Introduction to Astronomy **ANSWER KEY**
PowerPoint Notes

I. Essential Questions:

- What were the accomplishments of early astronomers?
- How does the geocentric model differ from the heliocentric model of the solar system?
- What are Kepler's Laws of Planetary Motion?
- What are astronomical units?
- What is gravity?
- What is the difference between mass and weight?
- What is Newton's Law of Universal Gravitation?

Astronomy is the study of the universe

- Properties of objects in space
- Laws that predicts the way the universe operates

II. Early Astronomers

Aristotle was the first to conclude that the Earth is shaped like a sphere.

- His evidence was that Earth casts a curved shadow on the moon when it passes between the sun and the moon.

Ancient Greeks believed in the geocentric model of the solar system.

- In the geocentric model, the moon, sun, and known planets revolve around Earth in a perfect circular orbit.

Egyptian-Greek Astronomer Ptolemy published the first idea of the geocentric model called the Ptolemaic System in the 2nd century, and the model persisted as the accepted view for the next 1500 years.

Aristarchus was the first Greek to propose that the solar system is heliocentric.

- In the heliocentric model, the Earth and other planets orbit the sun.
- Although there was evidence to support this model, the geocentric model prevailed for nearly 2000 years.

Ptolemy though it was odd that planets appeared to move slightly eastward among the stars, then stop, and reverse motion, and then resume an eastward movement.

- The apparent westward drift is called retrograde movement.
- Results from combination of Earth and the planet's own motion around the sun.

Ptolemy explained retrograde motion by saying the planets moved along smaller circles, which in turn moved along orbits around the Earth. He called these smaller circles epicycles.

Copernicus created the first detailed heliocentric model of the solar system.
He was the first to propose that:

- Earth is a planet
- Earth orbits the sun annually
- Earth rotates daily on its own axis

Brahe built many instruments (before the invention of the telescope) that accurately studied and measured the locations of planets and stars

- Brahe's observations, especially of Mars, were more precise than another other scientists before him.
- Tycho Brahe hired Johannes Kepler as an assistant and Kepler kept most of Brahe's work and put it to exceptional use.

III. Kepler's Laws of Planetary Motion

Kepler Discovered the 3 Laws of Planetary Motion

In 1596, Kepler publicly wrote of support for Copernicus's heliocentric model.

- This was risky because the Lutheran and Catholic churches did not support this idea and even put Galileo under house arrest in 1615 for his publication of support of this sun-centered model.

Kepler's First Law of Planetary Motion

The path around the sun is an ellipse.

- The path of each planet around the sun is not perfectly circular, but instead an oval shape called an ellipse.
- The ellipse contains two foci, or points.
- The sun is at one focus and the other focus is symmetrically located at the opposite end of the ellipse.
- The distance between the 2 foci determines the shape of the ellipse. The farther apart the foci, the more elongated, or eccentric the ellipse is.

Ellipses have eccentricity.

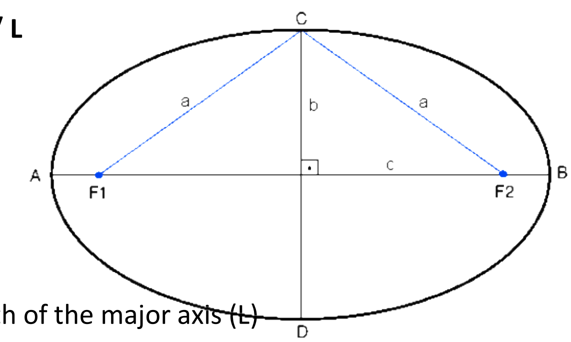
- Eccentricity is the measurement of how elongated a closed circle is and is measured from the foci to the length of the major (longer) axis.
- Eccentricity is measured in values of 0 to 1
- A perfect circle has only a single focus and an eccentricity of zero.
- Ellipses can have a value of 0.1 to 1. The greater the value, the more elongated the ellipse is.

