Newton's Law of Universal Gravitation

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P3.6A Explain earth-moon interactions (orbital motion) in terms of forces.

P3.6d Calculate force, masses, or distance, given any three of these quantities, by applying the Law of Universal Gravitation, given the value of G.

Newton decided that every apple, every rock, every particle in the universe attracts, and is attracted to, every other particle in the universe.

Consider two particles that have masses m_1 and m_2, and are separated by a distance r,
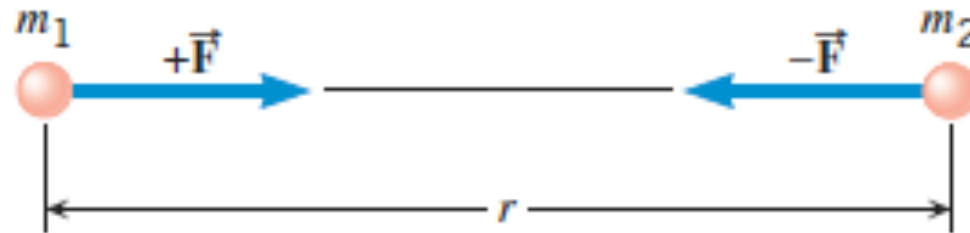
the two particles are attracted by gravitational forces + F and -F. The gravitational force (F) that each exerts on the other is directed along a line joining the particles.

$\vec{+F}$ is the gravitational force exerted on particle 1 by particle 2. $\vec{-F}$ is the gravitational force exerted on particle 2 by particle 1.

The strength of the gravitational force between tow masses is proportional to the masses and inversely proportional to the square of the distance between them.

Newton's Law of Universal Gravitation
$$F = G\frac{m_1 m_2}{r^2}$$
G is the universal gravitational constant. $G = 6.673 \times 10^{-11}$ N.m ^{2}/kg^2

The unit of Force is Newton (N).

The force of attraction between small objects is not zero, but it is too small for ordinary measuring instruments and is insignificant for practical purposes.

Sample Problem

What is the force of attraction between two apples, each with a mass of 0.5 kg, held so that their center are 10 cm apart?

$m_1 = m_2 = 0.5$ kg   r = 10 cm = 0.1 m $G = 6.673 \times 10^{-11}$ N.m^2/kg^2

According to Newton's Law of Universal Gravitation, the force of attraction is given by the formula:

$$F = G \, m_1 \, m_2 \, / \, r^2$$

Put the values of m_1 , m_2 , r and G in the formula

$$F = (\, 6.673 \times 10^{-11})(0.5)(0.5) \, / \, (0.1)^2$$

$$= 1.7 \times 10^{-9} \text{ N}$$

Practice Problem; Answer questions 1 and 2.

1. What is the force of attraction (gravitational) between a 60 kg girl ($m_1 = 60$ kg) and 70 kg boy ($m_2 = 70$ kg), whose centers are 1.0 m apart (r =1.0 m)? hint: Apply Newton's Law of Universal Gravitation

2. Use Newton's Law of Universal Gravitational to explain the force of gravitation between the Earth and the moon. Write the formula for this force.