# Gravity & Newton's Law of Universal Gravitation

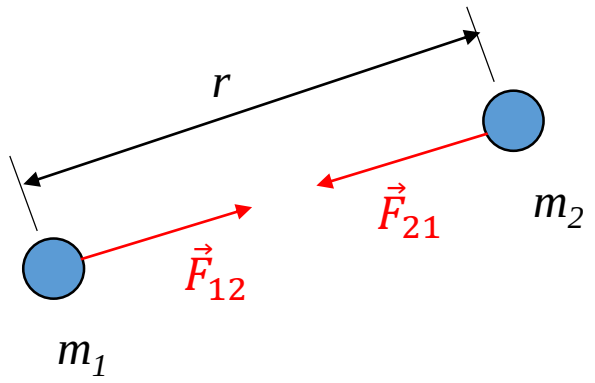
# As the story goes…

Before Isaac Newton, it was believed that the rules governing the motion of objects on Earth were different from those that governed the motions of the Moon and the planets. (After all, "terrestrial" objects fell to the ground and "celestial" objects stayed in the sky.)

One day, a young man was sitting under a tree while the moon was visible in the sky. Upon witnessing an apple fall from the tree, he pondered whether the force drawing the apple to the ground and the force that held the moon in its orbit were the same…

# Newton's Law of Universal Gravitation

Mutual attraction between objects that have mass.




$$\left|\vec{F}_{12}\right| = \left|\vec{F}_{21}\right| = F_{grav} = \frac{Gm_1m_2}{r^2},$$

where $G = 6.67 \times 10^{-11} \frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}$ is the *universal gravitational constant*.

The gravitational force obeys an *inverse-square law*. (If the distance between the two masses is doubled, the force of attraction will decrease by a factor of four. Triple the distance, and the force will become one-ninth.)

# The Gravitational Field

Recall that we described *weight* as the "force of gravity" acting on an object: That is, $F_{grav} = mg$. Combine this with Newton's law of universal gravitation:

$$F_{grav} = mg = \frac{Gm_1m_2}{r^2}$$

With $m_1$ being the mass of the object, $m_2$ being the mass of the Earth ($M_E$), and $r$ being the separation between the object and the center of the Earth ($R_E$):

$$mg = \frac{GmM_E}{R_E^2}\,.$$

$$\text{Then } g = \frac{GM_E}{R_E^2} = \frac{(6.67\times10^{-11}\frac{\text{N.m}^2}{\text{kg}^2})(5.98\times10^{24}\text{ kg})}{(6.637\times10^{6}\text{ m})^2} = 9.83\text{ m/s}^2.$$

# Common Misconception about *Weightlessness*

Misconception: “There is no gravity in space.”

Perhaps this misconception stems from the term: *weightlessness*.

Up until now, we described *weight* as the force of gravity acting on an object. More accurately, weight is what you “feel” when gravity presses you against the surface of the Earth (or, when in suspension, the tension in a rope). Either way, $weight = mg$.

Without support (as in free fall), objects accelerate downward due to the force of gravity even though they are “weightless.” With no support, astronauts do not “feel” their own weight despite being accelerated by gravity).