PHYSICS

Week of 3.30

Directions

First, cut out and fold your flash cards (attached)
Then, study the flash cards you cut out.
Next, read the attached text.
Then, answer the attached 10 questions.
Finally, complete the attached worksheets

Mariana Bracetti Academy

Newton's 1st Law of Motion

***Newton's first law of motion** is also known as the law of **inertia**. It states that an object in motion stays in motion and an object at rest remains at rest unless acted on by an unbalanced outside force.*

Inertia

Inertia is a property of matter that describes the tendency of an object to resist changes in its state of motion. Inertia is dependent upon the mass of an object. The more massive the object, the greater its inertia.
According to Newton's first law, if a ball is rolled across the floor, it should continue rolling across the floor in a straight line forever unless it is acted on by some other unbalanced force. From experience, we know that balls do not continue rolling forever. But this is because they are acted upon by unbalanced forces like *friction*, which cause them to slow down and eventually stop.

Likewise, if a box is resting on the floor, it should continue to rest on the floor forever unless it is acted upon by some other unbalanced force. So, if someone came along and pushed the box, the box would move because the person provided an unbalanced force.

When an unbalanced force causes the motion of an object to change, we say there is a **net force** acting on the object. Net force is the sum of all forces acting on an object. If the sum is zero, the forces acting on the object are balanced and the motion of the object will not change. If the forces are unbalanced, however, a net force will be acting on the object.

Click play on the video below to learn more about Newton's laws of motion.

Newton's Second Law Of Motion

*Newton's second law relates the net force on an object (**F**) to the object's mass (**m**) and acceleration (**a**). Note that **F** and **a** are both vectors.*

As demonstrated by many everyday examples, a force can set a stationary object in motion. A force can also change the motion of a moving object. The net force on an object is the sum of all the forces acting on that object. An object may have two or more forces acting upon it, but if the forces cancel one another, then the net force will be zero.

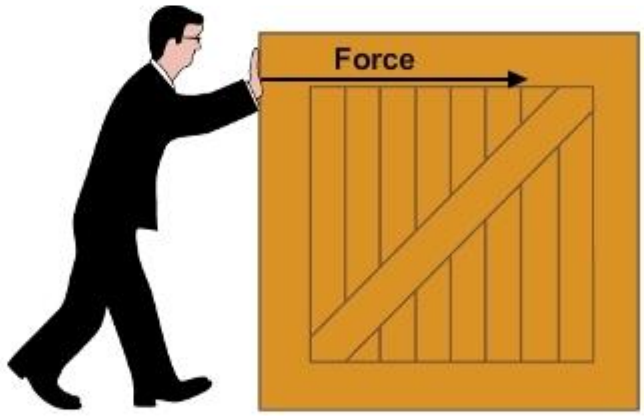
Newton's second law is:

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

Newton's second law states that an object that is subjected to a non-zero net force (often called an unbalanced force) will accelerate. When an object accelerates, its velocity changes over time. The acceleration is in the same direction as the net force, and its magnitude can be calculated by the equation shown above.

The SI unit for the magnitude of force is the newton (N). By substituting the SI units for mass and acceleration into the formula, it can be shown that 1 newton equals 1 kg·m/s^2.

Newton's second law describes a linear relationship between force and acceleration as long as the mass of the object in motion stays constant.



Suppose that a 10-kg box is being pushed to the right with a force of 12 N. Newton's second law can be used to calculate the box's acceleration.

Use the force and mass to find the acceleration.

$$a = \frac{F}{m} = \frac{12\ \mathrm{N}}{10\ \mathrm{kg}} = 1.2\ \mathrm{m/s^2}$$

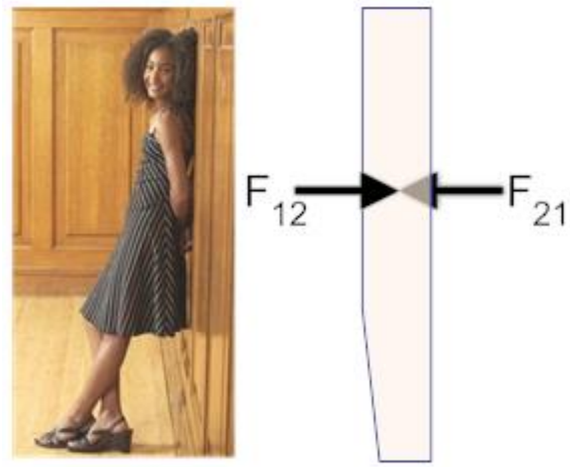
The box experiences an acceleration of 1.2 m/s^2 to the right.

