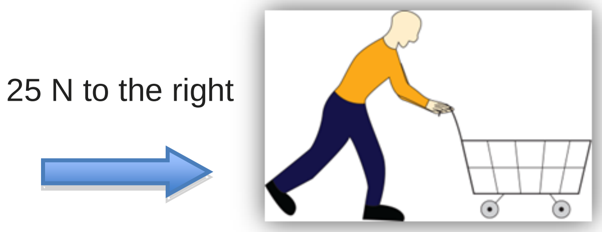
Reflect

Have you heard the story about Isaac Newton sitting under an apple tree? According to the story, an apple fell from a tree and hit him on the head. From that event, it is said that Newton discovered the force of gravity. No one knows for sure whether the story is true or not. What is certain is that Newton's ideas about gravity and other forces have explained some of the most significant scientific phenomena related to motion in the universe. How do forces like gravity affect motion? How is motion measured? Answers to these important questions may have begun with a falling apple!

How did an apple possibly lead to universal laws of physics?

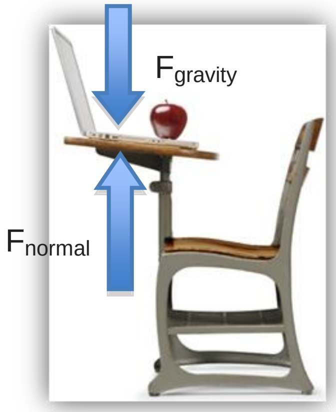
Different Forces Act on Objects

In order to understand motion, we must begin by talking about forces. A *force* is a push or a pull exerted on an object. Every force has a magnitude and a direction. The *magnitude* is how strong the push or the pull is and is measured in newtons (N.) *Direction* can be, for example, east, west, north, south, toward the left, or toward the right. The force the man is exerting on the cart below can be described as having a magnitude of 25 N and a direction to the right.



At any given time, all objects have a variety of forces acting upon them. For example, a laptop computer sitting on a desk has at least two forces acting upon it. Earth's gravitational force pulls the laptop down toward the center of the planet. Earth's gravity is what keeps everything on Earth, including people, from drifting off into space. It literally keeps us grounded!

The second force acting on the laptop is the normal force. The *normal force* is the force of the desk pushing up on the laptop, keeping it from falling through the desk and to the ground. When someone sits on a chair or leans against a wall, the normal force pushes back against that person, preventing him or her from falling through the chair or wall. The normal force acts in the opposite direction of gravity.

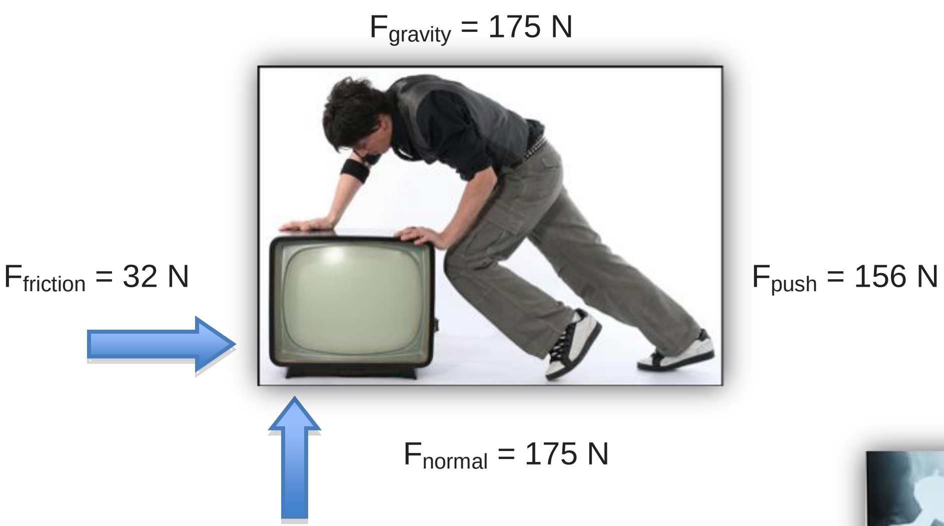


Together, gravity and the normal force combine to be the net force acting on the laptop. *Net force* is the total of all forces acting on an object at once. When calculating net force, any forces acting in the same direction are added together. Those acting in opposite directions are subtracted. The direction of the net force is the direction of the greatest force. So, for example, if a force of 10N to the left and a force of 8N to the right are acting on an object, the net force is 2N to the left.