The value of eccentricity is easy to find using the formula E = d / L

E = eccentricity

d = distance between 2 foci

L = length of the major axis



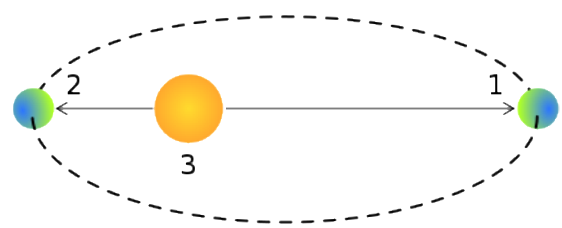
To find the eccentricity, follow these steps:

1) Measure the distance between the foci
2) Measure the distance of the long major axis
3) Divide the distance between the two foci (d) by the length of the major axis (L)

Kepler's 2nd Law of Planetary Motion

Kepler noticed that the speed of Mars in its orbit changes in predictable ways.

- As Mars approaches perihelion, it speeds up. As it approaches aphelion is slows down.
- Perihelion: the point in a planet's orbit closest to the sun
  - On Earth: 147 million km
  - Occurs annually on January 3
- Aphelion: the point in a planet's orbit farthest away from the sun
  - On Earth: 152 million km
  - Occurs annually on July 4



Each planet revolves so that an imaginary line connecting it to the sun sweeps over equal areas in equal time intervals.

- If a planet is to sweep equal areas in the same amount of time, it must move more faster at perihelion and slower at aphelion.
  - The sun's gravity pulls stronger on the planet when it is closest to it, causing it to move faster.
  - As distance decreases between two objects, the force of gravity also decreases, causing a planet to move slower at aphelion.

Kepler's 3rd Law of Planetary Motion

The closer a planet is to the sun, the shorter the orbital period is.

- An orbital period is the time it takes for a planet to complete one orbit around the sun in Earth years.
- 1 orbital period = 1 Earth year

The orbital period squared is equal to its mean solar distance cubed or $T^2 = d^3$
- T stands for orbital period in Earth years
- d stands for distance from the sun in astronomical units

The distance from the Earth to the Sun is 93 million miles or 1 Astronomical Unit
- Astronomical Units are used to measure distances in our solar system.
- 1 Astronomical Unit (AU) = 93 million miles or 150 million kilometers

IV. Galileo Galilei

Galileo was a groundbreaking astronomer whose inventions included the telescope, thermometer, and compass.
- Using his telescope, he was able to view the universe in a new way and made many discoveries that supported the ideas of Copernicus and Kepler.

Galileo's discoveries include:
1. Four satellites, or moons, orbit Jupiter.
2. Planets in the distance are circular disks, not stars.
3. Earth's moon's surface is not smooth, it contained mountains, craters, and plains.
4. The sun had spots, or dark regions and the sun had a rotational period of just under one month.

V. Mass Versus Weight

Mass:
- The total amount of matter (think atoms) in an object.
- Mass is constant and does not change with location
- Measured in kilograms (kg)

Weight:
- The force of gravity acting on an object.
- Weight changes depending where you are in the universe
- Measured in Newtons (N)

VI. Gravity
- Gravity is from the Latin word *gravitas*, meaning *weight*
- Gravity is a force by which all things with mass or energy, including planets, stars, and galaxies are brought toward one another.
- Gravity gives weight to objects
- Earth's gravitational acceleration is $9.8\ m/s^2$
- The gravitational attraction of the matter present in the universe cause it to coalesce into stars, galaxies, and even planets.
- Without gravity, planets would not move in an elliptical orbit. Instead, planets would move in a straight line out into space.
- The greater the mass of an object, the greater its gravitational force.
- The closer two objects are together, the greater the gravitational force.

VII. Isaac Newton
- Newton was the first person to formulate and test the Law of Universal Gravitation.
- The Law of Universal Gravitation states:
- Every object in the universe attracts every other object with a force that is directly proportional to their masses and inversely proportional to the square of the distance between their centers of mass.
- Newton believed gravity and inertia are two factors that keep the planets in orbit.
    - F= gravitational force between 2 objects
    - m_1 & m_2 = masses of the objects
    - r = distance between the centers of the masses of the objects squared
    - G = gravitational constant 6.67×10^{-11}