NEWTON'S LAW OF UNIVERSAL GRAVITATION

Isaac Newton compared the acceleration of the moon to the acceleration of objects on earth. Believing that gravitational forces were responsible for each, Newton was able to draw an important conclusion about the dependence of gravity upon distance. This comparison led him to conclude that the force of gravitational attraction between the Earth and other objects is inversely proportional to the distance separating the earth's center from the object's center. But distance is not the only variable affecting the magnitude of a gravitational force. Consider Newton's famous equation. $\mathbf{F_{net} = m \bullet a}$

Newton knew that the force that caused the apple's acceleration (gravity) must be dependent upon the mass of the apple. And since the force acting to cause the apple's downward acceleration also causes the earth's upward acceleration (Newton's third law), that force must also depend upon the mass of the earth.

The UNIVERSAL Gravitation Equation

But Newton's law of universal gravitation extends gravity beyond earth. Newton's law of universal gravitation is about the **universality** of gravity. Newton's place in the *Gravity Hall of Fame* is not due to his discovery of gravity, but rather due to his discovery that gravitation is universal. **ALL** objects attract each other with a force of gravitational attraction. Gravity is universal. This force of gravitational attraction is directly dependent upon the masses of both objects and inversely proportional to the square of the distance that separates their centers.

Since the gravitational force is directly proportional to the mass of both interacting objects, more massive objects will attract each other with a greater gravitational force. If the mass of one of the objects is doubled, then the force of gravity between them is doubled. If the mass of one of the objects is tripled, then the force of gravity between them is tripled. If the mass of both of the objects is doubled, then the force of gravity between them is quadrupled; and so on.

Since gravitational force is inversely proportional to the square of the separation distance between the two interacting objects, more separation distance will result in weaker gravitational forces. If the separation distance between two objects is doubled (increased by a factor of 2), then the force of gravitational attraction is decreased by a factor of 4 (2 raised to the second power). If the separation distance between any two objects is tripled (increased by a factor of 3), then the force of gravitational attraction is decreased by a factor of 9 (3 raised to the second power).

1. **Suppose that two objects attract each other with a gravitational force of 12 units.**
    a. **If the distance between the two objects is doubled, what is the new force of attraction between the two objects?**
    b. **If the mass of both objects was doubled, and if the distance between the objects was doubled, then what would be the new force of attraction between the two objects?**

$$F_{grav} = \frac{G \bullet m_1 \bullet m_2}{d^2}$$

where G represents the universal gravitation constant

$(G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2)$

The constant of proportionality (G) in the above equation is known as the **universal gravitation constant**. The units on G may seem rather odd; nonetheless they are sensible. When the units on G are substituted into the equation above and multiplied by $\mathbf{m_1 \bullet m_2}$ units and divided by $\mathbf{d^2}$ units, the result will be Newtons - the unit of force.