A FORCEFUL STORY!

-By Dr. John McArthur

Let's start with the most basic thing we can imagine…a rock. Let's assume for now that this rock is the only thing in existence, and it's out there sitting stationary in space, not moving anywhere. This rock is composed of something we call matter, and thus it has a mass to it, which is a measure of how much matter it contains. However, since the rock is stationary, is has no velocity. Of course, velocity is a measure of how fast an object composed of matter (like the rock) is moving.

So, how does one get the rock to move? Well, *Newton's 1st law states that an object will continue what its doing until a **force** acts upon it*. You're probably thinking "Wait a second…what's a force? I thought the only thing that existed was this rock?" Okay, you're right, let's have other things exist as well, and let's say these other things are able to produce a force. What these things are, isn't really important just yet, first I want to discuss what this idea of a "force" is. Well, a force is simply something that causes a mass to change what its doing. Thus, to get the rock to stop being stationary, something must apply a force to it. Let's say you exist now, and you happen to find yourself next to the rock. Both of you are just sitting, stationary in space, with no velocity. If you want to get the rock to move, you could apply a force simply by pushing on the rock with your hand…and whammo!... the rock moves away from you at a constant velocity. What other types of things can apply a force to this rock besides just pushing it?

Well, actually, there's this thing called "*gravity*" that produces a force between any two bodies of mass. Scientists don't fully understand why this thing called gravity exists, or exactly where it comes from, but they do have a pretty good idea that it is always around. They have also observed that the force always seems to make two objects move towards each other for some reason. So, let's again assume you're sitting next to this rock, nice and stationary, only this time you don't push it away. You decide you want to sit there with the rock, nice and stationary. Well guess what, you can't. That's right, this thing called "gravity" will cause both you and rock to start moving towards each other, and eventually you'll be touching the rock. That's why you always fall to the earth, because the "gravity" force between you and the earth is always pulling the two of you together.

There's lots of other things that can produce forces, like electrons, and photons, and even quarks (you'll learn about those when you're older), but one thing that should be pointed out is that just by blowing air on something, you can produce a force. If you're sitting next to the rock, and you blow on the rock, the rock will start moving away from you because the air in your lungs is pushing the rock away. It's really very similar to when you used your hand to push the rock, but this time, the air in your lungs is being forced out of your mouth, and is pushing the rock away from you. This is often called a *drag force*, and can only exist when air or other gases is present.

So, there's just a couple more important things to consider about a force before we move on. First, is that *Newton's 2nd law states that for every action, there is an equal and opposite reaction*. Really, what this means is that any time there's a force going in one direction, there's an equal force going the other direction! So, if you push the rock away from you, then the rock will start moving, right? Well guess what, so do you! You start moving in the opposite direction. But, the rock will have the higher velocity, since it has less mass than you do. This can be related to the idea of gravity, since when gravity acts on two objects, it makes both of them move, but it makes the object with less mass move faster and faster. *That means that when you jump in the air, the gravity acting between you and the Earth will cause both you and the Earth to move towards each other. But which one moves more? Of course you do, and it's because the Earth is so massive*.

Another thing to consider is what happens after the force is applied. So, after you push the rock away, the rock starts moving way at a high velocity, and you move the other direction at a lower velocity. But what happens after that? Do you just keep moving forever? Actually, yes. Both you and the rock would keep moving at a constant velocity forever. What would make you stop moving at a constant velocity? Well, another force. Remember, earlier we discussed Newton's 1st law, and said that an object will continue doing what its doing until it is acted upon by a force. Well, before we were talking about a stationary object. But guess what, the same applies to an object moving at constant velocity. *Well, this can be generalized, since sitting stationary is really the same thing as moving with a constant velocity of ZERO! So, any object moving at a constant velocity (including zero velocity), will continue moving at that constant velocity until a force acts upon it.* This is probably what Newton was trying to say, but he wasn't as smart as you and me…or maybe he was smarter.

