Article from SIRS Discoverer Database; (ProQuest) Lexile: 1220L

Newton's Three Laws of Motion

NEWTON'S THREE LAWS OF MOTION
by Calinda Brown

Unlike the laws made by government, the laws of mechanical motion cannot be broken by people!

We credit Sir Isaac Newton, a scientist who lived 300 years ago, with discovering and explaining the answer to a question that had puzzled people for over 3,000 years--Why do things move?

Two thousand years ago, the Greek philosopher Aristotle thought objects in nature moved because they were trying to return to their "natural" state. This was accepted as the truth until another early scientist, Galileo, wrote that objects moved only when something--a force--made them.

Newton used Galileo's theories to develop his own. When he was older, Newton would modestly say, "If I have seen further, it is by standing on the shoulders of giants." Newton's theories are the foundation of our understanding of dynamics, or the science of studying the behaviour of objects under forces. Let's take a look at each of Newton's Laws of Motion to see exactly what they mean and how they work.

THE LAWS

Isaac Newton believed there were forces acting on objects that made them move. A force is something that changes the motion of an object: it can make a resting object move; or stop a moving object; or change the motion of an object that is already moving.

As a result of his experiments, Newton came up with three principles we now call the Laws of Motion. These laws remained virtually unchanged and unchallenged until this century when Albert Einstein realized that objects moving VERY fast (around the speed of light) move differently than slower objects. But Newton's laws still hold true for us and objects moving at speeds we're used to.

THE FIRST LAW

The first law is sometimes called the law of **inertia**. Newton realized that most objects are lazy. If they are moving, they tend to continue moving at the same speed and in a straight line. If objects are at rest, they tend not to start moving. He called this tendency, **inertia**.

You can see this principle in action yourself when you kick a rock. Before you kick it, **inertia** prevents the rock from moving. Once you kick it, the rock keeps rolling on forever. No? Of course not, otherwise we would spend our day jumping out of the way of rolling rocks.

Newton called the force that slows and eventually stops moving objects, friction. The surface of every object is covered in tiny bumps and pits. When one object is moving against another object, the bumps of one surface fall into the pits of another and act as tiny brakes. Once an object stops, **inertia** prevents it from starting again until another force acts on it.

To overcome **inertia**, a force must be exerted. How much force? Well, **inertia** is related to how much something weighs. If an object weighs more, there is more **inertia** and it takes more force to move it. Once the object is moving, it takes less effort to keep it moving because you only have to overcome friction, not friction and **inertia** together.

THE SECOND LAW

The second law states that an object moves in the direction of the force being applied to it, and the more force applied, the faster the object accelerates.

You can feel the effect of force on you by heading out to the playground. Get on a swing and start swinging! Normally, you don't feel force acting on you as you walk around, eat, and sleep. You need to speed up, or accelerate, to increase the amount of force acting on you. When you finish swinging up and start down, you are accelerating and can feel force--you feel heavier or your tummy might feel funny.

The formula Newton developed to show the effect of the force and acceleration is F=ma. F stands for force, m is mass and a is acceleration. In honour of his work, we call the units we use to measure any force, newtons (N).

Here is an example. You're riding along in the back seat of your parent's minivan. The van can do 0 to 50 km/h in 7 seconds. That's an average acceleration of about 2 m/s squared. If we estimate that you weigh 40 kg, we can use F=ma to work out the force exerted on you. F = m(40kg) x a(2m/s squared) = 80 N.

Now imagine that instead of being in your parent's minivan you are in a drag racer which can do 0 to 450 km/h in 5 seconds. That's an average acceleration of 25 m/s squared. The force exerted on you would be: F = m(40 kg) x a(25 m/s squared) = 1,000 N!

THE THIRD LAW

The third law of motion says that for every action there is an equal and opposite reaction. This means that if you push against a wall, the wall pushes back against you. Otherwise, you would fall right through the wall! If an object isn't strong enough to produce an opposing force, it will crumple, like a wet cardboard box that you try to stand on.

To see this law in action, imagine you're on a skateboard. If you try to push against the air, no action happens because there is nothing for you to push against. But when you push against the ground, it pushes back and propels you and your skateboard forward.

Engineers and designers have to keep this law in mind when designing buildings, furniture, and machines. What would happen if a bridge wasn't strong enough to push back against the force of a car? Or if a chair you sat in wasn't strong enough to push back against the force of your body? Keeping Newton's third law in mind keeps us all safe.

