Section 2.7 Newton's First Law of Motion

Inertia - the ability of an object to **resist a change in its state of motion**.
- The greater mass, the greater the inertia.

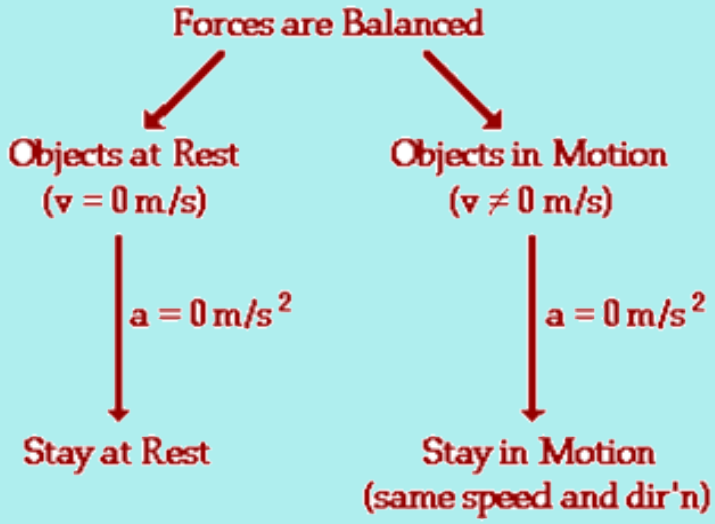
Newton's First Law of Motion or Newton's Law of Inertia has two parts:

1) **objects at rest tend to stay at rest unless acted upon by an external, unbalanced force.**

2) **objects in motion tend to stay in motion in a straight line at a constant speed unless acted upon by an external, unbalanced force.**

In other words,

If $F_{net} = 0$, then the object is at rest or the object is moving at a fixed speed in a straight line.



Examples of Part 1 **Objects at rest tend to stay at rest unless acted upon by an external, unbalanced force.**

- Card and coin on glass.
- Magic Trick: Silk cloth pulled from table leaving the dishes on the table.

Examples of Part 2 **Objects in motion tend to stay in motion in a straight line at a constant speed unless acted upon by an external, unbalanced force.**

- Riding in a car as it moves at a constant speed. The car suddenly stops.

What happens?

Why are seatbelts important?

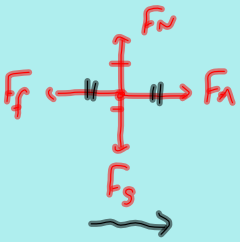
During an accident you will continue to stay in motion until an external, unbalanced force acts upon you. In the best case scenario, the seat belt will be that external, unbalanced force and hopefully it will reduce the seriousness of the accident for you. At worst, the external, unbalanced force is a telephone pole or windshield, in which case you will incur injuries.

Recall that the First Law was basically in two parts:
(1) objects at rest tend to stay that way and
(2) objects in uniform motion tend to stay that way, unless an external unbalanced force acts on it.

With this in mind, use the First Law to explain each

- blood rushes from your head to your feet when riding on a descending elevator which suddenly stops.
- the head of a hammer can be tightened onto the wooden handle by banging the bottom of the handle against a hard surface.
- to dislodge ketchup from the bottom of a ketchup bottle, the bottle is often turned upside down, thrust downward at a high speed and then abruptly halted.
- headrests are placed in cars to prevent whiplash injuries during rear-end collisions.
- while riding a skateboard (or wagon or bicycle), you fly forward off the board when hitting a curb, a rock or another object which abruptly halts the motion of the skateboard.

Consider the following situation: You see a car pass by at a fixed speed in a straight line. Are there any forces acting on the car?



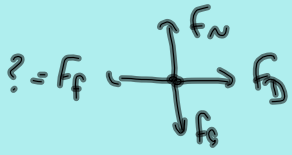
$F_{net} = 0$
$F_{net_x}: F_A - F_f$
$0 = F_A - F_f$
$F_f = F_A$

There can be forces acting on an object that is moving in a straight line at a fixed speed but THERE CAN NOT BE AN UNBALANCED FORCE. In other word, Fnet = 0 N.

Example:
You see an unfortunate (out-of-gas) driver pushing his car at a fixed speed along a level straight road. Being a keen physics student, you insert a 'special' set of bathroom scales between the driver's hands and the car and discover that he is pushing with a force of 400 N. What is the force of friction?

Fixed speed in a straight line implies $F_{net} = 0$
$F_D = 400$ N
$F_f = ?$

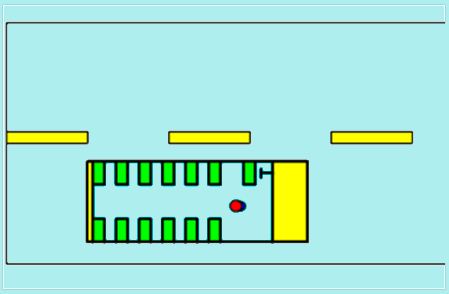
$F_D + F_f = F_{net}$
$F_f = F_{net} - F_D$
$F_f = 0$ N $- 400$ N
$F_f = -400$ N



Inertial and Non-inertial Frames of Reference

A bus: Two different examples.

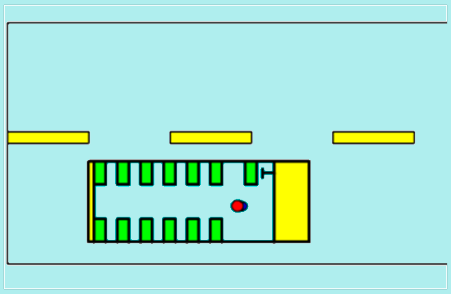
I. Bus is in uniform motion down a very smooth road. So, it has a constant speed in a straight line.



A small ball placed on floor of bus. What will happen?

It stay there b/c there are not external unbalanced forces acting on object.

II. Bus is in motion and driver very slightly touches the brake.



What happens now?

Ball will roll forward b/c there is no external unbalanced force acting on the ball.

Inertial and Non-inertial Frames of Reference

Remember, a frame of reference is a place from which motion is observed.

- **An inertial frame of reference is one in which Newton's First Law is valid.**

Ex: When there is **no motion** or When there is **uniform motion** (Constant speed in straight line)

- **A Non-Inertia frame of reference is one where Newton's First Law is NOT Valid.**

Ex: When there is acceleration involved in the frame of reference.

Example: Consider tossing an apple in a parked car or in a car moving at a fixed speed down a straight level road. The motion of the apple **to you** was identical in each case.

Newton's First Law makes it all clear. When the apple leaves your hand, it has an upward motion which you gave it and a horizontal motion due to the motion of the car. As stated in the first law, the apple has a tendency to maintain this motion because there is no external unbalanced force on it. It therefore comes back to your hand very nicely because it and your hand have had the same horizontal fixed speed.

Question: Imagine you are in a space shuttle orbiting earth where objects appear "weightless" and can float about the cabin. You are given two identical looking packages but one is empty and the other has a heavy object inside. Describe how you could use the Law of Inertia to tell the two packages apart.

Newton's First Law of Motion has several significant implications:

1. An **external, unbalanced force is required to change the velocity of an object**. Internal forces have no affect on an object's motion.

2. The **external force must be unbalanced** if it is to affect the motion of the object.

3. Objects at rest will not move unless an external, unbalanced force acts upon it.

4. Objects in motion will not stop unless an external, unbalance force acts upon it. For example, a car moving into a flat icy curve will tend to continue in a straight line, off the side of the road.