ASTR 1020

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

Good Things to Know

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

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

Kepler's 2nd Law

Kepler's 2nd 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 3rd Law

Kepler's Third Law states: A planet's orbital period (**P**) 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 **Velocity** of an object.

Acceleration

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

Galileo on Motion

Galileo broke with the tradition of turning to the work of the past philosophers and conducted his own experiments.

Galileo Drops the Ball

Galileo found by experiments that falling objects do not fall at constant rates, as Aristotle had said, but accelerated. That is they moved faster with each passing second.

Galileo also discovered that the acceleration does not depend on the mass of the object.

g

Near the surface of the earth objects are accelerated downwards due to the force of Gravity.

The value of the Acceleration due to **Gravity (g)** is:

$$g = 32\,\frac{\text{ft}}{\text{s}^2} = 9.8\,\frac{\text{m}}{\text{s}^2}$$

Objects Do Not Have to be at Rest

Galileo found that if there is no outside interactions acting on an object then the object will continue as it is either moving at a constant speed or remaining at rest.

Newton's Three Laws of Motion

Isaac Newton, 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.

$$a = \frac{F}{m} \text{ or } F = ma$$

Where the units for force are:

$$kg\frac{m}{s^2} = N \text{ (a Newton)}$$

Newton's Third Law of Motion

Whenever one object exerts a force upon a second object, the second object exerts an equal and opposite force upon the first object.

This law is sometimes referred to as the **Law of Action and Reaction**

Momentum

Newton’s 3^{th} law is true because a quantity called **Momentum** is conserved.

The momentum of an object is equal to its mass times its velocity.

Angular Momentum

Objects that are spinning will have momentum called **Angular Momentum**.

It turns out that Angular momentum is also conserved.

You can see this when you watch figure skating.

Angular Momentum is important for spinning and orbiting planets.

Energy

Light is important since it is how we get all the energy on earth.

Energy is what makes things go.

Anytime something moves, pushes another object, is about to fall, or glows it has energy.

The energy is stored in light's Electric and Magnetic fields.

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.

$$G = 6.67\times10^{-11}\ \frac{N\cdot m^2}{kg^2}$$

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 1st Law Modified

Because the Sun and a planet feel equal and opposite gravitational forces (by Newton's 3rd law), the Sun must also move (by Newton's 1st Law), driven by the gravitational influence of the planet. Thus Kepler's 1st 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**.

Kepler's Third Law Modified

The change to Kepler's 3rd law is small in the case of a planet orbiting the Sun but very important in other circumstances.

The true relationship between the semi-major axis ***a*** of the planets orbit relative to the Sun and its orbit period ***P*** is:

$$\left(m_1 + m_2\right)P^2 = \frac{4\pi^2}{G}a^3$$

where m_1 and m_2 are the masses of the two objects.