Newton's Third Law of Motion

Newton's third law of motion *states that for every action there is an equal and opposite reaction.*

One way to think of Newton's third law is that whenever one object exerts a force on another object, the second object exerts an equal force on the first object but in the opposite direction.

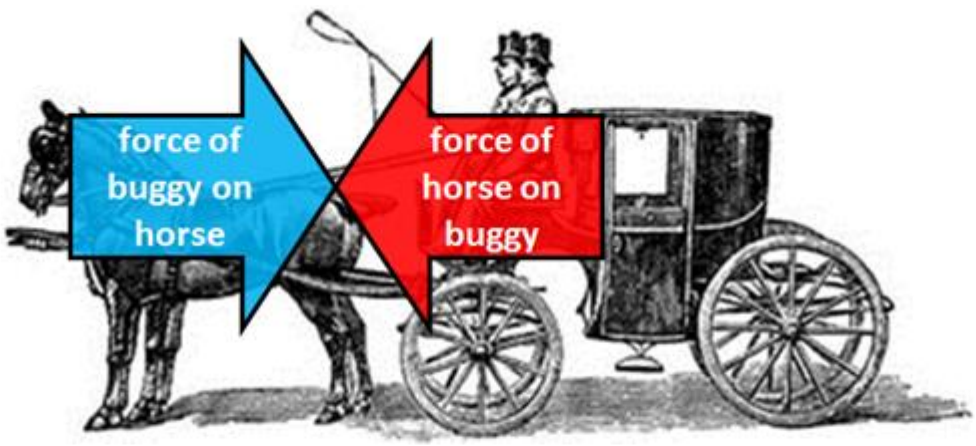
Example of Newton's Third Law



Consider a girl leaning up against a wall. The girl exerts a force on the wall by leaning against it, and the wall exerts a force on the girl that keeps her from falling over backward. These forces are equal in size but opposite in direction. If the girl turns around and starts pushing on the wall as hard as she can, as long as she doesn't knock over the wall, it pushes back with the exact same force.

