Name: ________________________________

Class: ____________ Date: ____________

Due Date	Redo Date
Recorded Grade	Satisfactory Grade

Lab 3
Kepler's Laws of Orbits

Introduction: Johannes Kepler (1571–1630) was a German astronomer who spent years poring over a vast store of planetary data compiled by his predecessor, Tycho Brahe. After many incorrect theories and other setbacks, Kepler, at last, determined the beautifully simple physical laws that govern orbiting bodies. These rules are now known as **Kepler's Laws**. Kepler's three laws describe how planetary bodies orbit about the Sun. Put simply, the laws are that

1. Planets' orbits are elliptical with the Sun as one of the foci, not perfectly circular.
2. Planets move faster when they are closer to the sun and slow down when further away.
3. A planet's orbital period is proportional to the size of its orbit; outer planets have longer years.

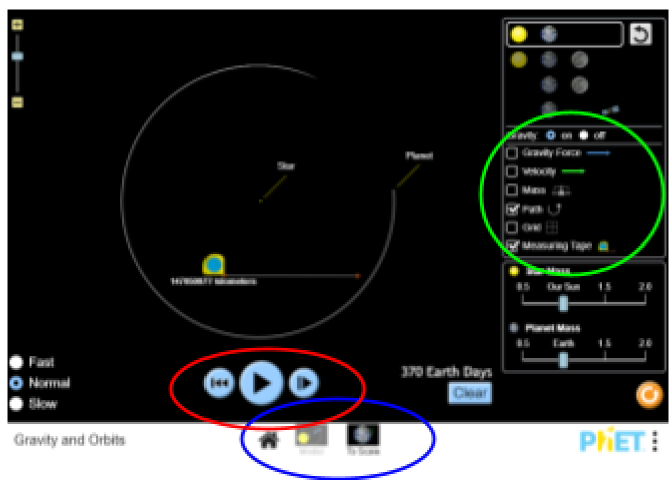
Objective: Investigate the shape of planetary orbits and relate how planetary orbits link to Kepler's first two laws of planetary motion.

Materials: [The Simulation]

Part 1: Is the orbit of a planet circular?

Directions:

1. Press the **To Scale** option at the bottom of the screen (**blue circle**).
2. Turn on the path/grid option ON, see the **green circle**.
3. Allow the planet to move through 360° (press play, **red circle**).
4. Turn on the measuring tape from the toolbar, see **green circle**.
5. Measure the horizontal distance from the path line on the left of the star. Record below.
6. Now do the same from the star to the path line on the right hand side.



Data:

	Distance (kilometers)
Left side from path to star	
Right side from path to star	

Analysis:

1. What do you notice about the distance?

The distance on each side is ____.

2. What does this data say about the orbit of the planet (is it a circle)?

The orbit is ____.

Part 2: Linking planetary orbits to Kepler's Laws

Part 2A Directions:

1. Go to the Model (at the bottom, **blue circle**).
2. Click on sun and planet (first option)
3. Turn on Path, Gravity Force, Velocity, and Grid (**green circle**).
4. Press **PLAY** (at the bottom, **red circle**) and leave it on for one cycle, then **PAUSE**.

Data:
Draw the orbit (path) of the planet. Label the Sun.

Analysis 2A:

3. What force holds the planet in orbit?

____

____

4. What shape is the orbit? Explain how you know by looking at the picture.

____

____

Press play again, but then turn gravity to **OFF** (the ON/OFF circles, not the gravity force checkbox).

5. What happens to the planet?

____

____

Part 2B Directions:

1. Press the orange reset button in the bottom right (**red circle**)
2. Re-select Gravity Force, Velocity, Path, and Grid (**green circle**)
3. <u>Slightly increase the velocity</u> of the planet (**blue circle**, **green arrow**).
4. You may change the speed to fast in the lower left corner.