Friction is a force that always acts in the opposite direction of movement. Friction occurs when two surfaces are in contact, such as the bottom of one's shoes and the ground on which he or she walks. The amount of friction between two surfaces depends on what the surfaces are made of and how hard they are pressing against each other. Smooth surfaces like an ice rink or wood floors have less friction than rough surfaces like sandpaper or cement. Also, surfaces that have less force pressing them together have less friction than surfaces that have a lot of force pressing them together.

What Do You Think?

What is the net force acting on the television? Remember to include both its magnitude and direction.



Career Corner: Tribologist, a Scientist of Friction

The force of friction between two surfaces that rub together can generate thermal energy and can wear down the surfaces. Rub your hands together vigorously. You can feel them heating up. That's thermal energy! Although you won't wear down your hands simply by rubbing them together now and then, other surfaces do break down over time due to this friction.

The force of friction between the bony socket and artificial joint often require second surgeries for patients.

For example, people who have hip replacements suffer a lot of wear on their artificial hip joint because of friction. The round surface of the artificial hipbone wears down over time as it rubs against the bony socket. It is a problem that often results in a second hip replacement. Tribologists, or scientists who study the force of friction, are working to invent new materials and methods for reducing friction and maximizing motion.

Speed and Direction

When an object moves, it travels over a distance in a certain period of time. This is the object's *speed*. Speed is calculated by dividing the distance traveled by the time it took to travel, or *s* = *d/t*. For example, suppose a dog runs 88 meters in 2 minutes to fetch a ball. To find the dog's speed, divide 88 meters by 2 minutes, which equals 44 meters per second, or 44 m/s. Units of speed include a "/" symbol pronounced as "per" because they are a division of distance and time units.

(Dog's speed) = *d* /*t*
= 88 meters / 2 minutes
= 44 m/s

To gain a better understanding of how an object moves, a direction is often included along with the speed. Together, speed and direction are an object's *velocity*.

Balanced and Unbalanced Forces

When the net force on an object adds up to zero, it is said that the forces are *balanced*. Balanced forces do not change an object's motion. This means that an object in motion stays in constant motion at the same speed and direction.

However, what happens if the net force is balanced on an object at rest? Recall the laptop sitting on the desk. Gravity and the normal force were balanced for a net force of zero. The laptop did not move. Objects at rest stay at rest when their forces are balanced.

Newton's first law of motion explains that an object's motion only changes when an unbalanced force acts upon the object. When the net force acting on an object does not add up to zero, the forces are *unbalanced*. Only unbalanced forces can cause a change in motion, or *acceleration*. This relates to Newton's second law of motion, which explains that a force acting on an object produces acceleration. The greater the mass of the object, the greater the amount of force needed to accelerate the object.

Think about pushing a box filled with books across the floor compared to pushing an empty box across the same floor. It takes a lot more force to push the box filled with books, right?

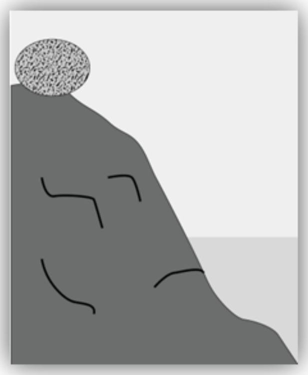
Look Out!

Acceleration is often used to describe an object that increases in speed. Although this is one meaning of the word, anything that changes its **velocity** accelerates. A change can mean the object speeds up, slows down, starts moving, stops moving, or changes direction. Acceleration is a change in speed or direction. For example, a carousel ride moves at the same speed throughout the ride. However, it is constantly accelerating because a carousel moves in a circle. It continuously changes direction. All objects that travel in a circle, despite their speed, are accelerating. Even Earth constantly accelerates as it travels around the Sun.

velocity: speed of an object in a given direction

What Do You Think?

