Name: ____ Date: _______

PHYSICS
UNIT 2: FORCES & ACCELERATION

NEWTON'S LAWS OF MOTION

Natural laws describe how matter and energy behave in our universe. The processes that are described by natural laws always occur regardless of physical state, place, time, or motion. **Newton's Laws of Motion** are natural laws that describe how forces affect the motion of objects in our universe.

Newton's 1ST Law of Motion

Newton's 1st Law of Motion: **"Law of Inertia",** *an object will maintain its original state of motion unless acted upon by an external unbalanced force. An object will maintain a constant velocity (straight-line, uniform rate of motion) unless acted upon by an external unbalanced force.*

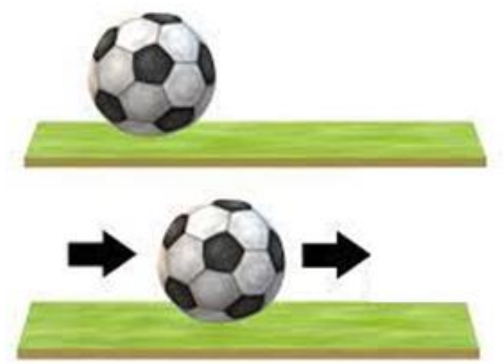
Newton's 1st Law tells us that objects accelerate (change their motions) when acted upon by external force, specifically, an unbalanced force. When an unbalanced force acts upon an object, the object will accelerate by getting faster, or getting slower, or change direction. Conversely, when an object is acted upon by balanced forces (net force = 0), no acceleration will happen. When at a state of balanced forces, the object will retain its original state of motion, no changes in velocity will happen. Newton's 1st Law also describes how inertia affects motion of objects. An object will try to resist forces that act upon it and try to keep its original state of motion.

What really happens to the motion of objects because of Newton's 1st Law?

- All objects at rest (motionless, v = 0 m/s) will remain at rest until it is disturbed by an unbalance force to get it moving.
- All objects in motion will move in a straight-line direction at the same velocity forever unless a force (a push or pull by another object) causes the object to speed up, slow down, or change direction.
- Objects "want to keep their original states of motion."
- Objects resist the forces that accelerate them. Greater masses resist forces more strongly.

Illustrative Example 1

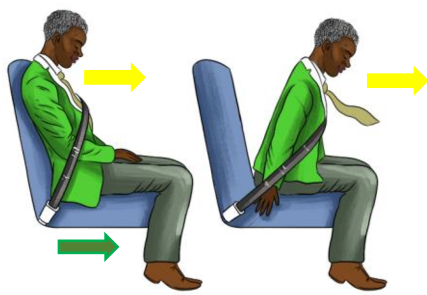
Objects have inertia. Objects want to keep their original states of motion. Objects want to "keep doing what they are already doing." Objects will keep their original states of motion until an unbalanced external force acts upon them and accelerates them.



The soccer ball is at rest. It wants to remain at rest. It will remain at rest until an external unbalanced force gets it to move.

The soccer ball is in motion. It wants to remain in motion and move at constant velocity in a straight line until an external unbalanced force gets it to accelerate (get faster, get slower, or change direction).

The shopping cart was initially motionless. It would have remained motionless (doing what it was already doing) until the man pushed it with a force. The force caused the shopping cart to move away in a straight line at a new velocity.



The man was a passenger on a bus. Initially, the bus was moving, but suddenly the bus came to a stop. The man's body folded forward. The bus was acted upon by the external force to get it to stop. The man's body was not. His inertia kept his body moving forward in a straight line at the same velocity as before the bus stopped.

The rock has a very, very large mass. Therefore, the rock has a very, very large inertia. The rock will resist forces that try to accelerate it. Even though the man is pushing on the rock with a force, the rock will remain motionless because its mass is so large that it resists the force trying to move it.

Newton's 2ND Law of Motion

Newton's 2nd Law of Motion: $a = \frac{F}{m}$ **"Law of acceleration and mass"**. The acceleration experienced by an object is proportional to the magnitude of the force (F) causing the acceleration and inversely proportional to the mass of the object being accelerated.

