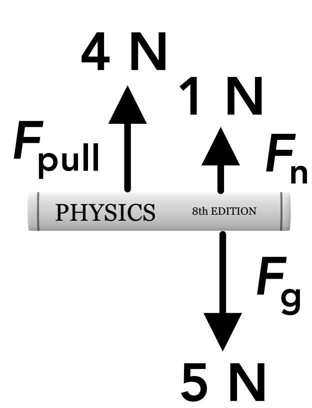


$a_y = 0$

$$\sum F_y = ma_y$$
$$\sum F_y = F_n - F_g - F_{push} = m(0)$$
$$F_n = F_g + F_{push}$$
$$F_n = 5\text{ N} + 3\text{ N}$$
$$F_n = 8\text{ N}$$

A book is sitting at rest on a table and someone pulls up on the book with a force of 4 N. The net force on the book is still zero (it is not accelerating) so the normal force decreases and is equal in magnitude to the gravitational force minus the pull force.





$a_y = 0$

$$\sum F_y = ma_y$$
$$\sum F_y = F_n + F_{pull} - F_g = m(0)$$
$$F_n = F_g - F_{pull}$$
$$F_n = 5\text{ N} - 4\text{ N}$$
$$F_n = 1\text{ N}$$

- An important thing to remember is that a normal force can't cause an object to accelerate if that acceleration means the objects are no longer in contact with each other, because then the normal force would be zero.