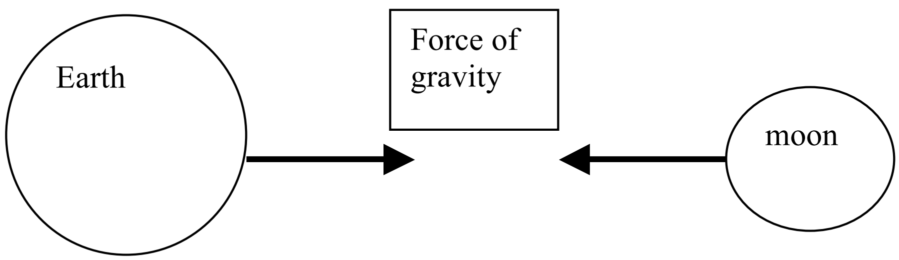
Cavendish, Henry (1731-1810) experimentally determined the value for the universal gravitational constant in Newton's Law of Gravity. Once that value was determined, the mass of the earth was easily calculated by equating the centripetal force applied to the moon as it orbited the Earth, with the force of gravity.

The force of gravity pulling on the moon, supplies the centripetal force that allows the moon to orbit the Earth. It takes the moon 27.3 days to circle the earth. The moon is approximately 3.84×10^8 meters from the Earth.



Newton's law of gravity states that:

$$F_G = \frac{\gamma m_1 m_2}{R^2} \text{ where } \gamma = 6.67 \text{x} 10^{-11} \frac{Nm^2}{kg^2}$$

The centripetal force is determined by using:

$$F_c = ma_c \text{ where } a_c = \frac{V^2}{R}$$

$$\text{Therefore } F_c = \frac{mv^2}{R}$$

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Since it is the force of gravity that supplies the centripetal force to the moon, the two forces must be equal.

$$F_G = F_c$$

$$\frac{\gamma M_E M_m}{R^2} = \frac{M_m V^2}{R}$$

Therefore, the mass of the Earth can be found by the following equation.

$$M_E = \frac{V^2 R}{\gamma}$$

To determine the velocity of the moon, we will make the approximation that the moon orbits the earth in a perfect circle (this is not strictly true, but not a bad estimate). The circumference of a circle = $2\pi R$

The moon's average velocity is found by dividing the circumference by the time required for the moon to make one complete revolution around the earth.

$$V_{average} = \frac{\Delta X}{\Delta T} = \frac{Circumference}{T} = \frac{2\pi R}{T}$$

$$V^2 = \frac{4\pi^2 R^2}{T^2}$$

Substituting for V^2 in the mass of earth equation yields the following:

$$M_E = \frac{V^2 R}{\gamma} = \frac{4\pi^2 R^3}{\gamma T^2}$$

Where R = 3.84 X 10^8 m is the average distance between the Earth and Moon, and T = 27.3 days = 2.3 X 10^6 seconds is the time for one complete revolution of the moon around the Earth.

Substituting these values in the mass of Earth equation, we get:

$$M_E = \frac{4\pi^2 R^3}{\gamma T^2} = \frac{4\pi^2 \left(3.84 X 10^8 m\right)^3}{6.67 X 10^{-11} \frac{Nm^2}{kg^2} \left(2.36 X 10^6 \sec\right)^2}$$

$$M_E = 6.02 X 10^{24} kg$$

The accepted value for the mass of the earth is 5.98 X 10^{24} kg.

Do you know why we are slightly off?

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