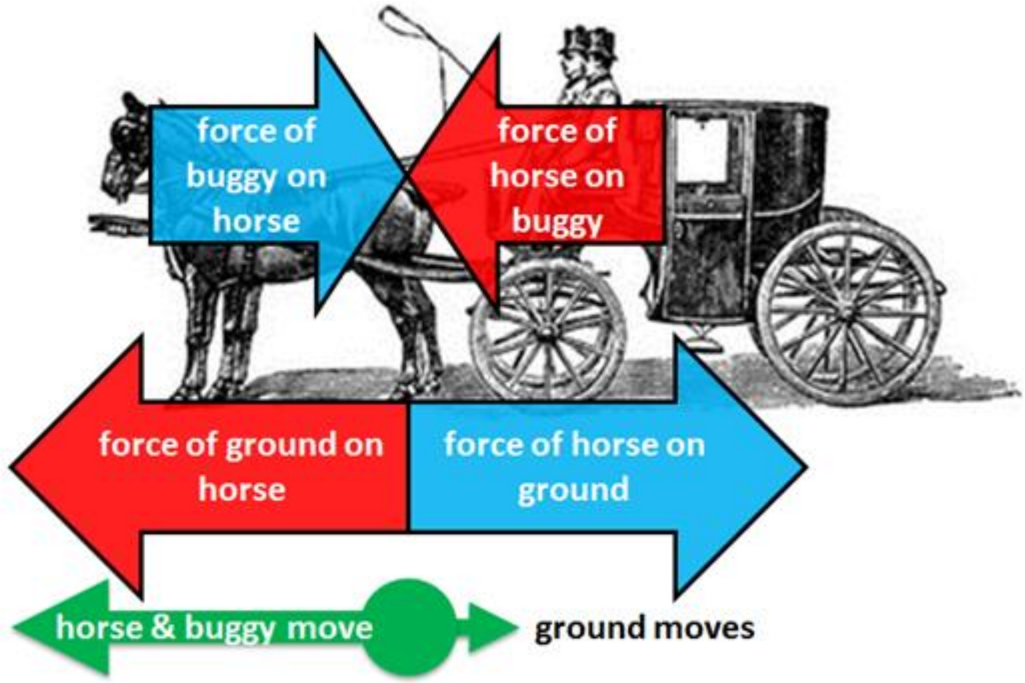
Newton's Third Law & Net Forces

Since Newton's third law suggests that all forces act in pairs, it's reasonable to wonder how anything ever moves. For example, if a horse is pulling forward on a buggy and the buggy is pulling back on the horse with the same force, the forces are balanced. And if the forces are balanced, how can anything move?



The short answer is that not all of the forces have been accounted for. If the only two forces involved were the horse pulling on the buggy and the buggy pulling back on the horse, neither would move. In this case, as in many others, it is very important to identify all of the forces and note which forces are acting on which objects in order to identify a net force.

In this example, the force of the buggy isn't the only force acting on the horse. As the horse walks, it pushes backward against the ground, and the ground pushes forward on the horse. These forces are also balanced, but they are acting on different objects. The horse's push acts on the ground, and the ground's push acts on the horse. The result is that the two are accelerated away from each other. However, since the Earth is so incredibly massive compared to the horse and buggy, the effect of the horse's push against it has almost no effect, while the horse and buggy visibly move forward.



Although the forces are balanced, the pushing forces between the horse and the ground allow each to move. The horse moves much, much more because it is much, much less massive.

Momentum

*An object's **momentum** is the product of its mass and velocity.*

The Momentum Equation

All moving objects have momentum. The more momentum an object has, the harder it is to stop. Momentum depends on the mass of the object and the velocity at which it is traveling. Momentum can be calculated using the following equation:

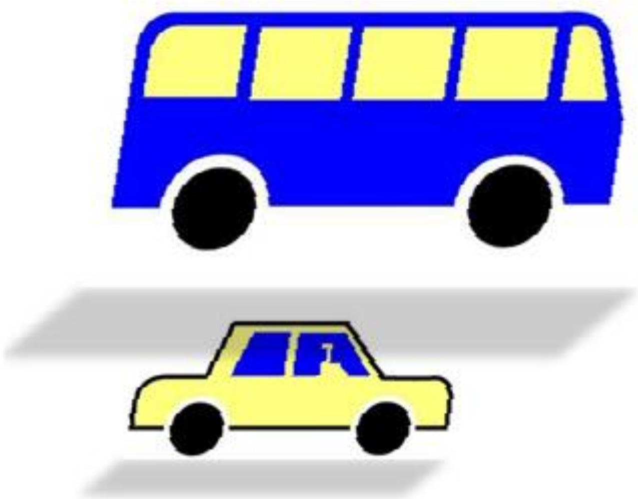
$$p = mv$$

where *p* is the object's momentum, *m* is its mass, and *v* is its velocity.

Momentum Depends on Mass and Velocity

As shown in the equation above, momentum is directly proportional to mass and velocity. Therefore, if either mass or velocity increases, momentum also increases. For two objects traveling at the same velocity, the object with more mass will have more momentum.

For example, suppose the bus and the car shown below are traveling at the same velocity. However, the bus is far more massive than the car. As a result, the bus has more momentum than the car, and it will be more difficult to stop.



Conservation of Momentum

Momentum is always conserved in a closed system. Therefore, the total momentum of a closed system is constant through time.

Newton's Second Law

Newton's second law of motion says that the only way an object can be accelerated is if a force is applied to it. So if an object is flying through space with a velocity *v*, this velocity will never change as long as no external forces are acting on the object. The law of momentum conservation says essentially the same thing: If no net force acts on a system, then the momentum of that system cannot change.
Mathematically, momentum is given by the formula $p = mv$, so the conservation of momentum can also be expressed in these terms:

[Total Initial Momentum] = [Total Final Momentum]

$$\boldsymbol{m_i v_i = m_f v_f}$$

If there are several objects in a system, the momentum of each object before an event must be added to the momentum of the other objects before the event. This sum will equal the sum after the event.

