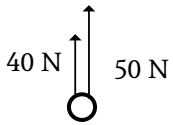
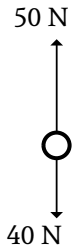
Physics Honors
Newton’s Laws of Motion

Net Force



The vector sum of the forces acting on an object is called the net force.

If two forces are in the same direction, you add them to find their vector sum. The net force of this object is 90 N up.



If two forces are in opposite directions, you subtract them to find their vector sum. The net force of this object is 10 N up.

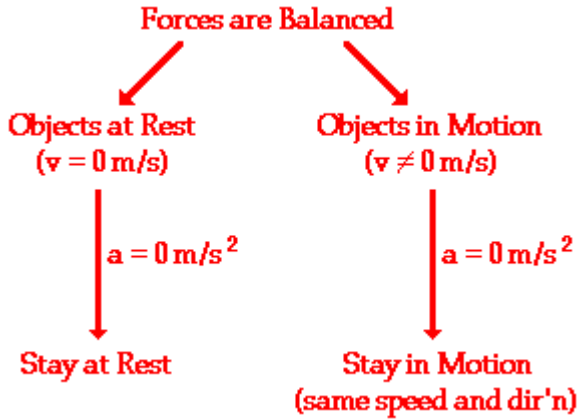
Newton’s 1st Law of Motion

An object at rest remains at rest, and an object in motion continues in motion with constant velocity unless the object experiences a net external force.

Newton’s 1st Law of Motion

Newton’s 1st Law of Motion tells us that:

- Forces cause acceleration
- If the net force on an object is 0, the object does not accelerate
- If the net force on an object is not 0, the object accelerates



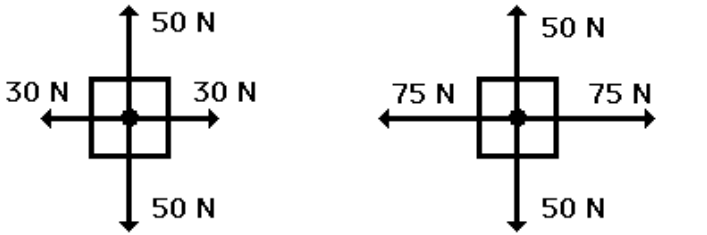
Newton’s 1st Law of Motion - Quick Check

Can an object be moving if it has no forces acting on it? How?

Newton’s 1st Law of Motion

Objects that are at rest or moving with constant velocity are in equilibrium.

Newton’s 1st Law describes objects in equilibrium - the state in which the net force on an object is zero.



These two objects are at equilibrium since the forces are balanced. However, the forces are not equal.

Newton’s 1st Law of Motion

Newton’s 1st Law is also called the Law of Inertia.

Inertia is the tendency of an object to resist changes in its motion.

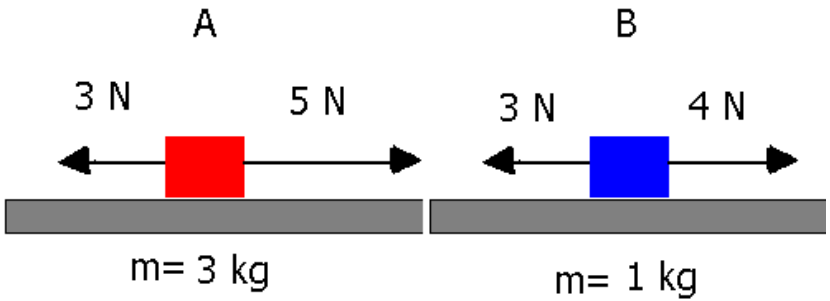
Mass is a measure of inertia. The more mass an object has, the more inertia it has.

Making Predictions

Newton's First Law primarily discusses objects in equilibrium. What happens when objects are not in equilibrium?

Using your knowledge of forces and motion, make a prediction:

Compare the acceleration of the following objects. Briefly explain your prediction.



Newton’s 2nd Law

Newton’s 2nd Law tells us that forces cause acceleration. An object accelerates if there is a net external force acting on it. We can write Newton’s 2nd Law in an equation form:

$$F = ma$$

Newton’s 2nd Law - Quick Check

The net force on the propeller of a 3.2 kg model airplane is 7.0 N forward. What is the acceleration of the airplane?

$F = 7.0\ N$

$m = 3.2\ kg$

$F = ma \rightarrow a = F / m$

$a = 7.0\ N / 3.2\ kg = 2.2\ m/s^2$

Newton’s 2nd Law - Quick Check

A sled is accelerating at a rate of 2 m/s^2. If the net force is tripled and the mass is doubled, then what is the new acceleration of the sled?

$a = 2\ m/s^2$

Force is 3 times

Mass is 2 times

$F = ma \rightarrow a = F / m = 3 / 2 = 1.5$ times the acceleration

$a = 2\ m/s^2 * 1.5 = 3\ m/s^2$

Independent Practice

1. How large is the acceleration of a 35-kg mass that has a net force of 270 N applied to it horizontally?
2. A crate is pushed east across a frictionless surface with a force of 240 N and pulled east by a rope with a force of 120 N. What is the net force on the crate?
3. What is the mass of an object that can be accelerated horizontally at 4.4 m/s^2 by a net force of 970 N?
4. A 2300 kg car slows down at a rate of 3.0 m/s^2 when approaching a stop sign. What is the net force causing it to slow down?

Weight

We previously saw that weight is the common term for the force of gravity acting on an object.

The force of gravity acting on an object on Earth is determined by two factors:

1. The object's mass
2. The acceleration of gravity

Weight

We can write this as an equation:

$$F_g = mg$$

F_g = force of gravity

m = mass

g = acceleration of gravity

Weight

Remember that mass and weight are not the same thing!

