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Foguete prático
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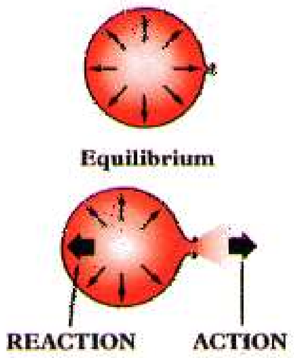
Princípios do Foguete

Um foguete em sua forma mais simples é uma câmara contendo um gás sob pressão. Uma pequena abertura em uma extremidade da câmara permite que o gás escape e, ao fazê-lo, fornece um impulso que impulsiona o foguete na direção oposta. Um bom exemplo disso é um balão. O ar dentro de um balão é comprimido pelas paredes de borracha do balão. O ar empurra para trás de modo que as forças de pressão para dentro e para fora sejam equilibradas. Quando o bocal é solto, o ar escapa por ele e o balão é impulsionado na direção oposta.



Quando pensamos em foguetes, raramente pensamos em balões. Em vez disso, nossa atenção é atraída para os veículos gigantes que transportam satélites em órbita e espaçonaves para a Lua e os planetas. No entanto, há uma forte semelhança entre os dois. A única diferença significativa é a forma como o gás pressurizado é produzido. Com foguetes espaciais, o gás é produzido pela queima de propelentes que podem ser sólidos ou líquidos na forma ou uma combinação dos dois.

Um dos fatos interessantes sobre o desenvolvimento histórico dos foguetes é que, embora foguetes e dispositivos movidos a foguetes estejam em uso há mais de dois mil anos, foi apenas nos últimos trezentos anos que os experimentadores de foguetes tiveram uma base científica para entender como eles funcionam.

A ciência dos foguetes começou com a publicação de um livro em 1687 pelo grande cientista inglês Sir Isaac Newton. Seu livro, intitulado Philosophiae Naturalis Principia Mathematica, descrevia os princípios físicos da natureza. Hoje, o trabalho de Newton é geralmente chamado apenas de Principia. Nos Principia, Newton declarou três princípios científicos importantes que governam o movimento de todos os objetos, seja na Terra ou no espaço. Conhecendo esses princípios, agora chamados de Leis do Movimento de Newton, os fogueteiros foram capazes de construir os modernos foguetes gigantes do século 20, como o Saturno V e o Ônibus Espacial. Aqui agora, de forma simples, estão as Leis do Movimento de Newton.

1. Objetos em repouso permanecerão em repouso e objetos em movimento permanecerão em movimento em linha reta, a menos que sejam afetados por uma força desequilibrada.
2. Força é igual a massa vezes aceleração.
3. Para cada ação há sempre uma reação oposta e igual.

Como será explicado em breve, todas as três leis são declarações realmente simples de como as coisas se movem. Mas com eles, determinações precisas do desempenho do foguete podem ser feitas.

Primeira Lei de Newton

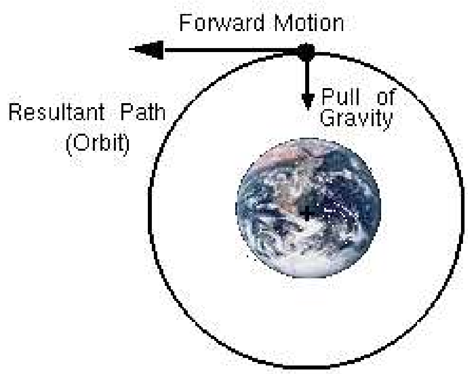
Esta lei do movimento é apenas uma declaração óbvia de um fato, mas para saber o que significa, é necessário entender os termos repouso, movimento e força desequilibrada.

Rest and motion can be thought of as being opposite to each other. Rest is the state of an object when it is not changing position in relation to its surroundings. If you are sitting still in a chair, you can be said to be at rest. This term, however, is relative. Your chair may actually be one of many seats on a speeding airplane. The important thing to remember here is that you are not moving in relation to your immediate surroundings. If rest were defined as a total absence of motion, it would not exist in nature. Even if you were sitting in your chair at home, you would still be moving, because your chair is actually sitting on the surface of a spinning planet that is orbiting a star. The star is moving through a rotating galaxy that is, itself, moving through the universe. While sitting "still," you are, in fact, traveling at a speed of hundreds of kilometers per second.