Example

Consider two billiard balls, Ball A and Ball B, colliding into each other from opposite directions. If the collision is "head on," the balls bounce off of each other and reverse their directions.

If friction and other forces that might affect the balls are neglected, the law of conservation of momentum can be applied:

$$m_i v_i = m_f v_f$$

Beware, however, for this formula is not quite as simple as it may appear. The balls are traveling in opposite directions, both before and after the collision. This means that one direction must be designated positive and the other direction must be designated negative.

Let us designate the direction of Ball A before the collision to be the positive direction. So the formula becomes:

$$m_A v_{Ai} + m_B(-v_{Bi}) = m_A(-v_{Af}) + m_B v_{Bf}$$

Elastic and Inelastic Collisions

When billiard balls collide, they bounce away from each other. If two wads of bubble gum should collide, however, they would likely stick together. Momentum can be conserved in both situations. The collisions differ, however, in elasticity.

In an elastic collision, the total kinetic energy of the colliding masses is conserved. In an inelastic collision, some or all of the total kinetic energy is lost. Often the energy is lost as heat. It may also be lost to the deformation of one or more of the colliding masses. An automobile fender that deforms in a car crash is one example of this type of energy conversion.

In a completely inelastic collision, the colliding particles stick together. A thrown dart that sticks into a dart board is an example of a completely inelastic collision.

Mechanics and Motion

PHYSICS STUDIES MANY DIFFERENT TYPES OF MOTION AND FORCES.

Motion is one of the key topics in physics. Everything in the universe moves. It might only be a small amount of movement and very very slow, but movement does happen. Don't forget that even if you appear to be standing still, the Earth is moving around the Sun, and the Sun is moving around our galaxy. The movement never stops. Motion is one part of what physicists call **mechanics**. Over the years, scientists have discovered several rules or **laws** that explain motion and the causes of changes in motion. There are also special laws when you reach the **speed of light** or when physicists look at very small things like atoms.

Speed it Up, Slow it Down

The physics of **motion** is all about forces. **Forces** need to act upon an object to get it moving, or to change its motion. Changes in motion won't just happen on their own. So how is all of this motion measured? Physicists use some basic terms when they look at motion. How fast an object moves, its speed or **Velocity**, can be influenced by forces. (Note: Even though the terms 'speed' and 'velocity' are often used at the same time, they actually have different meanings.)

Acceleration is a twist on the idea of velocity. Acceleration is a measure of how much the velocity of an object changes in a certain time (usually in one second). Velocities could either increase or decrease over time. **Mass** is another big idea in motion. Mass is the amount of something there is, and is measured in grams (or kilograms). A car has a greater mass than a baseball.

THIS SOLID GOLD CAR HAS A MASS, A VELOCITY, AND A RATE OF ACCELERATION.

Simple and Complex Movement

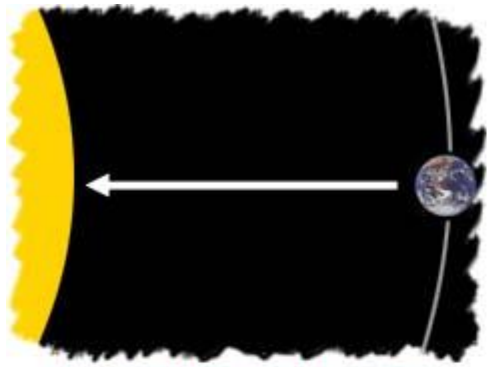
There are two main ideas when you study mechanics. The first idea is that there are **simple movements**, such as if you're moving in a straight line, or if two objects are moving towards each other in a straight line. The simplest movement would be objects moving at constant velocity. Slightly more complicated studies would look at objects that speed up or slow down, where forces have to be acting.

There are also more **complex movements** when an object's direction is changing. These would involve curved movements such as circular motion, or the motion of a ball being thrown through the air. For such complex motions to occur, forces must also be acting, but at angles to the movement.

In order to really understand motion, you have to think about forces, acceleration, energy, work, and mass. These are all a part of mechanics.