Analysis 2B:

6. What happens to the planet's distance from the Sun?

____

____

7. How does the orbit's size, shape, and eccentricity change? (check one from each category)

Size	Shape	Eccentricity
☐ the orbit gets smaller	☐ the orbit gets more elliptical (more oval)	☐ the orbit gets more eccentric
☐ the orbit gets larger	☐ the orbit gets less elliptical (rounder)	☐ the orbit gets less eccentric

Part 2C Directions:

5. Press the orange reset button in the bottom right (**red circle**)
6. Re-select Gravity Force, Velocity, Path, and Grid (**green circle**)
7. <u>Increase the velocity by a lot</u>, then press play. You may need to zoom out (on the left) to see the orbit now.

Analysis 2C:

8. What happens to the planet's distance from the Sun?

____

____

Part 2C Directions:

8. Press the orange reset button in the bottom right (**red circle**)
9. Re-select Gravity Force, Velocity, Path, and Grid (**green circle**)
10. <u>Slightly decrease the velocity</u>, then press play.

Analysis 2C:

9. What happens to the planet's distance from the Sun?

____

____

10. How does the orbit's size, shape, and eccentricity change? (check one from each category)

Size	Shape	Eccentricity
☐ the orbit gets smaller	☐ the orbit gets more elliptical (more oval)	☐ the orbit gets more eccentric
☐ the orbit gets larger	☐ the orbit gets less elliptical (rounder)	☐ the orbit gets less eccentric

Step 5 Directions:

11. Press the orange reset button in the bottom right (**red circle**)
12. Re-select Gravity Force, Velocity, Path, and Grid (**green circle**)
13. Decrease the velocity by a lot, then press play.

Analysis 5:

11. What happens to the planet's distance from the Sun?

___

___

12. Identify the correct explanations for why this happens, using the concepts of velocity (v) and gravity. (Choose the **two** that best describe the phenomena)

- ☐ The force of gravity increases when Earth gets closer to the Sun
- ☐ The Sun stops pulling on the Earth with the force of gravity
- ☐ The velocity changes direction to point into the Sun
- ☐ Earth's velocity decreases, and it stops moving

Reset the simulation and set it to a normal orbit, but one that is very **elliptical** (oval-shaped).

13. Is the velocity of the planet constant throughout its orbit around the sun? If not, how does it change?

___

___

14. Explain why this happens, using the terms velocity (v) and gravity.

___

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___

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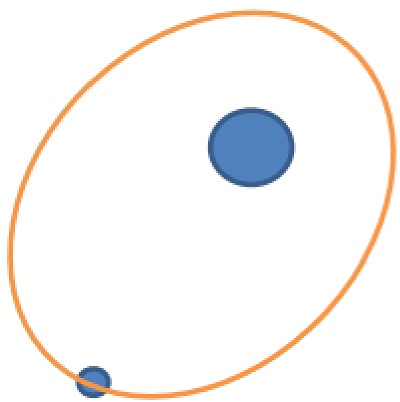
Part 3: Perihelion and Aphelion

In the late 1500s and early 1600s, the geocentric (Earth-centered) view of the universe was challenged by an assortment of astronomers, mathematicians, and physicists. They argued that a heliocentric (Sun-centered) solar system was the proper explanation for the motion of the planets, the Moon, and the Sun in our sky. Tycho Brahe realized that accurate observations of the positions of the planets were needed to resolve this disagreement. Brahe spent 20 years recording the positions of the planets using only his eyes and some equipment designed to measure the angular separation between objects. His assistant, Johann Kepler, carefully analyzed Brahe's data and formulated three laws of planetary motion.

Kepler's first law states that the orbit of each planet around the Sun is an ellipse with the Sun at one focus. This means that a planet's distance from the Sun varies during its orbit. When the planet is at its closest to the Sun, it is called **perihelion**. When the planet is at its farthest from the Sun, it is called **aphelion**. When we refer to a planet's average distance from the Sun, we are referring to the average of the perihelion and aphelion distances. Figure 1 is meant to refresh your memory of an ellipse.



Elliptical Orbit

1. On the Elliptical Orbit above, label the **aphelion** location (A) and the **perihelion** location (P).
    a. Aphelion means the planet is **closest to** / **furthest from** the Sun. (circle one)
    b. Perihelion means the planet is **closest to** / **furthest from** the Sun. (circle one)
2. At which location would the planet be traveling the fastest in its orbit? ________________
3. At which location would the planet be traveling the slowest in its orbit? ________________
4. Justify your answers to 2 and 3 using the concept of **gravity/gravitational force**.

