Sir Isaac Newton is quite possibly the most historically significant figure in the physics. If not for his life work, for his influence of on everyday living. Newton summarized critical principles that guide us still today. From the space program to everyday architecture, the modern world would not be what it is today without the laws that he helped to articulate in such a concise manner.

**::NEWTON'S UNIVERSAL GRAVITY LAW::**

"All objects with mass exert an inherent gravitational force on all other objects with mass".

Newton discovered in his studies of gravity was that the Earth and other celestial objects were not the only objects that generated gravity. In fact, every object in the universe that has mass generates a gravitational field whose strength is determined by the following formula

| | |
|---|---|
| $F_g = \dfrac{GM_1M_2}{r^2}$ | Where<br>$F_g$ = the force of gravity in Newtons ($N$)<br>$G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$<br>$M_1$ = mass of object 1, in $kg$<br>$M_2$ = mass of object 2, in $kg$<br>$r$ = the separation distance between the centre of mass of the two objects, in meters ($m$) |

**::BIG IDEAS::**

- All objects that have mass produce their own gravity
- As **mass** increases the strength of gravity **increases**
- As **distance** to the object **increases** the strength of gravity **decreases** as the square of that distance.

  example: Distance doubles, gravity is reduced to one quarter. Distance triples, gravity decrease to one ninth.

**::ALTERNTATIVE NOTATION::**

Newton's Universal Gravity equation can also be expressed in the following way when working with masses of greatly differing size. For example a **planet** (big "M") and a **satellite** (small "m")

| | |
|---|---|
| $F_g = \dfrac{GMm}{r^2}$ | Where<br>$G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$<br>$M$ = mass of the very large object, in $kg$<br>$m$ = mass of the much smaller object, in $kg$<br>$r$ = the separation distance between the centre of mass of the two objects, in meters ($m$) |

**:: COMPARING NEWTON'S UNIVERSAL GRAVITY EQUATION VS. FORCE OF GRAVITY**

Earlier in the unit, we had an equation for the force of gravity

$$F_g = mg$$

How does this formula compare to our new one?

$$F_g = mg \ (1) \quad \text{and} \quad F_g = \frac{GMm}{r^2} \ (2)$$

Let (1) = (2)

$$\cancel{m}g = \frac{GM\cancel{m}}{r^2}$$

| | |
|---|---|
| $g = \dfrac{GM}{r^2}$ | Where<br>$g$ = the acceleration due to gravity in $m/s^2$<br>$G = 6.67 \times 10^{-11}\ N \cdot m^2/kg^2$<br>$M$ = mass of the very large object, in $kg$<br>$r$ = the separation distance between the centre of mass of the two objects, in meters ($m$) |

**Ex1:** Find the force of gravity between two 100kg objects, separated by a distance of 3.0m

**Ex2:** Two objects separated by a distance R have a mutual gravitational attraction of 10N. What would be the effect on the force of gravity if

a) one mass is doubled
b) both masses are doubled
c) the distance is doubled and the masses remain the same
d) the distance and masses are doubled

**Ex3:** Two large masses, separated by a distance of 10m. The masses of each are $1\times10^5 kg$ and $5\times10^5 kg$, from left to right respectively. Where would you place a third mass if the system is to remain in equilibrium?

**Ex4:** Two solid spheres are separated by a distance of 10m. The sphere on the left is 500kg and the sphere on the right is 100kg. Find:

a) The net force due to gravity acting on a $3^{rd}$ sphere, of mass 1kg, if it is located 5m right of the 100kg mass.
b) The net force due to gravity acting on a $3^{rd}$ sphere, of mass 1kg, if it is located 5m left of the 500kg mass.
c) The point where the net force acting on the third mass is zero.