Skill 26: Universal Gravitation

All functions of the Universe are controlled by four Fundamental Forces. Those four forces are

- Strong force
- Electromagnetic
- Weak
- Gravitational

The **Gravitational Force, F_g** is a force that exists between any two objects that have the property of **mass.** Gravitational Force is always attractive. Therefore all masses in the universe feel some force pulling them together.

The strength of the gravitational attraction (F_g) between two objects is based on:

- The **mass of each object** (m_1 and m_2)
- The **distance between centers of objects** (r)
  - For an object on the surface of the Earth, r, the distance between centers is the Earth's Radius. (6.37×10^6m)
- **Universal Gravitational Constant (G)** which is equal to $6.67 \times 10^{-11} Nm^2/kg^2$ (note NOT the same as "g" which is the gravitational field strength or acceleration due to gravity which is equal to 9.81 N/kg or 9.81 m/s^2 on Earth)

These three factors are summarized in the equation:

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

We have two equations for F_g

F_g=mg **and** $F_g = G\frac{m_1m_2}{r^2}$

Used to find F_g in a uniform gravitational field. (ie, on the surface of a planet).

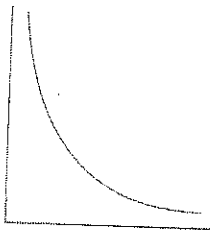
To find F_g **without** a uniform field. The distance between two masses is "r", and the Universal Gravitational Constant is $6.67 \times 10^{-11} N\frac{m^2}{kg^2}$

For any large object (such as a planet or moon) you can find the gravitational field strength "g" (aka acceleration due to gravity) by setting these equations equal to each other (where m_1 is a mass of the object such as a person, a book etc)

$m_1g = G\frac{m_1m_2}{r^2}$ the m_1's cross off so $g=G\frac{m_2}{r^2}$

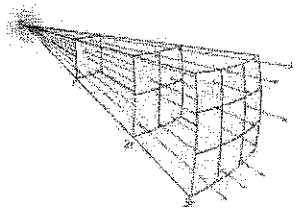
The Universal Gravitation equation reveals a fourth relationship known as **Inverse square**

The graph for inverse square takes the same shape as the inverse graph but perhaps the curve more pronounced



What ever happens to "x" the opposite and square happens to "y"

Equation format is $y = \frac{m}{x^2}$



As the distance from the center increases the strength of the gravitational field is spread out over a larger surface area. If the distance from the center doubles the gravitational field is spread out over 4 times the area, so therefore the gravitational force is 4 times weaker. [ie, as "r" or distance between centers "x" doubles, the F_g or gravitational force of attraction "y" is quartered.]

The equation $F_g = G\frac{m_1 m_2}{r^2}$ reveals a direct relationship between F_g and the product of the masses and an inverse relationship between F_g and the distance between the centers of two masses (r)

TOPIC 3C

Skill 27: Conservation of Momentum

Collisions between objects follow a predictable pattern of behavior due to the fact that momentum is a conserved quantity.

This means that the total momentum of the objects before a collision is equal to the total momentum of the objects after a collision. In equation format this concept can be summarized as

$$p_{before} = p_{after}$$

3 main categories of collisions exist: for any object at rest p=0 since v=0

Elastic collisions - The objects remain separate when the collision occurs. 2 or more objects 2 different velocities.

$$P_{before} = P_{after}$$
$$\mathbf{p_1 + p_2 = p_1' + p_2'}$$
$$\mathbf{m_1v_1 + m_2v_2 = m_1v_1' + m_2v_2'}$$

Inelastic collisions – The objects stick together when the collision occurs. 2 individual objects combine to a single object with a single velocity.

$$P_{before} = P_{after}$$
$$\mathbf{p_1 + p_2 = (p_1 + p_2)'}$$
$$\mathbf{m_1v_1 + m_2v_2 = (m_1 + m_2)v'}$$

Separation or Explosions – Two (or more) joined objects separate when the collision event occurs. If one object moves forward the other moves backward. This backward motion, known as **recoil**, is common when firing guns, cannons etc.

$$\mathbf{P_{before} = P_{after}}$$
$$\mathbf{0 = p_1 + p_2}$$
$$\mathbf{0 = m_1v_1 + m_2v_2}$$

REMEMBER VELOCITY AND MOMENTUM ARE BOTH VECTORS. DIRECTION IS INDICATED BY + or – sign.