## ASTR 1020

Look Over Chapter 4: Making Sense of the Universe: Understanding Motion, Energy, and Gravity

Kepler's laws (from	Center of Mass
Chapter 3)	Open Orbits
Velocity	Laws of motion
Acceleration	Newton's Law of
Inertia	Universal Gravity
Force	Angular momentum
Momentum	

#### The Start of Astronomy

The beginnings of Astronomy goes back to ancient people trying to understand the motion of planets and stars.

It was the Greek philosopher Aristotle who for 2000 years was the authority on the motion both in the sky and on the ground.

This started to changed with Copernicus' model of the solar system and the work of Galileo and Kepler.

## Kepler's 3 Laws of Planetary Motion

Kepler Published two books with his theories on planetary motion. These ideas are summarized as <u>Kepler's</u> laws of Planetary Motion.

Kepler's 1<sup>st</sup> Law states: The orbits of the planets around the sun are ellipses with the Sun at one focus.

#### Kepler's 2<sup>nd</sup> Law

Kepler's 2<sup>nd</sup> Law states: A line from a planet to the sun sweeps over equal areas in equal intervals of time

This means that when the planet is closer to the Sun and thus the line connecting it to the sun is shorter, the planet must move faster if the line is to sweep over the same area.

Kepler's 3 <sup>rd</sup> Law	
	Kepler's Third Law states: A planet's orbital period ( <b>P</b> ) squared is proportional to its average distance from the Sun (a) cubed.
$P^2 \propto a^3$	Where the average distance that a planets is from the sun is equal to the semi- major axis.

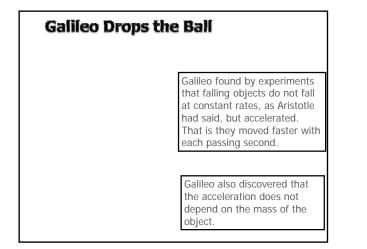
## Velocity

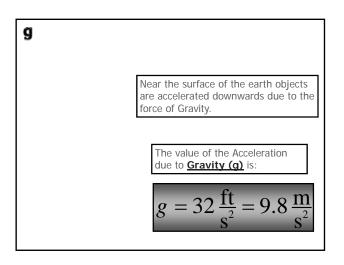
To complete describe the motion of an object we need to know its speed and which direction it is going. Both of theses pieces of information are referred to as the <u>Velocity</u> of an object.

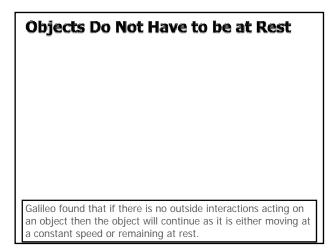
## Acceleration

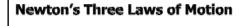
Acceleration is the rate at which velocity changes with respect to time.

Galileo on Motion









**<u>Isaac Newton</u>**, a British physicist and mathematician formulated the the laws of motion, discovered the law of universal gravity, and invented calculus before he was 30 years old.

### Newton's First Law of Motion An object at rest remains at rest and an object in motion will continue in motion with a constant velocity (that is, constant speed in a straight line) unless it experiences a net external Force A Force is any influence that can change the speed or direction of motion of an object.

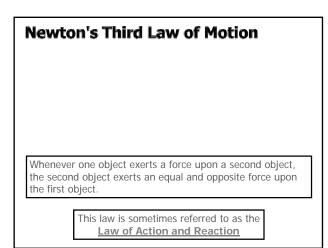
Mass
Some objects will resist forces more then others. Inertia is the tendency of an object to resist outside forces.
The Mass of an object is a measure of its Inertia.

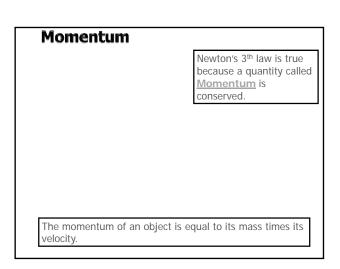
The metric unit of mass is the Kilogram (kg)

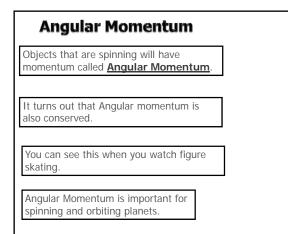
Newton's Second Law of Motion  
The acceleration of an object is directly proportional to the  
net force acting on it and is inversely proportional to its mass.  

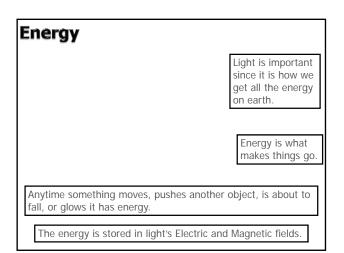
$$\begin{aligned}
\mu &= \frac{F}{m} \text{ or } F = ma \\
\text{Where the units for force are:}
\end{aligned}$$
Where the units for force are:









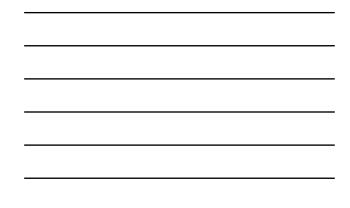


#### **Conservation of Energy**

The Universe started with a certain amount of energy which can be transformed from one type to another and from one object to another. But all the energy is still present in the Universe.

The law of conservation of energy is that energy can not be created of destroyed, but can be transformed from on type to another and from one object to another.

Newton's Law of Universal Gravity
$$F = G \frac{m_1 m_2}{r^2}$$
Where *G* is a constant that is the same though out the universe.
$$G = 6.67 \times 10^{-11} \frac{N \cdot m^2}{kg^2}$$



Center of Mass It turns out that a planet does not orbit the exact center of the Sun. Instead, both the planet and the Sun orbit their common Center of Mass.

# Kepler's 1<sup>st</sup> Law Modified Because the Sun and a planet feel equal and opposite gravitational forces (by Newton's 3<sup>rd</sup> law), the Sun must also move (by Newton's 1<sup>st</sup> Law), driven by the gravitational influence of the planet. Thus Kepler's 1<sup>st</sup> Law becomes:

The orbit of a planet around the Sun is an ellipse, with the center of mass of the planet–Sun at one focus.

#### **Open and Closed Orbits**

Kepler's laws refer to elliptical orbits, which includes circular orbits. These orbits are called closed orbits because they return back on themselves.

Newton's laws reveal the existence of another kind of orbit. An open orbit leads away from the central body, never to return. **Open Orbits** are also called **Escape Orbits**.

