Gravitational force depends on the masses and the distance

Newton developed the following equation to describe quantitatively the magnitude of the gravitational force if distance r separates masses m_1 and m_2:

NEWTON'S LAW OF UNIVERSAL GRAVITATION

$$F_g = G\frac{m_1 m_2}{r^2}$$

$$\text{gravitational force} = \text{constant} \times \frac{\text{mass 1} \times \text{mass 2}}{(\text{distance between masses})^2}$$

G is called the *constant of universal gravitation.* The value of G was unknown in Newton's day, but experiments have since determined the value to be as follows:

$$G = 6.673 \times 10^{-11}\,\frac{\text{N} \cdot \text{m}^2}{\text{kg}^2}$$

Newton demonstrated that the gravitational force that a spherical mass exerts on a particle outside the sphere would be the same if the entire mass of the sphere were concentrated at the sphere's center. When calculating the gravitational force between Earth and our sun, for example, you use the distance between their centers.

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Gravitational force acts between all masses

Gravitational force always attracts objects to one another, as shown in **Figure 7.** The force that the moon exerts on Earth is equal and opposite to the force that Earth exerts on the moon. This relationship is an example of Newton's third law of motion. Also, note that the gravitational forces shown in **Figure 7** are centripetal forces. As a result of these centripetal forces, the moon and Earth each orbit around the center of mass of the Earth-moon system. Because Earth has a much greater mass than the moon, this center of mass lies within Earth.

Gravitational force exists between any two masses, regardless of size. For instance, desks in a classroom have a mutual attraction because of gravitational force. The force between the desks, however, is negligibly small relative to the force between each desk and Earth because of the differences in mass.

If gravitational force acts between all masses, why doesn't Earth accelerate up toward a falling apple? In fact, it does! But, Earth's acceleration is so tiny that you cannot detect it. Because Earth's mass is so large and acceleration is inversely proportional to mass, the Earth's acceleration is negligible. The apple has a much smaller mass and thus a much greater acceleration.

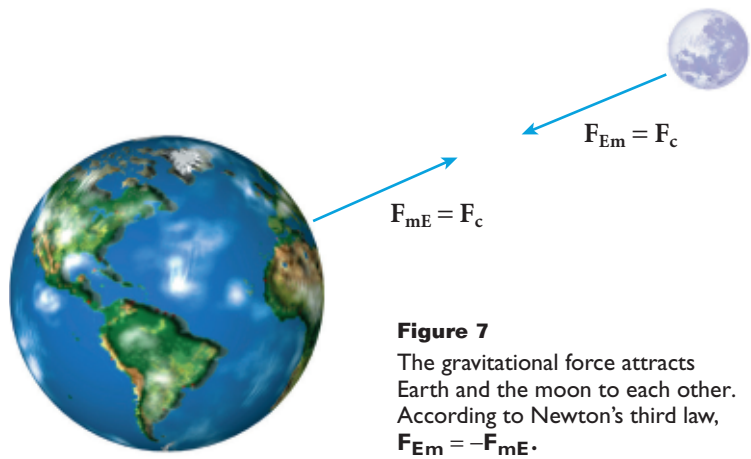

Figure 7
The gravitational force attracts Earth and the moon to each other. According to Newton's third law, $F_{Em} = -F_{mE}$.