Newton's three laws and Racing

Questions for Analysis

- What are Newton's laws of motion?
- How do Newton's laws of motion apply to automobile racing today?

Key Concepts

Acceleration

The rate at which an object's velocity changes; $a = \Delta v / \Delta t$.

Air resistance

The force created by the air when it pushes back against an object's motion.

Force

Any push or pull.

Friction

The opposing force between two objects that are in contact with and moving against each other.

Inertia

An object's tendency to resist any changes in motion.

Mass

The amount of matter in an object.

Momentum

The combined mass and velocity of an object, or mass times velocity.

Safety features

In an automobile, things that make the car safer or that make racing safer.

Speed

The distance an object travels divided by the time it takes to travel the distance.

Velocity

The speed of an object, including its direction.

Weight

The force of gravity pulling on an object. Weight equals mass times the acceleration due to gravity.

Background

Isaac Newton was an English physicist and mathematician who lived from 1642 to 1727. He worked in many areas of physics, but he is primarily known for his three laws of motion. These laws of motion can help us describe the speed, acceleration, thrills and dangers of automobile racing.

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Racing Oral History Interviews

Listen to Jim Hall talk about changing force and changing how fast cars will go. He also discusses how he works within the rules and yet still tries to find ways to make his car go faster.

- Jim Hall: Safety Rules
- Jim Hall: Engineer to Go Faster

Newton's First Law – The Law of Inertia

Newton's first law is called the law of inertia. Inertia is the resistance to change in motion. Newton's first law states that a body at rest remains at rest and that a body in motion remains in motion unless acted upon by an outside force. This law means that once we start moving, we continue moving.

In everyday life, we exhibit inertia because we tend to keep doing what we are already doing. When we are up, we like to stay up. If we are sitting or sleeping, we like to stay sitting or sleeping.

If a car is standing still without the motor running, the car will remain there. Look at the picture of the drag race car sitting in front of *Henry Ford Museum*. [Willys Gasser, 1958 (side view ID# THF69391)] As long as the engine is not started and no one pushes this car, it will remain where it is.

If a driver starts the engine and pushes the accelerator, the motor produces a force that moves the car forward. The driver and passengers feel as though they are thrown or pushed backwards, but actually the car goes forward and the driver and passengers remain where they are. When the car accelerates forward and the car seats hit them in their backs, they feel as though they are being thrown backwards.

Newton's first law can also be seen in a car that is stationary and gets hit in the rear end. The driver feels as if he or she flies backwards, but actually the car is pushed forward, leaving the driver behind.

There are many safety features designed to protect race car drivers. Race cars have high-backed seats so that when the drivers accelerate forward, their entire body goes forward with the car. Look at the picture of the inside of Lyn St. James's race car with its tall car seats. [Lyn St. James Suited Up in Race Car, Giving a Thumbs-Up, 2008 ID# THF58671] Racecar drivers' heads do not snap back because they are up against a tall seat. In your family car, your car's head rests and seats keep you from feeling as though you are thrown backwards.

Once race cars reach a high rate of speed, they continue at the high rate of speed, according to Newton's first law. [Start of the Indianapolis 500 Race, 1937 ID# THF68313] If there is a crash and the car is stopped by an outside force (for example, another car or a wall), the driver keeps on going. Safety belts help slow the driver to prevent him or her from flying out of the car or from hitting the front windshield. In a passenger car, air bags slow the driver and passenger.

In a modern race car, the race car safety belts are called 5-point belts. They go around both shoulders as well as around the waist and down to the center of the front of the seat, and they attach at 5 points. Modern race drivers also use a HANS Device, which wraps around the driver's neck to help protect his or her neck from flying side to side. Five-point belts and HANS Devices help protect race car drivers from the effects of Newton's first law.

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Look at the picture of an Indy race car. [March 84C Race Car, 1984 (cockpit view ID# THF69363)] In serious auto racing accidents, especially those that involve Indy-style cars (called open wheel race cars), many pieces of the car fly off. Why is it actually good that parts fly off the race car? Rather than the energy going into the driver, the kinetic energy can be dissipated in the flying parts. Roll bars are also used to prevent the car from crushing around the driver.

Newton's Second Law – F = ma

Newton's second law can be stated mathematically as force equals mass times velocity, written as F = ma. An unbalanced force will create acceleration. The greater is the force, the greater will be the acceleration. The greater the mass, the less the acceleration. Thus a car with larger mass will accelerate more slowly.

What do car builders and engineers do to increase acceleration and speed? Race car designers and innovators aim for the most powerful engine possible, for more force and acceleration. The designers also want to make the car lighter so that the car has better acceleration and speed. Most races regulate engine size, so designers or car builders cannot put too large an engine in their race car. Therefore, race car builders try to make cars lighter where possible, by using aluminum or plastic rather than steel, which is heavier. Many wheel rims are made from lightweight magnesium to decrease mass in the car.

Look how light the 1960 Slingshot dragster looks. [Buck & Thompson Class D Slingshot Dragster, 1960 ID# THF36041] The Slingshot car is very light. It is designed and built for drag racing, where the track is straight and only a quarter-mile long.

Notice the 1902 Ford 999 race car built by Henry Ford. [Race Car "999" Built by Henry Ford, 1902 ID# THF70568] The 999 car had a large, 1,150-cubic-inch engine to provide a large force to make it accelerate and go fast. Notice how heavy the 999 car is; its weight slows it down.

Newton's Third Law – Action and Reaction

Newton's third law states that for every action in one direction, there is an equal and opposite reaction. Another way to state the third law is for every force in one direction, there is an equal and opposite force in the other direction.

When a race car accelerates, the motor and engine transfer force to the tires, which push backwards against the pavement. The pavement or track pushes back on the race car. Because forces cause objects to accelerate, the car moves forward. When two forces push against each other, the lighter object moves farther and faster.

Thus the car moves rather than the track. If there is gravel or dirt on the track, then the track does move, in a way: You see the gravel or dirt fly back as the car goes forward.

There are numerous examples of action and reaction in everyday situations. When a jet is flying, the engine forces hot gas out in one direction and the jet flies in the opposite direction. A swimmer pulls water backward to propel forward. A bullet is shot out of a gun in one direction and the gun recoils in the opposite direction.

Sometimes motion is expressed by the term momentum. The momentum of an object, such as a race car, is the combination of its mass and its velocity. When two objects push against each other, they go in opposite directions, and the momentum in one direction equals the momentum in the other direction.