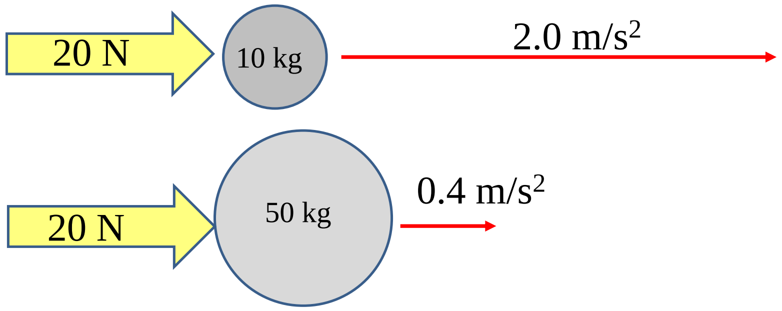
Newton's 2nd Law describes how much an object may accelerate when an unbalanced force acts upon the object. A more massive object requires more force to change its state of motion (accelerate it). Conversely, a less massive object requires lesser force to change its state of motion. A stronger force will accelerate the object more. A weaker force will accelerate the object less.

What really happens to the motion of objects because of Newton's 2nd Law?

- A stronger force will cause a greater acceleration; a weaker force will cause a lesser acceleration.
- The greater the mass of the object, the greater the force required to accelerate the object.
- The lesser the mass of the object, the lesser the force required to accelerate the object.
- If two objects of unequal mass (one greater, one lesser) are affected by the same force, the object with the greater mass experiences a lesser acceleration, the object with the lesser mass experiences the greater acceleration.

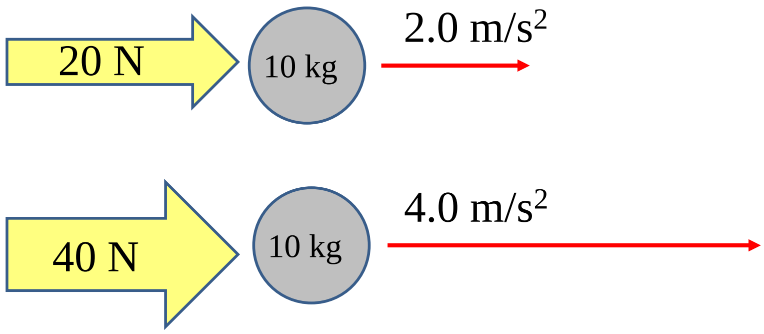
Illustrative Example 2

Two objects of unequal mass are pushed by equal magnitude of force. **Acceleration is inversely proportional to the mass of the object.** The greater the mass, the greater the inertia of the object, the greater the resistance to acceleration. The smaller the mass, the lesser the inertia of the object, the lesser the resistance to acceleration.



The object with the smaller mass has the greater acceleration. The object with the greater mass has the lesser acceleration.

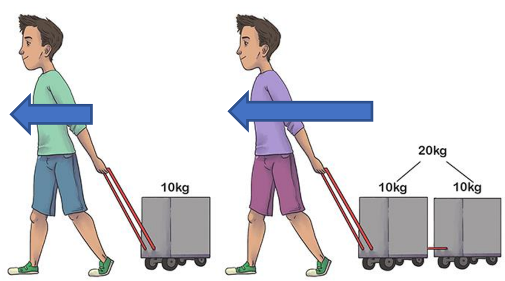
Two objects of equal mass are pushed by unequal magnitudes of force. **Acceleration is proportional to the net force acting upon the object.** The stronger the unbalanced force applied to the object, the greater the acceleration. The weaker the unbalanced force applied to the object, the lesser the acceleration.



The object pushed by the weaker force has the lesser acceleration. The object pushed by the stronger force has the greater acceleration.

Illustrative Example 3

Acceleration is proportional to the net force applied to the object and inversely proportional to the mass of the object.



Twins Bobby and Billy are pulling boxes across the floor. Bobby is pulling one 10-kg box. Billy is pulling two 10-kg boxes, or 20 kg total. Billy must pull his boxes with 2-times the force as Bobby to move equally fast as Bobby.

Lorenzo putts the golf ball on the green into the cup. He uses a weak force and only taps the ball with the putter club. As a consequence, the ball has a slow acceleration and rolls slowly a very short distance towards the cup.

Paul drives the golf ball from the tee across the field. He uses a strong force and slams the ball with the driver club. As a consequence, the ball has a very fast acceleration and flies quickly through the air a very long distance.