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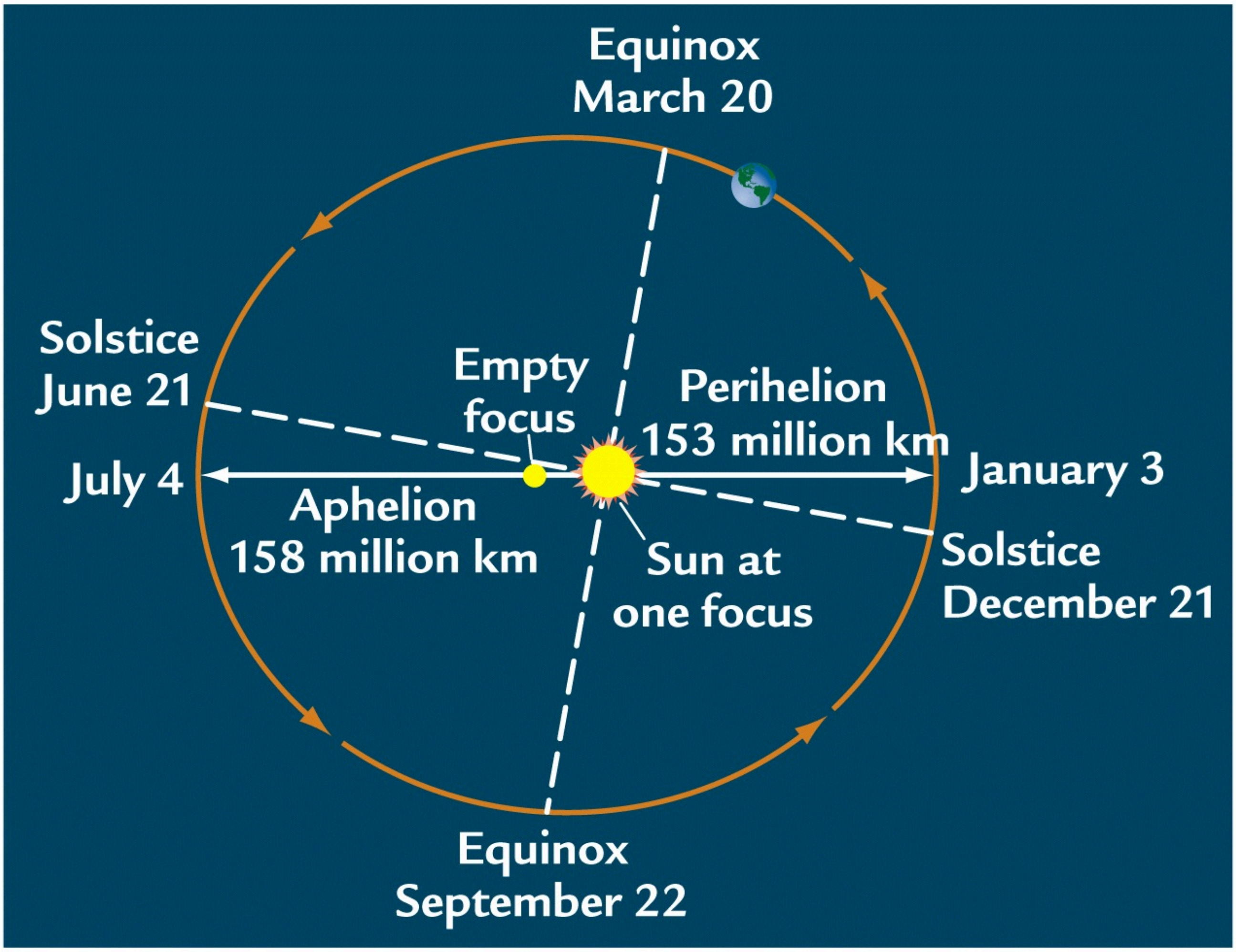
Model of Earth's Orbit



Use the model of Earth's orbit above to answer the following questions.