Forces of Nature

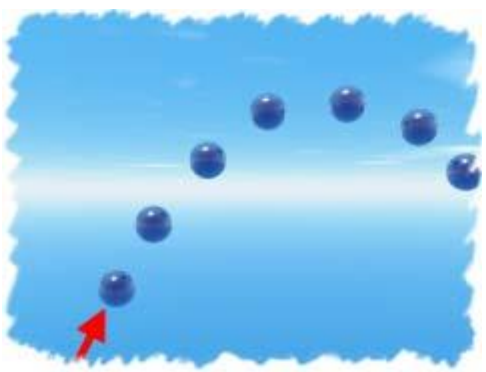
Forces are a big part of physics. Physicists devote a lot of time to the study of **forces** that are found everywhere in the universe. The forces could be big, such as the pull of a star on a planet. The forces could also be very small, such as the pull of a nucleus on an electron. Forces are acting everywhere in the universe at all times.



THE GRAVITATIONAL PULL OF THE SUN IS ONLY ONE TYPE OF FORCE.

Examples of Force

If you were a ball sitting on a field and someone kicked you, a force would have acted on you. As a result, you would go bouncing down the field. There are often many forces at work. Physicists might not study them all at the same time, but even if you were standing in one place, you would have many forces acting on you. Those forces would include **gravity**, the force of air particles hitting your body from all directions (as well as from wind), and the force being exerted by the ground (called the **normal force**).



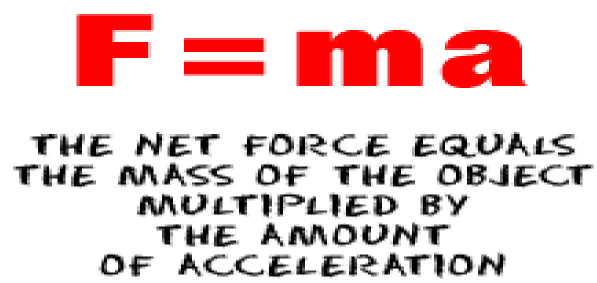
THE FORCE OF GRAVITY CAUSES THE BALL TO RETURN TO THE SURFACE.

Let's look at the forces acting on that soccer ball before you kicked it. As it sat there, the force of gravity was keeping it on the ground, while the ground pushed upward, supporting the ball. On a molecular level, the surface of the ball was holding itself together as the gas inside of the ball tried to escape. There may have also been small forces trying to push it as the wind blew. Those forces were too small to get it rolling, but they were there. And you never know what was under the ball. Maybe an insect was stuck under the ball trying to push it up. That's another force to consider.

If there is more than one force acting on an object, the forces can be added up if they act in the same direction, or subtracted if they act in opposition. Scientists measure forces in units called **Newtons**. When you start doing physics problems in class, you may read that the force applied to the soccer ball (from the kick) could be equal to 12 Newtons.

A Formula of Force

There is one totally important formula when it comes to forces, **F = ma**. That's all there is, but everything revolves around that formula. "F" is the total (net) **force**, "m" is the object's **mass**, and "a" is the **acceleration** that occurs. As a sentence, "The net force applied to the object equals the mass of the object multiplied by the amount of its acceleration." The net force acting on the soccer ball is equal to the mass of the soccer ball multiplied by its change in velocity each second (its **acceleration**). Do you remember the wind gently blowing on the soccer ball? The force acting on the ball was very small because the mass of air was very small. Small masses generally exert small forces, which generally result in small accelerations (changes in motion).

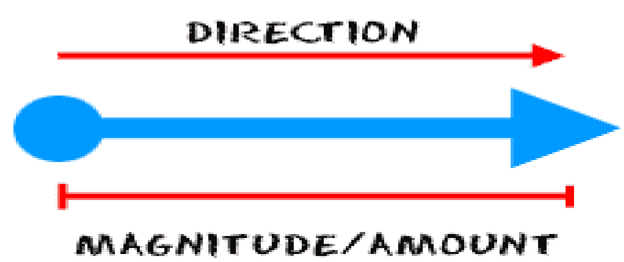


Forces and Vectors

We cover the details of **vectors** on another page. A vector can be used to represent any force. A **force vector** describes a specific amount of force that is applied in a specific direction. If you kick that soccer ball with the same force, but in different directions, and you get different results...

