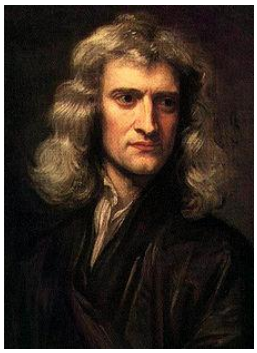
Newton's Laws



Newton's Laws of Motion, as written in Sir Isaac Newton's book "the Principia", are actually very difficult to read.

● At the time, Newton didn't care too much about the "readability" of his book. He just wanted to get the stuff put down on paper.
● As a result, the way we state his laws today, and the formulas we use, are in some ways different from the way he originally wrote them. However, they still mean the same thing. He actually wrote the laws in a specific order for a specific reason.
● As we go through the laws, you should realize that he builds one on top of the other.

Newton's First Law (The Law of Inertia)

"A body at rest will remain at rest and a body in motion will remain in motion with the same speed and direction unless acted upon by a net force."

Note:
The term "net force" is key here. For example, if you have a book that is at rest on a table top, there are two forces acting on the book: a normal force and a gravitational force. However, since the normal force and gravitational force cancel each other out there is no net force, thus the book remains at rest. It is not until a net force is applied to the book that the book will begin moving.

In a nutshell, the first law can be written as:

$$\textit{If}$$
$$F_{NET} = 0$$

$$\textit{Then}$$
$$\Delta v = 0$$

● If there is no net force then there will be no change to the velocity of the object.

Newton's Second Law (The Law of Motion)

"The acceleration of an object is directly proportional to the net force causing the acceleration, and is inversely proportional to the mass of the object."

Note:
Once again the term "net force" is key here. For example, the object must accelerate in the direction of the net force, otherwise there would need to be some mysterious force that we didn't account for in our calculations. Thus, the acceleration of the object must be directly proportional to the net force acting on the object.

In a nutshell, the second law can be written as:

$$a \propto F_{NET}$$

$$a \propto \frac{1}{m}$$

● The little swimming fish symbol (α) is the Greek letter "alpha" and means "varies with" in math.

● As shown above, the acceleration of an object varies directly with the net force causing the acceleration.
● What this means is that if we double the acceleration, we double the force. Similarly, if we cut the acceleration in half, we cut the amount of force in half.

● The acceleration of an object varies inversely with the mass of the object.
● This means that if we double the acceleration, we will be removing half the mass, and if we half the acceleration, we will be doubling the mass.

When we look at the second law from a formula perspective, we find that:

$$a = \frac{F}{m}$$

When we talk about acceleration, it is implied that we are dealing with a net force since an object can only accelerate in the direction of a net force. It doesn't make sense for an object to accelerate in a direction other than the direction of the net force does it? Because of this, when dealing with forces and accelerations in the same formula we usually drop the word NET underneath the F. Rearranging this formula we find that:

$$\boxed{\begin{aligned} a &= \frac{F}{m} \\ ma &= F \\ F &= ma \end{aligned}}$$

This formula is so important that I will give it its own special box.

$$\boxed{F = ma}$$

F = force (Newtons, N)
m = mass (kg)
a = acceleration (m/s^2)

The units for force are called Newtons.
- It's equivalent to kgm/s^2.
- It was named in honour of the outstanding work that Newton did in physics.
- By definition, a one kilogram mass will be accelerated at 1 m/s^2 if a 1 Newton force is applied to it.

F = ma is the simplest way of writing Newton's Second Law and you will find it on your formula sheet. Of the two most famous equations in physics, F = ma is one of them. The other is $E = mc^2$(which may get discussed near the end of the course if you're lucky!).

Newton's Third Law (The Action-Reaction Law)

"For every action there is an equal and opposite reaction."

Some examples of the third law:
- Jumping – You exert a force on the ground, the ground exerts a force on you which causes you to move upwards.
- Walking – You can begin walking across the floor because you push on the floor and the floor pushes back on you.
- Punch in the Face – You should not punch people in the face! But, if you did, who would get hurt? The person who got punched obviously... but what about you? Yes, you would get hurt too as it will hurt your hand.