5. Identify the date when Earth is closest to the Sun. ____________________

   During which season does this date occur? ____________________

6. Identify the date when Earth is farthest from the Sun. ____________________

   During which season does this date occur? ____________________

7. A student makes the claim, "It is hotter in the summer because Earth is closer to the Sun."

   a. Evaluate the validity of this claim. **Valid** **Not Valid**

   b. Justify your response with evidence from the model.

   ____

   ____

Part 4: Comparing Eccentricity

Background:

Kepler's first law states that an orbit is in the shape of a slightly flattened circle, or **ellipse**. While a circle contains a single point at its center, an ellipse contains two critical points, called **foci**. The **Sun** is located at one focus of a planet's orbit.

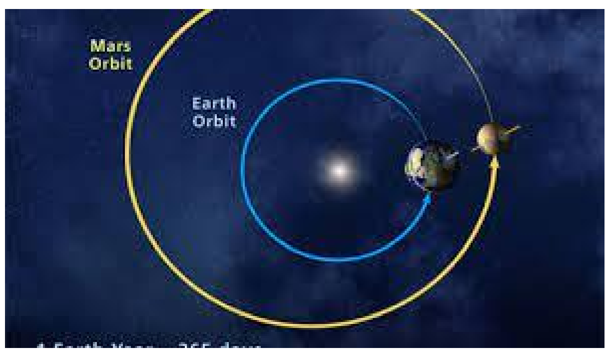
The **eccentricity** of an ellipse describes how "flattened" it is. A circle has an eccentricity of 0, and a flat line segment has an eccentricity of 1.

Planet	Eccentricity
Mercury	0.206
Venus	0.007
Earth	0.017
Mars	0.093
Jupiter	0.048
Saturn	0.054
Uranus	0.047
Neptune	0.009
Pluto	0.248

Questions:

15. What is the eccentricity of Mercury's orbit?

e = ________________



16. Compare the shapes and eccentricities of the orbits of Mars and Earth.

Mars has a __________ elliptical orbit than Earth.

(**more** or **less**)

Explain using the word **eccentric** or **eccentricity** and **quantitative evidence** (a *numerical value*).

____

____

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Conclusion:

Describe the true shape of Earth's orbit around the Sun.

Word Bank:

circle	**elliptical**	**faster**	**foci**	**geocentric**	**heliocentric**
longer	**orbit**	**oval**	**period**	**slower**	**solar system**

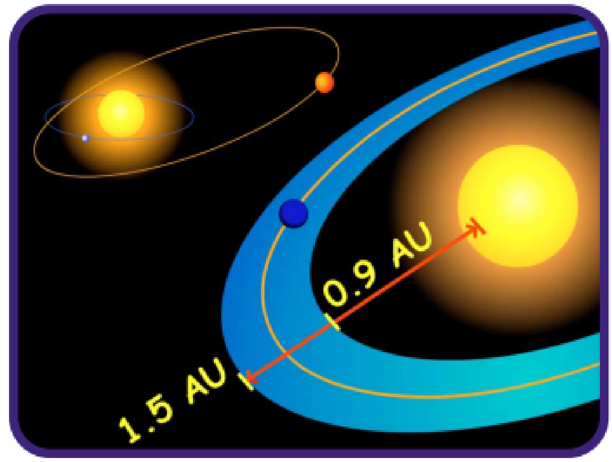
Ancient people thought the Sun and other planets revolved around the Earth. This is called the ________________________ model. This was challenged by Nicolaus Copernicus in the 1500s and expanded on by German astronomer Johannes Kepler. Their model was ________________________, which means all the planets orbit the Sun. Unlike Copernicus's model, though, Kepler claimed the planets traveled in __________________ paths. Not only was Kepler able to develop an accurate model of the ________ ______________, he came up with three Laws of Planetary Motion, which can be summarized as:

1. Planets follow an elliptical __________________, not a perfect circle.
2. Planets move __________________ when they are closer to the sun and __________________ when they are farther away.
3. The more distant planets will take a __________________ time to complete their orbit (this is called the __________________ of revolution)

The Sun is located at one of the __________________ of the ellipse. The other is empty and has nothing at it. All planets have elliptical orbits, but some are more eccentric than others. The most elliptical and most eccentric orbit is Mercury's, which means it looks more like a/an _______________. The least elliptical and least eccentric is Venus's, which means it looks more like a/an _____________.