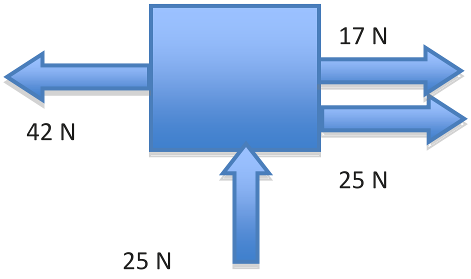
What happens to an object at rest when unbalanced forces act upon it? For example, describe what happens when the rock on the top of the hill is pushed?

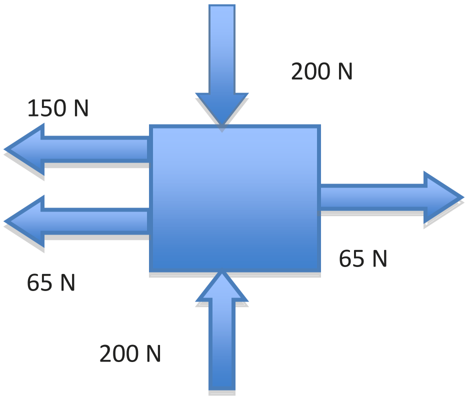


What Do You Know?

When forces interact, they produce an overall balanced or unbalanced net force on an object. Unbalanced forces result in change to an object's motion.

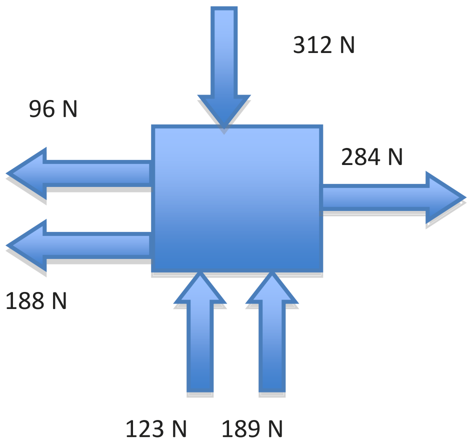
Determine the net force acting on each object below and on the next page. Be sure to include its direction and magnitude.

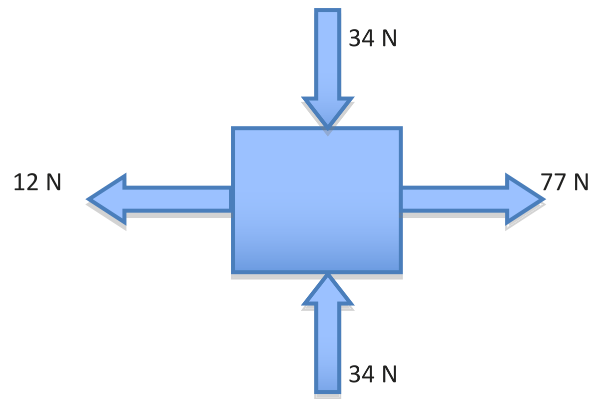




Net force:

Net Force:





Net force:

Net Force:

Connecting With Your Child: Unbalanced Forces in Action

To help your child learn more about forces and motion, set up a series of simple events in your backyard or at a park where you can demonstrate motion. If you are unable to travel to an outside area, you can spend time looking through books or magazines together to find examples of unbalanced forces and motion.

Suggestions for events include:

- Compete in a tug-of-war in which you and your child pull on opposite ends of a rope. Ask your child determine when the forces are balanced, when they are unbalanced, and the direction of the net force.
- Conduct a foot race in which you time your child traveling various distances: 100 meters, 50 meters, and 25 meters. Have your child calculate his or her speed for each distance.
- Participate in a challenge to push an exercise ball across a line. Set up two lines of masking tape approximately 12 meters apart. Place a large exercise ball in the middle between the lines. Stand on one side of the ball, and have your child stand on the opposite side of the ball. Each person has to try to push the ball over the line behind the opponent. Encourage your child to shout out when the forces are balanced.
- Follow an acceleration trail. Make a finish line at least 50 meters from the start. Yell out a variety of acceleration directions to your child. The directions should include, “An unbalanced force acts in your direction, accelerate speed, frictional force increases, accelerate accordingly (slow down), accelerate left, or accelerate right.” Your child should follow your directions, following a path from the start to the finish at various speeds.

Here are some questions to discuss with your child:

- How do you know when forces are balanced on an object?
- What are some ways to create an unbalanced net force on an object?
- How can you make an object accelerate without speeding it up?