29:52 Exploration of the Solar System
Notes for February 22, 2008
Gravity and Orbits II

Centripetal Acceleration

If the direction of motion of an object changes as it moves, it is undergoing an acceleration, because the **velocity**, a vector, is changing. As is shown clearly in Figure 5.7 of the textbook, an object moving on a circular path is undergoing a *centripetal acceleration,* in which the acceleration points at the center of the circle.

According to Newton's 2nd Law, if an object with mass m is subject to an acceleration, there is a force acting on that object. Put 2 and 2 together and you conclude that there is a force exerted by the Sun on the planets which is causing them to move on their roughly circular orbits (remember, the orbits are precisely ellipses).

Newton's Force Law

Isaac Newton figured out the equation for the force between two objects, one having mass m1 and the other having mass m2, separated by a distance r. The force is $F=Gm1(m2)/r^2$. This is called an inverse square law. The value of the constant G (the gravitational constant) is $6.6726X10^{-11}$. The solar system is held together by the gravitational forces between the Sun and each of the planets.

You should note and wonder at the statement in p88 of your textbook. "every pair of particles in the universe, no matter how far apart, exert a gravitational force on each other".

Of course, the planet, the Moon, etc aren't point masses, they are spherical objects with a certain mass and radius. What is the gravitational force between a sphere with a certain mass M, and a mass outside m. Look at Figure 5.9 to visualize what we are talking about.

Newton invented calculus to solve this problem. The answer is that the gravitational force is the same as if you concentrated all of the mass of the spherical object in a massive marble at the center of the spherical object. It is an amazing coincidence of nature that it doesn't matter that the mass is spread out to such an extent.

When we are standing on the surface of the Earth, we aren't accelerating inwards or outwards. In terms of Newton's 2nd law of motion, this means that the *net force* on us is zero. The Earth is exerting a gravitational force on us, but the surface of the Earth is exerting an equal force upward, in the opposite direction, so that the net force is zero. The force we exert downwards on the surface of the Earth is your *weight.*

If you went to the Moon or a different planet, your mass would be the same, but your weight would be different.

Summary: Newton's Laws and Kepler's Laws.

Newton's Laws, and the equation for the force of gravity described in your textbook describe an incredible amount about our universe, not just the phenomena in the solar system. They help us understand Kepler's Laws in the following way.

1. Newton's 2nd Law and the equation for gravitational force can be used to *show that* planets will move on elliptical paths. This means that we can explain Kepler's 1st law, and understand that it is a consequence of Newtonian mechanics.
2. These same equations also *show that* Kepler's 3rd law holds. Again, we explain the 3rd law and see that it is a consequence of Newtonian dynamics.
3. Although we didn't talk about it, Newtonian mechanics shows that the *angular momentum* of an object is conserved (keeps the same value). Kepler's 2nd law is a consequence of this.

Next time, we start talking about the properties of the Earth's Moon. This material is in Chapter 9.