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NEWTON'S LIFE

1642

In England, one of the greatest scientists of all time, Isaac Newton, gets off to a rocky start in life. Born small and weak, he is not expected to live.

1655

During most of his time at school Newton does not distinguish himself as a particularly good student. He is curious, however, and seems to enjoy making kites, sundials, clocks, and even a model windmill "powered" by a mouse on a treadmill.

1661

Although Newton comes from a family of farmers, he proves to be completely useless at farming and is sent to study at Cambridge University.

1664

While studying, Newton often forgets to eat or sleep. Interested in mathematics, he goes on to discover several theorems (rules) which lay the foundation for a branch of mathematics called calculus.

1665-66

While the deadly bubonic plague rages in London, Newton returns to his mother's farm where he theorizes about gravitation and experiments with light and colour. One experiment involves passing a beam of sunlight through a triangular piece of glass, a prism. The light separates into a band of rainbow colours. When Newton passes the light back through a second prism, white light again appears. He concludes that white light is made up of a combination of colours.

1668

Newton makes the first reflecting telescope. Instead of using a lens, Newton's telescope forms an image using a large, curved mirror that focuses light rays. Today the largest modern telescopes are reflecting telescopes.

1669

While still in his twenties, Newton is appointed as a professor of mathematics at Cambridge University. Newton's assistant writes that very few students come to his classes and even fewer understand what he is saying--sometimes Newton even lectures to an empty room!

1670

Newton has no hobbies, is untidy, absentminded, and although he lives and works at a busy university, he is often alone. According to one story, he forgets all about some guests on his way to get a bottle of wine. He sits down at his desk and starts to work.

1672

Newton is made a member of the Royal Society of London, one of the world's oldest scientific associations, and soon shares his experiments on light and colour with the other members. One member of the society, Robert Hooke, questions Newton's findings. They quarrel bitterly, and Newton retreats from the scientific spotlight.

1675

Alchemy is Newton's new interest. The goals of alchemy include turning non-precious metals into gold and discovering a way to extend life. Although he fills notebook after notebook with his alchemy experiments, he never publishes any papers on the subject.

1684

A prize is offered to anyone who can mathematically prove how the planets move. An astronomer named Edmond Halley asks Newton if he can solve the problem. Newton says he has already solved it, but he has misplaced his calculations. He promises to do the work over again and send it to Halley. Soon Newton sends Halley a nine page proof which explains why the planets travel around the sun in elliptical orbits.

1687

Halley suggests Newton publish his work, and after 18 months Newton finishes the Philosophiae naturalis principia mathematica (or the Principia as it comes to be called). Perhaps the greatest scientific work of all time, the Principia describes Newton's law of universal gravitation and outlines his three laws of motion. Despite the importance of the book, it is almost not published until Edmond Halley offers to pay to publish it.

1689

Newton is offered a position representing Cambridge University in England's Parliament. Legend has it that he only speaks once during his term--apparently he asks an usher to close a window because there is a draft!

1693

Newton suffers a mental breakdown--some blame the illness on mercury poisoning while others say it is because his dog knocks over a candle and causes a fire which destroys years of work. Still others say Newton has neither the symptoms of mercury poisoning nor a dog, and his illness is the result of mental exhaustion.

1696

Newton is appointed Warden of the Royal Mint and energetically goes after counterfeiters.

1703

Elected president of the Royal Society, Newton enthusiastically sets about increasing membership and interest in the society.

1704

A year after his rival Hooke's death, Newton publishes Opticks which summarizes his work on light and colour.

1705

Knighted by Queen Anne, Newton is now Sir Isaac Newton.

1727

On March 20th, Newton dies. Three days later the following message is recorded in the Journal Book of the Royal Society: "The Chair being vacant by the death of Sir Isaac Newton there was no meeting this day". Newton is buried in Westminster Abbey. His family later erects a monument to his memory in what becomes known as the Scientist's Corner of the abbey--Newton shares this resting place with other famous English scientists such as Charles Darwin and Michael Faraday.

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An object at rest stays at rest unless acted upon by an outside force. An object in motion continues in motion in a straight line unless acted on by an outside force.

The amount of force needed to move an object is directly related to the object's mass and its acceleration. Expressed mathematically, this is $F = ma$.