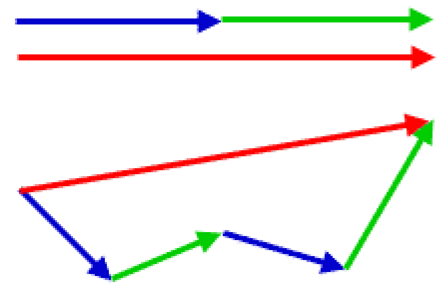
Vector Basics

Force is one of many things that are vectors. What the heck is a vector? Can you hold it? No. Can you watch it? No. Does it do anything? Well, not really.
A **vector** is a numerical **value** in a specific **direction**, and is used in both math and physics. The force vector describes a specific amount of **force** and its direction. You need both value and direction to have a vector. Both. Very important. Scientists refer to the two values as direction and **magnitude** (size). The alternative to a vector is a scalar. **Scalars** have values, but no direction is needed. Temperature, mass, and **energy** are examples of scalars.



When you see vectors drawn in physics, they are drawn as arrows. The direction of the arrow is the direction of the vector, and the length of the arrow depends on the magnitude (size) of the vector.

Real World Vectors



Imagine a situation where you're in a boat or a plane, and you need to plot a course. There aren't streets or signs along the way. You will need to plan your navigation on a map. You know where you're starting and where you want to be. The problem is how to get there. Now it's time to use a couple of vectors. Draw the vector between the two points and start on your way. As you move along your course, you will probably swerve a bit off course because of wind or water currents. Just go back to the map, find your current location, and plot a new vector that will take you to your destination. Captains use vectors (they know the speed and direction) to plot their courses.

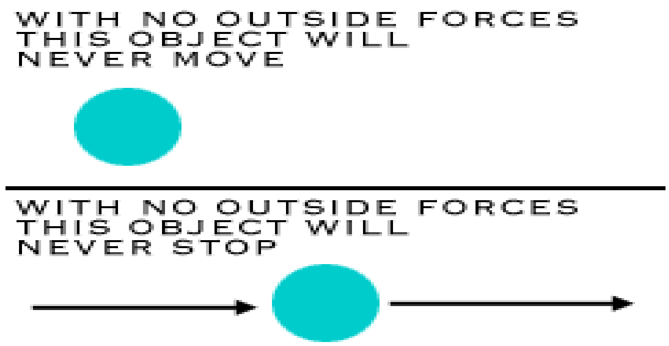
Combining Vectors

We're hoping you know how to add and subtract. Scientists often use vectors to represent situations graphically. When they have many vectors working at once, they draw all the vectors on a piece of paper and put them **end to end**. When all of the vectors are on paper, they can take the starting and ending points to figure out the answer. The final line they draw (from the start point to the end point) is called the **Resultant vector**. If you don't like to draw lines, you could always use geometry and trigonometry to solve the problems. It's up to you. Unlike normal adding of numbers, adding vectors can give you different results, depending on the direction of the vectors.

Newton's Laws of Motion

There was this fellow in England named **Sir Isaac Newton**. A little bit stuffy, bad hair, but quite an intelligent guy. He worked on developing **calculus** and **physics** at the same time. During his work, he came up with the three basic ideas that are applied to the physics of most **motion** (NOT **modern physics**). The ideas have been tested and verified so many times over the years, that scientists now call them **Newton's Three Laws of Motion**.

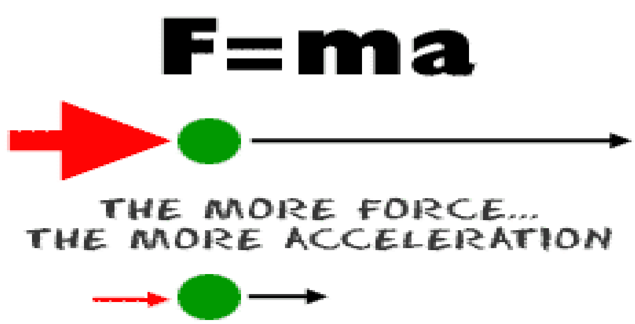
First Law



The first law says that an object at **rest** tends to stay at rest, and an object in **motion** tends to stay in motion, with the same direction and **speed**. Motion (or lack of motion) cannot change without an unbalanced **force** acting. If nothing is happening to you, and nothing does happen, you will never go anywhere. If you're going in a specific direction, unless something happens to you, you will always go in that direction. Forever.