Motion is also a relative term. All matter in the universe is moving all the time, but in the first law, motion here means changing position in relation to surroundings. A ball is at rest if it is sitting on the ground. The ball is in motion if it is rolling. A rolling ball changes its position in relation to its surroundings. When you are sitting on a chair in an airplane, you are at rest, but if you get up and walk down the aisle, you are in motion. A rocket blasting off the launch pad changes from a state of rest to a state of motion.

The third term important to understanding this law is unbalanced force. If you hold a ball in your hand and keep it still, the ball is at rest. All the time the ball is held there though, it is being acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. The forces acting on the ball are balanced. Let the ball go, or move your hand upward, and the forces become unbalanced. The ball then changes from a state of rest to a state of motion.

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity tries to pull it down. As the engines are ignited, the thrust from the rocket unbalances the forces, and the rocket travels upward. Later, when the rocket runs out of fuel, it slows down, stops at the highest point of its flight, then falls back to Earth.

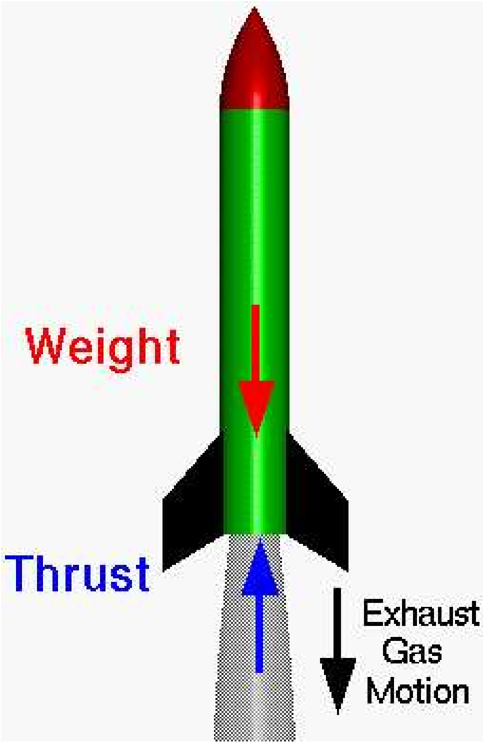


Objects in space also react to forces. A spacecraft moving through the solar system is in constant motion. The spacecraft will travel in a straight line if the forces on it are in balance. This happens only when the spacecraft is very far from any large gravity source such as Earth or the other planets and their moons. If the spacecraft comes near a large body in space, the gravity of that body will unbalance the forces and curve the path of the spacecraft. This happens, in particular, when a satellite is sent by a rocket on a path that is parallel to Earth's surface. If the rocket shoots the spacecraft fast enough, the spacecraft will orbit Earth. As long as another unbalanced force, such as friction with gas molecules in orbit or the firing of a rocket engine in the opposite direction from its movement, does not slow the spacecraft, it will orbit Earth forever.

Now that the three major terms of this first law have been explained, it is possible to restate this law. If an object, such as a rocket, is at rest, it takes an unbalanced force to make it move. If the object is already moving, it takes an unbalanced force, to stop it, change its direction from a straight line path, or alter its speed.

Newton's Third Law

For the time being, we will skip the second law and go directly to the third. This law states that every action has an equal and opposite reaction. If you have ever stepped off a small boat that has not been properly tied to a pier, you will know exactly what this law means.



A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The whole process is very similar to riding a skateboard. Imagine that a skateboard and rider are in a state of rest (not moving). The rider jumps off the skateboard. In the third law, the jumping is called an action. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's opposite motion is called a reaction. When the distance traveled by the rider and the skateboard are compared, it would appear that the skateboard has had a much greater reaction than the action of the rider. This is not the case. The reason the skateboard has traveled farther is that it has less mass than the rider. This concept will be better explained in a discussion of the second law.

With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the mass of the rocket. In space, however, even tiny thrusts will cause the rocket to change direction.

One of the most commonly asked questions about rockets is how they can work in space where there is no air for them to push against. The answer to this question comes from the third law. Imagine the skateboard again. On the ground, the only part air plays in the motions of the rider and the skateboard is to slow them down. Moving through the air causes friction, or as scientists call it, drag. The surrounding air impedes the action-reaction.

As a result rockets actually work better in space than they do in air. As the exhaust gas leaves the rocket engine it must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely.

