# Newton's Law of Gravity

Newton's law of gravity defines the attractive force between all objects that possess mass. Understanding the law of gravity, one of the fundamental forces of physics, offers profound insight into the way our universe works.

The famous story that Isaac Newton (1642 – 1727) came up with the idea for the law of gravity by having an apple fall on his head is probably not true, although he did begin thinking about the issue on his mother's farm when he saw an apple fall from a tree. Newton theorized that the same force that had pulled the apple down from the tree was responsible for keeping the Moon, planets, and other heavenly bodies in their orbits. Along with his Three Laws of Motion, Newton also outlined his law of gravity in the 1687 book *Philosophiae Naturalis Principia Mathematica (Mathematical Principles of Natural Philosophy)*, which is generally referred to as the *Principia*.

Johannes Kepler (German physicist, 1571-1630) had developed three laws governing the motion of the five then-known planets. He did not have a theoretical model for the principles governing this movement, but rather achieved them through trial and error over the course of his studies. Newton's work, nearly a century later, was to take the laws of motion he had developed and apply them to planetary motion to develop a rigorous mathematical framework for this planetary motion.
Newton eventually came to the conclusion that, in fact, the apple and the moon were influenced by the same force. He named that force gravitation (or gravity) after the Latin word *gravitas* which translates into "heaviness" or "weight."

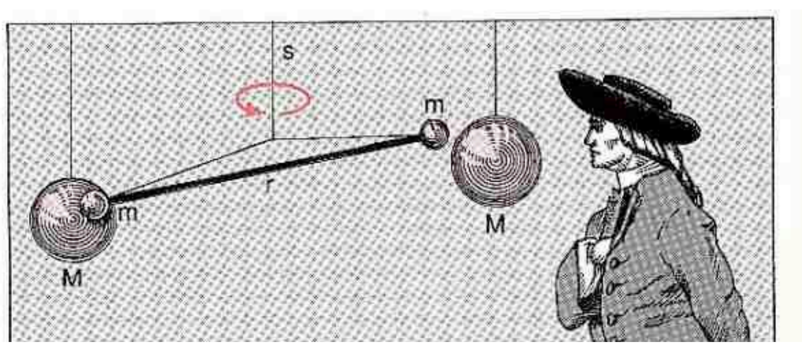
In the *Principia*, Newton defined the force of gravity in the following way:

*Every particle of matter in the universe attracts every other particle with a force that is directly proportional to the product of the masses of the particles and inversely proportional to the square of the distance between them.*

Symbolically,

$$\mathbf{F \propto \frac{m_1 m_2}{d^2}}$$

Nearly one hundred years after Newton first proposed his law of universal gravitation, it was experimentally confirmed by Henry Cavendish (1731-1810). He created a torsion balance by attaching a small lead ball (1.61 lbs) on each end of a long rod and suspended the rod by a thin wire. He then placed two large spheres (348 lbs each) near the small ones so that the wire would rotate slightly due to the attraction between the small and large spheres. By measuring the angle through which the wire turned, and knowing the torque of the wire for a given angle, Cavendish was able to find the force between the lead masses. He found that the force exactly followed the law of gravitation. In addition, by plugging in the masses of the spheres and the distance between their centers, he was able to solve for the proportionality constant, G.




$$\mathbf{G = 6.67 \times 10^{-11}\ Nm^2/kg^2}$$

Notice how tiny this is – no wonder we don't feel a force of attraction to other masses unless one of the masses is huge! (The mass of Earth is ~ 6 x $10^{24}$ kg.)

We can now take the inverse law relationship that Newton discovered and express it as an equation:

$$\mathbf{F = \frac{G m_1 m_2}{d^2}}$$

When this equation is written formally (as it is on your AP formula sheet) it includes a negative sign. The negative sign indicates that the force is attractive. Generally when we use this formula we will be interested in the magnitude of force acting on an object so we will not be including the negative sign in our calculations. Also, the symbol 'r' is often used instead of 'd' to represent the center-to-center separation between the two masses so be comfortable with either.