Newton's 3rd Law of Motion

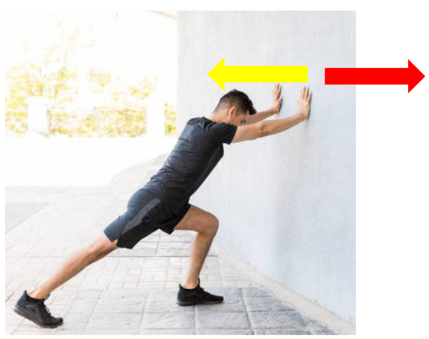
Newton's 3rd Law: "Law of paired forces", when two objects interact, the forces acting on the two objects are paired. The force applied by one object on the second is equal in magnitude and opposite in direction to the force applied by the second object onto the first.

Newton's 3rd Law describes an **action force and its reaction force counterpart**. At the point of contact or the point of interaction, the forces acting upon both objects is equal in magnitude and opposite in direction. When an object pushes on another, the other object pushes back. When an object pulls on another, the other object pulls back.

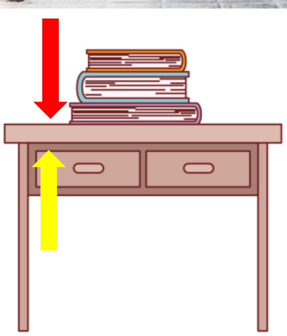
What really happens to the motion of objects because of Newton's 3rd Law?

- Object 1 pushes or pulls with a force upon object 2, object 2 pushes or pulls upon object 1, but in opposite directions.
- If you push on an object, the object pushes back with equal force in opposite direction.
- If you pull on an object, the object pulls back with equal force in opposite direction.

Illustrative Example 4

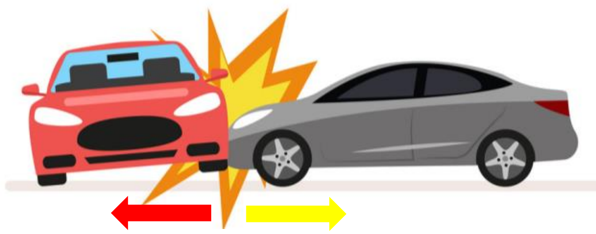


The man pushes on the wall with a force to the right. The wall is pushing back on the man's hands to the left. The force of the man's push is equal in magnitude and opposite in direction to the push back force by the wall. The point of interaction is at the wall's surface.



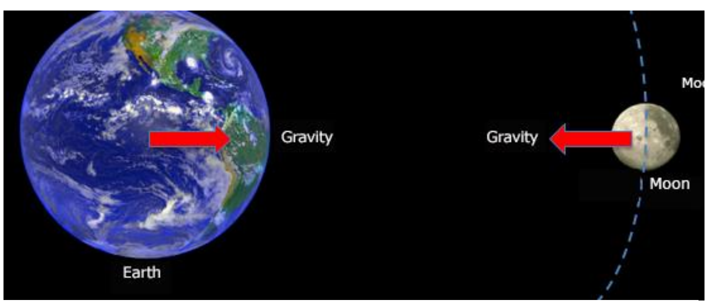
The weight of the books pressing down on the surface of the desk (gravity force) is equal in magnitude and opposite to the desk pushing back on the books (normal force). The point of interaction is at the desktop.

The force of the baseball hitting the baseball bat is equal in magnitude and opposite in direction to the force of the baseball bat hitting the baseball. The point of interact is where the baseball touches the bat.



The force of impact between the two automobiles is paired regardless of the speed of either vehicle just before the impact. The force of the gray auto crashing into the red auto is equal in magnitude and opposite in direction to the force of the red auto pushing back on the gray auto.

Gravitional attraction is an action-at-a-distance force. Even though the Earth and Earth's moon are not touching, they are still interacting through forces.



The gravitational attraction between the Earth and Earth's moon is equal and opposite in direction. The force of the Earth pulling on the moon is equal in magnitude and opposite in direction to the force of the moon pulling back on the Earth. Gravitational attraction is always equal and opposite regardless of the masses or differences in masses of the objects.

The force inside the gun forcing the bullet out of the muzzle is equal in magnitude and opposite in direction of the force of the bullet pushing back on the gun. The gun will recoil (jerk back and shake) by the force of the bullet at is leaves the muzzle.