Newton's Second Law

This law of motion is essentially a statement of a mathematical equation. The three parts of the equation are mass (m), acceleration (a), and force (f). Using letters to symbolize each part, the equation can be written as follows:

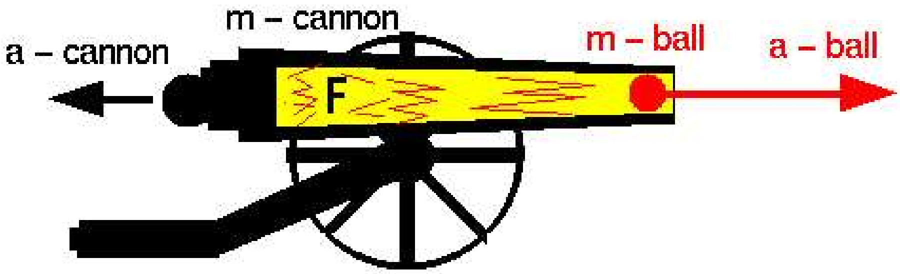
f = ma

By using simple algebra, we can also write the equation two other ways:

a = f/m

m = f/a

The first version of the equation is the one most commonly referred to when talking about Newton's second law. It reads: force equals mass times acceleration. To explain this law, we will use an old style cannon as an example.



When the cannon is fired, an explosion propels a cannon ball out the open end of the barrel. It flies a kilometer or two to its target. At the same time the cannon itself is pushed backward a meter or two. This is action and reaction at work (third law). The force acting on the cannon and the ball is the same. What happens to the cannon and the ball is determined by the second law. Look at the two equations below.

f = m(cannon) * a(cannon)

f = m(ball) * a(ball)

The first equation refers to the cannon and the second to the cannon ball. In the first equation, the mass is the cannon itself and the acceleration is the movement of the cannon. In the second equation the mass is the cannon ball and the acceleration is its movement. Because the force (exploding gun powder) is the same for the two equations, the equations can be combined and rewritten below.

m(cannon) * a(cannon) = m(ball) * a(ball)

In order to keep the two sides of the equations equal, the accelerations vary with mass. In other words, the cannon has a large mass and a small acceleration. The cannon ball has a small mass and a large acceleration.

Let's apply this principle to a rocket. Replace the mass of the cannon ball with the mass of the gases being ejected out of the rocket engine. Replace the mass of the cannon with the mass of the rocket moving in the other direction. Force is the pressure created by the controlled explosion taking place inside the rocket's engines. That pressure accelerates the gas one way and the rocket the other.

Some interesting things happen with rockets that don't happen with the cannon and ball in this example. With the cannon and cannon ball, the thrust lasts for just a moment. The thrust for the rocket continues as long as its engines are firing. Furthermore, the mass of the rocket changes during flight. Its mass is the sum of all its parts. Rocket parts includes engines, propellant tanks, payload, control system, and propellants. By far, the largest part of the rocket's mass is its propellants. But that amount constantly changes as the engines fire. That means that the rocket's mass gets smaller during flight. In order for the left side of our equation to remain in balance with the right side, acceleration of the rocket has to increase as its mass decreases. That is why a rocket starts off moving slowly and goes faster and faster as it climbs into space.

Newton's second law of motion is especially useful when designing efficient rockets. To enable a rocket to climb into low Earth orbit, it is necessary to achieve a speed, in excess of 28,000 km per hour. A speed of over 40,250 km per hour, called escape velocity, enables a rocket to leave Earth and travel out into deep space. Attaining space flight speeds requires the rocket engine to achieve the greatest action force possible in the shortest time. In other words, the engine must burn a large mass of fuel a[illegible] the resulting gas out of the engine as rapidly as possible. Ways of doing this w[illegible]scribed in the next chapter, practical rocketry.

Newton's second law of motion can be restated in the following way: the greater the mass of rocket fuel burned, and the faster the gas produced can escape the engine, the greater the thrust of the rocket.

Putting Newton's Laws of Motion Together

An unbalanced force must be exerted for a rocket to lift off from a launch pad or for a craft in space to change speed or direction (first law). The amount of thrust (force) produced by a rocket engine will be determined by the mass of rocket fuel that is burned and how fast the gas escapes the rocket (second law). The reaction, or motion, of the rocket is equal to and in the opposite direction of the action, or thrust, from the engine (third law).