You can see good examples of this idea when you see video footage of **astronauts**. Have you ever noticed that their tools float? They can just place them in space and they stay in one place. There is no interfering force to cause this situation to change. The same is true when they throw objects for the camera. Those objects move in a straight line. If they threw something when doing a spacewalk, that object would continue moving in the same direction and with the same speed unless interfered with; for example, if a planet's **gravity** pulled on it (Note: This is a really really simple way of descibing a big idea. You will learn all the real details - and math - when you start taking more advanced classes in physics.).

Second Law



The second law says that the **acceleration** of an object produced by a net (total) applied force is directly related to the **magnitude** of the force, the same direction as the force, and inversely related to the mass of the object (inverse is a value that is one over another number... the inverse of 2 is 1/2). The second law shows that if you exert the same force on two objects of different mass, you will get different accelerations (changes in motion). The effect (acceleration) on the smaller mass will be greater (more noticeable). The effect of a 10 newton force on a baseball would be much greater than that same force acting on a truck. The difference in effect (acceleration) is entirely due to the difference in their masses.

Third Law

The third law says that for every action (force) there is an equal and opposite reaction (force). Forces are found in pairs. Think about the time you sit in a chair. Your body exerts a force downward and that chair needs to exert an equal force upward or the chair will collapse. It's an issue of symmetry. Acting forces encounter other forces in the opposite direction. There's also the example of shooting a cannonball. When the cannonball is fired through the air (by the explosion), the cannon is pushed backward. The force pushing the ball out was equal to the force pushing the cannon back, but the effect on the cannon is less noticeable because it has a much larger mass. That example is similar to the kick when a gun fires a bullet forward.

Definition:

a collision in which the total momentum and kinetic energy are the same before and after the collision

Vocabulary Word:

elastic collision

Identify this physical law:

$$m_1 v_{1_i} + m_2 v_{2_i} = m_1 v_{1_f} + m_2 v_{2_f}$$

Law of Conservation of Momentum

Definition:

a push or a pull needed to start motion, stop motion, or change the direction of motion

Vocabulary Word:

force

Identify the physical law that states that the total momentum of a system is the same before and after a collision.

law of conservation of momentum

Definition:

a change in velocity over time

Vocabulary Word:

acceleration

Formula:

Force = ? × Acceleration

Mass

True or False:

An object cannot move unless it is being acted on by a net outside force.

False

True Statement:
An object's motion cannot change unless it is being acted on by a net outside force.

Formula:

? = mass × velocity

momentum

Formula:

Force = Mass × ?

Acceleration

Identify this law of motion: $$\sum \vec{F} = m\vec{a}$$	Newton's 2nd Law

Newton's Laws of Motion & Momentum

Question 1 .

According to the principle of conservation of momentum,

- **A.** in an open system, the total amount of momentum of the objects is conserved.
- **B.** the amount of momentum of all the objects in the universe is constant.
- **C.** in a closed system, the speed of any two colliding objects will remain constant.
- **D.** in a closed system, an object's momentum before a collision will equal its momentum after the collision.

Question 2 .

Kiku and Alex are wearing rollerskates. Kiku is right behind Alex, and both skaters are standing still. Alex weighs more than Kiku. If Kiku gives Alex a forward push, which of the following will be true after the push? *Assume that this is a closed system and friction can be ignored.*

- **A.** Alex's momentum will be greater than Kiku's momentum.
- **B.** Alex's speed will be greater than Kiku's speed.
- **C.** Kiku's momentum and Alex's momentum will add up to zero.
- **D.** Kiku's velocity and Alex's velocity will add up to zero.

Question 3 .

Lou is trying out two different baseball bats. The bats are identical except for their weights: one bat weighs 27 ounces and the other weighs 24 ounces. If Lou swings both bats with the same speed and all other conditions are equal, which of the following is true?

- **A.** A ball hit by the lighter bat will travel faster than a ball hit by the heavier bat.
- **B.** There is not enough information to determine which bat will impart more velocity on the ball.
- **C.** A ball hit by the heavier bat will travel faster than a ball hit by the lighter bat.
- **D.** A ball hit by either bat will have the same velocity.

Question 4 .