Mass is a scalar, while weight is a vector.

Weight depends on where an object is (on Earth, on the Moon, in space, etc.), but mass does not.

Quick Check

What is the mass of an object that weighs 98 N?

Answer = 10 kg

Example - lifting a rock

Arnold needs to lift a 35.0 kg rock. If he exerts an upward force of 502 N on the rock, what is the rock's acceleration?

Knowns:
Unknown:

m = 35.0 kg a = ?

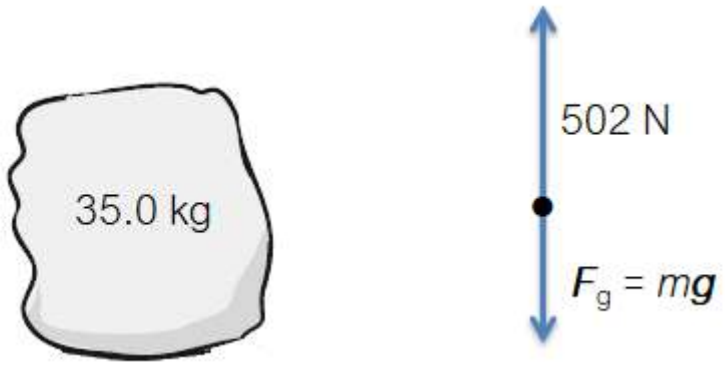
Arnold's force = 502 N

g = 9.8 m/s^2

Example - lifting a rock

Arnold needs to lift a 35.0 kg rock. If he exerts an upward force of 502 N on the rock, what is the rock's acceleration?

Free body diagram:



Example - lifting a rock

Arnold needs to lift a 35.0 kg rock. If he exerts an upward force of 502 N on the rock, what is the rock's acceleration?

Find the net force using the free body diagram:

$F_{net} = F_{Arnold} - F_g$

$F_{net} = F_{Arnold} - mg$

$F_{net} = 502 - (35.0)(9.8)$

$F_{net} = 159\ N$

Example - lifting a rock

Arnold needs to lift a 35.0 kg rock. If he exerts an upward force of 502 N on the rock, what is the rock's acceleration?

Find the acceleration using Newton's Second Law:

$F_{net} = ma$

$a = F_{net} / m$

$a = 159 / 35.0 = 4.54\ m/s^2$

Now you try!

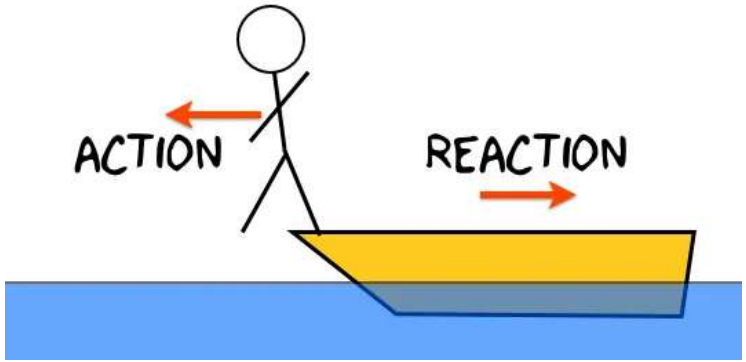
A book as a mass of 2 kg. You exert an upwards force of 25 N to lift it. What is the acceleration of the book while it is being lifted?

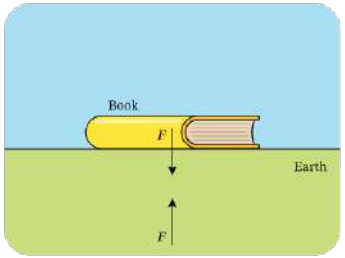
Answer = 2.7 m/s^2

Newton’s Third Law

Newton’s third law states that when two bodies interact, they apply forces to one another that are equal in magnitude and opposite in direction.

The third law is also known as the law of action and reaction.





Example

You are walking along when you slip on some ice and fall. For a moment you are in free fall. During this time, what force do you exert on Earth if your mass is 55 kg?

Knowns:

$m_{you} = 55$ kg

$g = 9.8$ m/s^2

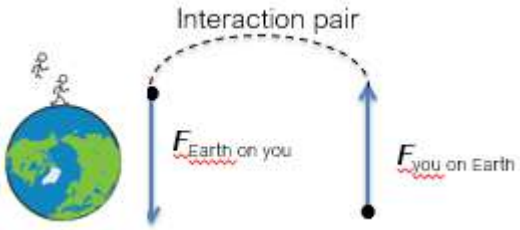
Unknown:

$F_{you\ on\ Earth} = ?$

Example

You are walking along when you slip on some ice and fall. For a moment you are in free fall. During this time, what force do you exert on Earth if your mass is 55 kg?

Identify the interaction pair:



Example

You are walking along when you slip on some ice and fall. For a moment you are in free fall. During this time, what force do you exert on Earth if your mass is 55 kg?

Solve using Newton's Third Law:

$F_{\text{you on Earth}} = F_{\text{Earth on you}} = m_{\text{you}}g$

$mg = (55\ \text{kg})\ (9.8\ \text{m/s}^2) = 540\ \text{N}$

The force you exert on Earth is equal in magnitude and opposite in direction to the force Earth exerts on you.

Additional Practice

You are fishing and catch a fish with a mass of 6 kg. If the fishing line can withstand a maximum tension of 100 N, what is the maximum acceleration you can give the fish as you reel it in?

Answer = 7 m/s^2