Dr. Mitch Hoselton 6/27/2003
Physics: An Incremental Development, John H. Saxon, Jr.

Newton's Laws of Motion

First Law

Newton: "Every body continues in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it." (THIS AND OTHER QUOTES ARE FROM CAJORI'S 1934 REVISION OF MOTTE'S 1729 ENGLISH TRANSLATION FROM THE ORIGINAL LATIN VERSION OF NEWTON'S ***PHIILOSOPHIAE NATURALIS PRINCIPIA MATHEMATICA; KNOWN ALMOST UNIVERALLY BY THE SIMPLER APPELATION "PRINCIPIA***.")

A body has a constant velocity unless there is a net force acting on it. If more than one force acts on a body, the vector sum of the forces equals the net force. The acceleration created by the net force is in the same direction as the net force. The net force must be zero anytime the velocity is constant. Note that zero is just another of the possible constant velocities.

This is often called the "law of inertia. Bodies keep moving with no change in their motion because they have something called inertia. Inertia is a property of matter, but we have no specific measure called the quantity of inertia. Newton did not use this term. His approach is phenomenological. This is just the way things behave. Newton loved solving astronomical problems because the planets and comets being larger and moving without the hindrance of friction or air resistance agreed with these notions most exactly of all the bodies whose motions he investigated.

Corollaries and Conclusions:

1. You cannot detect your own velocity (if your velocity is constant)
2. All velocities are relative.
3. You cannot distinguish motion from rest.
4. Spinning bodies keep spinning unless acted upon by a torque.

Second Law

Newton: "***The change of motion is proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed***"

The rate of change in momentum (mv) is proportional to the net force and in the same direction.

$$\mathbf{F = [\Delta(mv)]/\Delta t = m\,(\Delta v/\Delta t) = ma}$$

Corollaries & Conclusions:

1. You cannot feel motion, only changes in motion (accelerations).
2. The proportionality means that if you double the force you double the acceleration.
3. The bigger they are, the harder they fall.
4. Vectors are required to understand these changes in motion. Newton includes sections in the ***Principia*** that introduce vectors, vector components, and vector addition by the parallelogram method.

Third Law

Newton: "***To every action there is always opposed an equal reaction; or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts***."

"Whatever draws or presses another is as much drawn or pressed by that other. If you press a stone with your finger, the finger is also pressed by the stone. If a horse draws a stone tied to a rope, the horse … will be drawn equally back towards the stone…"

The action and reaction forces arise from one interaction involving two objects.

The reaction force to gravity is gravity pulling back.
The reaction force to a squeeze (normal force) is a squeeze back.
The reaction force to friction is friction in the other direction.
(try walking forward in a canoe)

Corollaries & Conclusions:

1. You cannot hit someone without having them hit you back, and just as hard.
2. The action/reaction pair of forces act in exactly opposite directions.
3. All guns must recoil.
4. Every time something falls, something else must rise.
5. Every time something stops, something else must speed up.
6. Every time you leave a stop sign, the Earth changes its rotation.

Final Thoughts

All three of these laws of motion are undermined if not completely obliterated by Einstein's Special and General Theories of Relativity, including his 1929 treatment of gravity as a curvature of space rather than, as in Newton, another property of matter. Nevertheless, at any speed every achieved by us or observed by us outside the realm of high energy physics, Newton's Laws of Motion are sufficiently good approximations of the real situation to build any device, reach any planet, and go anywhere and do anything modern science needs to achieve here on Earth or in this solar system. NASA uses Newton's Laws of Motion and Newton's Law of Universal Gravitation to send people and satellites to the Moon and the planets. Except for a few famous errors made in the calculations, these laws have always worked well enough to get our equipment and us to the intended destination.