So wait, *if an object moves at a constant velocity until it is acted upon by a force, then the force is something that changes the velocity of an object*…wow. That makes things considerably easier. *Any time an object is changing its velocity; there must be a force acting upon it. In fact, we have a name for changing velocity, and we call it acceleration.* Any time an object is accelerating (or decelerating if it's slowing down), then the object is changing its speed, which means a force is acting upon it. *So, a force is something that causes acceleration!!!!* This is a huge revelation, and it allows us to write our first equation, an equation that relates the amount of force acted on a body, to the amount of acceleration (or velocity change) experienced by that body. Lets say that a force is abbreviated with 'F', and acceleration with 'a'. Let's also say that this object has a mass which is abbreviated with 'm'. With this convention, we can write one of the most famous equations of all time: Force equals mass times acceleration:

$$F = ma$$

Remember that letters that are next to each other are multiplied. This equation says that the amount of force you apply to an object, is directly related to the acceleration experienced by that object, and its related by the mass of the object. Let's assume you apply a force of a certain magnitude, then if the object's mass is small, then it will accelerate a great deal (and thus will attain a high velocity). If the object's mass is large, then it will not accelerate as much (and thus will attain a lower velocity). Well, that's pretty obvious, cause you can't throw a heavy ball as fast as you can throw a lighter ball. Sure, its obvious, but the equation is powerful because now we can use numbers to predict just how much slower you will throw that heavier ball. *If that ball is twice as heavy, you will throw it half as fast*.

Before we move onto a discussion of energy, let's take a moment to consider units. Units are the things we use to measure. For instance, when you want to know how far it is from your house to your school, it's not very helpful to say 1. Obviously, you would wonder, 1 what's??? 1 mile, 1 foot, 1 kilometer, 1 earth diameter? So, when you measure something, there is almost always a unit associated with that measurement. So, what is the unit of force? Well, the best way to get the unit of force is to look at the equation of force. We know that force is the mass multiplied by the acceleration*. Thus, the unit of force is the unit of mass multiplied by the unit of acceleration. The unit of mass that is used by most people on this earth is the kilogram, and is abbreviated with kg.* However, just like most people on the earth measure distance with the kilometer, but we in America use the mile, we Americans also use something different for measuring mass. We actually have two different things we use, and one is called a "slug" and the other is called the "pound-mass". For the purposes of this discussion, we will stick to the less-confusing and more widely-used unit of kilogram (kg). Okay, so what about acceleration? This one is a bit trickier, but acceleration (*a*) is (=) the change (Δ) of velocity (*v*) per time (*t*), written in equation form as:

$$a = \frac{\Delta v}{t}$$

Since velocity is a measure of distance per time, and since distance is measured by most people by using meters (m) and time is measured by most people by using seconds (s), then velocity is measure in meters per second (m/s). This can be applied to the acceleration equation above to find that the units of acceleration (*a)* are defined as ([=]) meters per second squared (m/s^2):

$$a\left[=\right]\frac{\text{m/s}}{\text{s}} = \frac{\text{m}}{\text{s}^2}$$

Using this information, along with the knowledge that the unit of mass is the kilogram (kg), we can say that the unit of force (*F*), which is equal to (=) mass times acceleration (*ma*), is defined as ([=]) a kilogram-meter per second squared ($kg.m/s^2$).

$$F = ma\left[=\right]\text{kg}\frac{\text{m}}{\text{s}^2} = \frac{\text{kg.m}}{\text{s}^2}$$

For units, a period is often used to indicate multiplication since many units are abbreviated with more than a single letter. Since forces are used in math, science and engineering very frequently, and since saying “kilogram-meter per second squared” takes a very long time, we have decided to name unit of force after the person that first identified what a force is by calling the unit of force a “Newton” and abbreviating it with “N”. For us Americans, we usually don’t use the Newton to measure force, instead we use the “Pound” and we often abbreviate it “lb”. So yes, when you measure yourself on a scale in the bathroom, you are actually measuring how much force you are applying to the Earth by standing on it. Amazing isn’t it?