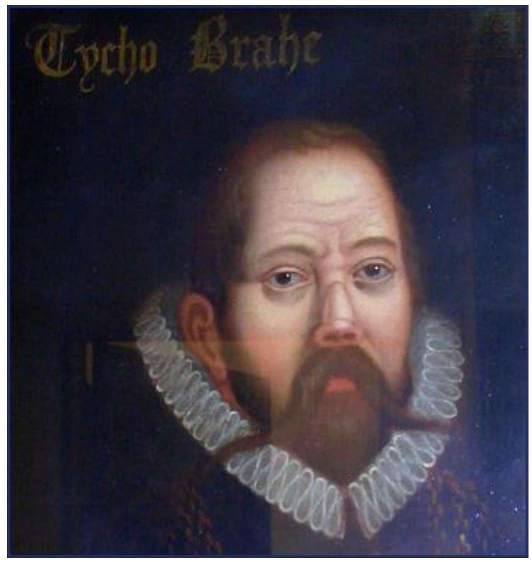
UNIVERSAL GRAVITATION

- The force of gravity (F_g) causes your body to undergo an acceleration (g) when you fall.
  - g is the same for all objects, *regardless of mass*.

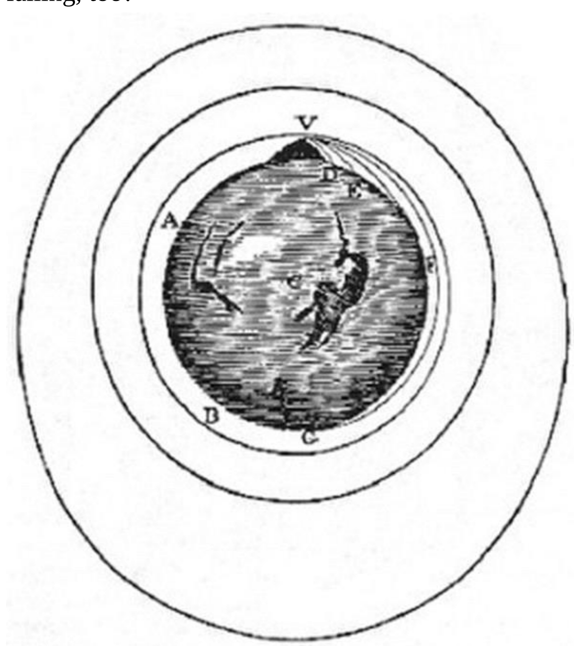
THE LAW OF UNIVERSAL GRAVITATION

- Tycho Brahe had been collecting vast amounts of astronomical data from his island observatory for years.
- Upon his death, Johannes Kepler steals the data and comes up with Kepler's 3 Laws of Planetary Motion (more on that in circular motion notes).
  - Kepler's Laws only tell you how the planets move, not ***why***.



Kepler Brahe

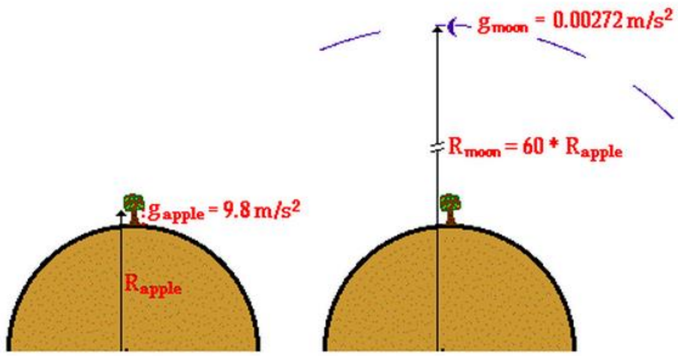
- Newton, according to legend, is walking through an orchard one day and an apple hits him in the head. He starts to wonder why the apple falls. And is the moon falling, too?
- **Newton's Mountain →** a thought experiment in which Newton imagined launching cannon balls horizontally from a tall mountain, in which each shot had a higher initial velocity than the last.



- Newton also knew that on the surface of the planet, objects accelerated towards Earth at a rate of 9.8 m/s^2.
  - It was also known that the moon accelerated towards the Earth at a rate of 0.00272 m/s^2.

$$\frac{g_{moon}}{g_{apple}} = \frac{1}{3600}$$

  - He then noted that the moon is 60x further from the center of the Earth than an apple at the Earth's surface.
  - He concluded that distance must play a factor in gravitation and it must follow an **inverse square law**.



  - He only was able to come up with a proportion—*not* an equation.

$$F_g \sim \frac{1}{r^2}$$

  - The force of gravity is inversely related to the square of the distance between the centers of the two objects.
- **The Law of Universal Gravitation** → *all* objects have a force of gravitational force of attraction with every other object.
- Nearly 100 years later, in 1798, Lord Henry Cavendish discovered the **universal gravitation constant (G)** and an equation was able to be developed.
  - **G** = 6.673 x 10^{-11} N·m^2/kg^2

$$F_g = \frac{Gm_1m_2}{r^2}$$

Example Problem 1

Determine the force of gravitational attraction between the earth (m = 5.98 x 10^{24} kg) and a 70-kg physics student if the student is standing at sea level, a distance of 6.38 x 10^6 m from earth's center.

Example Problem 2

Determine the force of gravitational attraction between the earth (m = 5.98 x 10^{24} kg) and a 70-kg physics student if the student is in an airplane at 40000 feet above earth's surface. This would place the student a distance of 6.39 x 10^6 m from earth's center.

- You can derive that formula to find the acceleration due to gravity on any given planet.

$$g = \frac{GM_p}{r^2}$$

- Where M_p is the mass of the planet in kg.

Example Problem 3

Mars has a mass of 6.4169×10^{23} kg and a radius of 3.397×10^{6} m. What is the acceleration due to gravity on the surface of Mars?