Newton’s Law of Gravitation

Isaac Newton stated this law of universal gravitation:

Every object attracts every other object with a force called gravity. The force of gravity between two objects is directly proportional to the masses of the two objects and inversely proportional to the square of the distance between the two objects.

Newton gave us this equation for the gravitational force between objects 1 & 2:

Fg – gravitational force in newtons

G – Gravitation Constant = 6.67 X 10-11 N•m2/kg2

M1 – mass of object 1 in kg

M2 – mass of object 2 in kg

r – distance between the centers of mass of the two objects

Doubling the mass on ONE object will double the gravitational force. Doubling the distance between the two objects will reduce the force by ¼.

Be careful with the value for *r*. For an object at the surface of the earth, the value for *r* is the radius of the earth, not zero. For a satellite in orbit, the value for *r* is the altitude of the orbit + the radius of the earth. Example: A satellite in orbiting at an altitude of 600 miles. The radius of the earth is about 4000 miles. The value for *r* = 600 + 4000 = 4600 miles.

The acceleration due to gravity for an object depends only upon the object that produces the gravitational field, not the object moving in the field. So if object 2 accelerates in the gravitational field of object 1, the acceleration of object 2 due to object 1 can be determined:

Net F on 2 = M2a2. But the NET force is the gravitational force, FG = GM1M2/r2

a 2 = NET F on 2/M2 = GM1M2/r2M2. The M2’s will cancel giving the equation: a2 = GM1/r2.

a2 is the acceleration due to the gravity of mass 1. We can give it the symbol *g*1.

This equation now becomes a very valuable one:

This equation allows you to calculate the acceleration due to gravity on a planet or at any altitude above the planet if you know the mass of the planet.

If the planet is earth and *r*  is the radius of the earth, this equation give the acceleration due to gravity at the surface of the earth, 9.8 m/s2.

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**For an object orbiting a planet**

The only orbits at which we will look are circular orbits. The speed of the satellite will be constant, so the satellite orbits the planet with uniform circular motion. The general equation for uniform circular motion applies



The centripetal force is provided by the gravitational force of the earth on the satellite.

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The orbital speed of the satellite is then



*r* – radius of the satellite orbit measured from the center of the earth

*r* = radius of earth + altitude of orbit

The orbital speed equation shows that there is only one speed for a given orbital altitude.

Notice also that the mass of the satellite in not in the final equation. All satellites, regardless of size, must have the same speed for the same altitude.

If the satellite were orbiting Mars, you would use the mass of Mars and the radius of Mars in the equation. The same equation applies and the value of *G* does not change.