29:52 Exploration of the Solar System
Class Notes for February 20, 2008
Gravity and Orbits I

Today we begin explaining why planetary orbits have the properties they do, and the role gravity plays in the nature of the solar system. The beginning of physics as we now know it, and the discovery of the laws that govern the orbits of the planets came from the work of Isaac Newton in the late 17th century.

Newton's description of *dynamics*, or the laws governing the motion of the planets, relied on the development of *kinematics*, which is the mathematical language that describes motion of objects. Here are some terms which are important in kinematics.

- *speed* is the rate at which you are moving. It has units of meters/sec. The speed doesn't depend on the direction you are going.
- *velocity* is a mathematical quantity called a *vector*; it has both magnitude and direction. The magnitude of velocity is the speed. However, the velocity, being a vector, has a direction as well. The velocities corresponding to moving east at 50 mph is different from moving south at 50 mph.
- *acceleration* is also a vector. The acceleration is the amount the velocity changes, divided by the time interval over which this change occurs. In terms of equations, we have

$$acceleration = a = \frac{\text{change in velocity}}{\text{change in time}} = \frac{V_2 - V_1}{t_2 - t_1} \tag{1}$$

  Acceleration occurs if the speed of an object changes while the direction of motion stays the same, if the speed stays constant while the direction of motion changes, or if both the speed and the direction changes.

Newton's Laws of Motion

With the kinematic definitions above, we are ready to state Newton's Laws.

1. An object in motion remains in motion with the same velocity, unless acted on by an external force. An object at rest remains at rest unless acted on by an external force.

2. If an object with a mass m is acted upon by an external net force F, it accelerates according to the law

$$F = ma, \text{ or} \tag{2}$$

$$a = \frac{F}{m} \tag{3}$$

3. "To every action, there is an opposite and equal reaction". That definition sounds neat, but a more useful definition is: If an object A exerts a force on object B, object B also exerts a force on A, which is equal in magnitude, but opposite in direction to the first force.

Centripetal Acceleration

An important case of acceleration (and the force associated with that acceleration) occurs when an object moves on a circular path, or a path which is close to being circular at some point. Look at Figure 5.7 of the book.