Josh is playing pool. During his shot, an orange billiard ball with a momentum of 170 $g \cdot m/s$ hits a green billiard ball at rest. After the collision, the orange billiard ball continues in the same direction with a momentum of 35 $g \cdot m/s$. What is the momentum of the green ball right after the collision?

- **A.** 35 $g \cdot m/s$
- **B.** 205 $g \cdot m/s$
- **C.** 0 $g \cdot m/s$
- **D.** 135 $g \cdot m/s$

Question 5 .

Naoki's bicycle has a mass of 8 kg. If Naoki sits on her bicycle and starts pedaling with a force of 96 N, causing an acceleration of 1.5 m/s^2, what is Naoki's mass?

- **A.** 2 kg
- **B.** 64 kg
- **C.** 56 kg
- **D.** 12 kg

Question 6 .

An object with a mass of 8.9 kg experiences a force of 16.02 N. What is the acceleration of the object?

- **A.** 142.6 m/s^2
- **B.** 2.3 m/s^2
- **C.** 1.8 m/s^2
- **D.** 14.22 m/s^2

Question 7 .

Danielle is designing a system to help race cars slow safely and rapidly at her local racetrack. The racetrack is a straight, 1,000-meter stretch of asphalt. Half of the track is devoted to races and the other half is designed to let cars decelerate after crossing the finish line.

Danielle has designed a pair of small parachutes that are automatically released out the back of a car once it crosses the finish line. When her system works properly, the race car driver does not need to apply the brakes to bring the car to a stop before running out of track.

When Danielle tests a prototype of her design, it brings a race car to a stop 275 meters behind the finish line. After taking some measurements, she decides that her design causes the driver to experience too much force. To correct this, she could

- **A.** make the parachutes smaller in order to decrease the drag forces on the car and bring it to a stop 400 meters after crossing the finish line.
- **B.** remove one of the parachutes in order to decrease the drag forces on the car and bring it to a stop 550 meters after crossing the finish line.
- **C.** make the parachutes larger in order to increase the drag forces on the car and bring it to a stop 200 meters after crossing the finish line.
- **D.** add a third parachute in order to increase the drag forces on the car and bring it to a stop 175 meters after crossing the finish line.

Question 8 .

Directions: Select each correct answer. More than one answer may be correct.

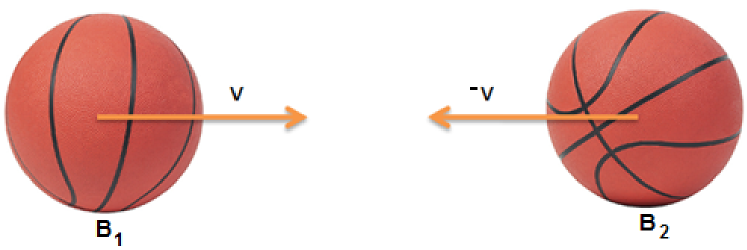
In which of the following scenarios is the momentum before the interaction the same as the momentum after the interaction?

Assume there are no net outside forces acting on each system.

- ☐ A cue ball rolls across a pool table and collides with another billiard ball. The cue ball stops, and the other ball rolls away.
- ☐ A figure skater holds a sandbag in the middle of an ice rink. When the skater throws the bag, the skater moves in the opposite direction of the bag.
- ☐ A coasting bicyclist moves along a sidewalk. The bicycle and rider collide with a wheeled trash can, and all three move together along the sidewalk.

Question 9 .

Two basketballs of equal mass are rolling toward each other at constant velocities. The first basketball (B_1) has a velocity of 1.8 m/s, and the second basketball (B_2) has a velocity of -1.8 m/s.



If these basketballs have a perfectly elastic collision, B_1 will have a final velocity of _______, and B_2 will have a final velocity of _______.

- **A.** 0 m/s; 0 m/s
- **B.** -3.6 m/s; 3.6 m/s
- **C.** -1.8 m/s; 1.8 m/s
- **D.** 0.9 m/s; -0.9 m/s

Question 10 .

How is acceleration related to force when mass is constant, according to Newton's second law of motion?

- **A.** The acceleration is directly proportional to the net force.
- **B.** The acceleration is inversely proportional to the square root of the net force.
- **C.** The acceleration is inversely proportional to the net force.
- **D.** The acceleration is directly proportional to the square root of the net force.