Lab 3 Extension:

Habitable Zone Reading



What is the Habitable Zone?

Life as we know it needs liquid water to survive. The Habitable Zone is the distance from a star where liquid water can exist on a planet's surface. If a planet is too far from its star, water freezes. If a planet is too close to its star, water evaporates. A planet must stay in the Habitable-Zone throughout its orbit for water to remain liquid.

Where is the Habitable Zone?

The distance at which a planet can have water is determined by how much energy is given off by the star. This distance is measured in astronomical units or AU. An astronomical unit is the average distance from Earth to the Sun, which is equal to 149,598,770 km or 93,000,000 miles. For **cooler** red dwarfs, the Habitable Zone is so close to the star that solar flares and radiation from the star would destroy life. For very **hot** blue stars, the Habitable Zone is further away. These stars tend to burn at such high temperatures that they have very short lives, lasting only a few million years. (It took 700 million years for life to become established on Earth). Our Sun's Habitable Zone for larger life forms, including humans, is between 0.9 AU and 1.5 AU.

Is the Habitable Zone always in the same place?

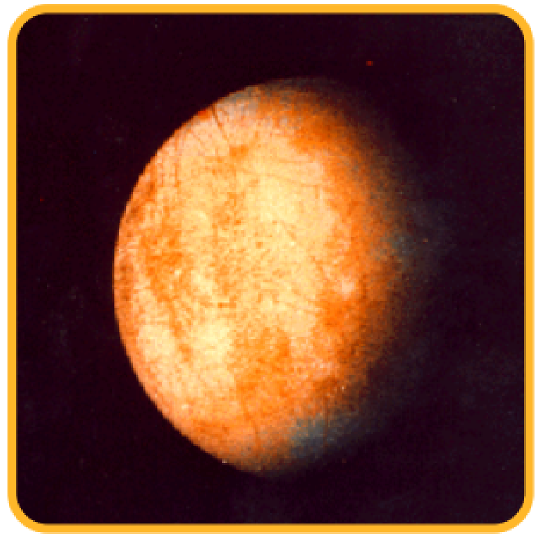
The Habitable Zone can move as a star changes. As a star grows older, it grows **hotter**, causing the zone to move further away from the star. At one time, Earth was on the outer edge of the Sun's Habitable Zone, but now the zone has moved further away, so Venus is no longer in the Habitable Zone. Since stars **change**, it is important to have a star with a temperature that stays about the same for a long time. It's also important that the orbit of an Earth-size planet be in the area of the zone that remains in the zone as the zone changes.

If I'm in the Zone, is Survival Guaranteed?

Even if a planet is in the Habitable Zone throughout its entire orbit, human survival is not guaranteed. The planet may not even have water on it, to begin with, or the water it has may not be liquid. Mars, for example, has such a low surface pressure that its water cannot be liquid on the surface. Water goes from a solid to a gas without ever being liquid. Also, the planet may not have the right kind of atmosphere and may not be the right size to hold onto the atmosphere that humans need. Without the right kind of atmosphere to trap heat and maintain a stable temperature, surface water would not be found on a planet. Furthermore, the planet may not host plant and animal life that humans can eat. Finally, there may be other dangers, such as large planets, solar flares, or radiation, from which humans need protection.

Is the Habitable Zone the same for all life?

The Habitable Zone for **microbes** is much larger than the Habitable Zone for humans because microbes can survive under conditions that humans cannot. A microbe is an animal or plant so small it can be seen only with a **microscope**. A bacterium is an example of a microbe. Some microbes can survive in the frozen ice of Antarctica and in the extremely hot thermal vents on the ocean floor. That's why scientists are looking for life on Mars and one of Jupiter's moons, **Europa**.



Jupiter's moon, Europa

Questions

1. What is the definition of a Habitable Zone?

____

____

2. Are all stars' Habitable Zones at the same distance? Why or why not?

____

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3. What would happen if a planet weren't in the Habitable Zone?

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4. Would a microbe's Habitable Zone be closer or further from a star than a human's Habitable Zone? Explain your answer.

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