Name: ____________________________
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Motions of the Planets

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Explaining the motions of the planets was the most difficult task ancient astronomers faced. Unlike the stars, which move smoothly across the sky along with the Sun and Moon, the planets' motions are much more complex. They move relative to the background stars from day to day and week to week, and sometimes appear to stop, turn around and move in the opposite direction for a few weeks! This odd "backwards" motion is called **Retrograde Motion**, and explaining it was no easy feat! Let's try to see what causes this Retrograde Motion.

PART A

Let's try to figure out how the planets "normally" move across the sky. Start *Stellarium.* Change the **Date & Time** to **June 15, 1998** at **7:00 AM**. **Zoom** out and **drag** the horizon until the whole sky is centered on the screen. Turn off the **Atmosphere**, if it is on, and **label** the planets by opening the **View** window and putting a check mark next to **Solar System Objects** and **Show Planet Markers** in the **Sky** sub-menu. Also check the **Labels and Markers** box in the same section and drag the **slider** next to it about halfway to the right. Close the **View window**. All the planets are visible in the sky at this moment, as you can see, along with the **Sun** and **Moon** (and also several of the largest **Asteroids: Ceres** and **Vesta**!).

- What do you notice about how the Sun, Moon, Planets and Asteroids are arranged in the sky?

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- What is the name of this imaginary line across the sky? _______________________________

To check your answer, press the "**,**" ("comma") key to display the **Ecliptic** in orange.

Press the **ALT** and **=** keys at once to make one **Sidereal Day** pass. A **sidereal day** is the amount of time it takes for any *star* (except the SUN!) to circle the sky once. A sidereal day is **23 hours, 56 minutes**, or 4 minutes shorter than a 24-hour solar day.

Hold down the **ALT** and **"="** keys and watch the planets move through the sky as the Sidereal Days pass. Notice that the planets do not stand still relative to the stars, but move, generally in one direction, as the days and weeks pass. Keep holding down "**ALT =**" and note the way the planets move.

- Which way do the planets (and the Sun and Moon and Asteroids) normally move across the sky from day-to-day (N to S, S to N, E to W or W to E)? ______________________

This normal direction of movement is called **Direct Motion**. Keep letting the time pass. Every so often, something strange happens to one or another of the planets. It slows down, stops, then turns around and starts moving in the opposite direction for a few days or weeks! This strange backward motion is called **Retrograde Motion**.

- When the planets move in Retrograde motion, which way do they move (N to S, S to N, E to W or W to E)? _________________________

Let's see if this strange motion happens to *all* the planets, and to the Sun & Moon. Keep holding down **Alt =** and watching each planet (and the Sun & Moon) travel across the background stars. Let at least a year or two go by, or at least two complete trips across the sky for each planet (until you come back to where you started twice). After you've watched each object carefully for a while, record in **Table 1** a "yes" or "no" whether you ever see the object undergo retrograde motion.

Table 1

Object	Retrograde motion?
Sun	
Moon	
Mercury	
Venus	
Mars	
Jupiter	
Saturn	
Uranus	
Neptune	

- Which objects in Table 1 show <u>no</u> retrograde motion? _________________________________

PART B

Now let's try to explain what *causes* retrograde motion. The **Geocentric** (Earth at the center of the Solar System) explanation for such motion required the use of **epicycles**, as we discussed in class. Epicycles, as Figure 1 below shows, are "orbits superimposed on orbits." First proposed by Greek thinkers, epicycles were made popular by the astronomer Ptolemy in the 1st century. Ptolemy was able to explain almost all the observed planets motions by assuming that the Earth was at the center of the Solar System, and that each planet (except the Moon and Sun) moved in a circular epicycle that was itself centered on the planet's circular orbit around the Earth (called the "deferent").

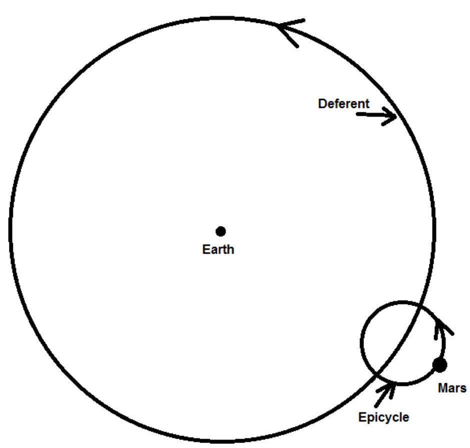

Figure 1

- Assuming that the planet moves counterclockwise around the epicycle, and the epicycle itself moves counterclockwise around on the deferent, **shade the part of the path along the epicycle** in **Figure 1** where the planet will exhibit retrograde ("backwards") motion when seen from the Earth.

Epicycles work fine, but Copernicus threw them in doubt when he came up with his **Heliocentric** theory, postulating that the *Sun* was at the center of the Solar System. Then, when Galileo provided the proof that he was right, epicycles were officially thrown out for good. The heliocentric theory provided a better explanation of retrograde motion. To understand it, let's look more closely at Mars' retrograde motion.

Change the **Date & Time** to **October 1, 2007 (the time doesn't matter – any time that day will do)**. Turn the **Ground** off (use the **G** key). **Search** for the star **Tejat** to select and center it on screen. Turn the **constellation names and lines** on by pressing **C** and **V**. **Zoom in** until the **Field of View** (**FOV**) is about **30°**. Click on the **Switch Between Equatorial and Azimuthal Mount** button on the bottom toolbar until the little telescope icon is lit up. This makes the Ecliptic plane horizontal. Remember, West is to your <u>right</u>, and East to your <u>left</u>. You should see **Mars** just to the West of Tejat, which is selected and surrounded by the rotating crosshairs onscreen.

- What constellation is Tejat in? ____

Now press **L** five or six times to let time pass quickly. You should see Mars moving across the background stars in direct motion, from West to East. Mars will eventually slow down, stop direct motion, reverse direction and begin retrograde motion. **Stop time** (you may have to step forwards or backwards by a few days) and find the exact day when Mars begins its retrograde, or "backwards" motion.

- What day does Mars come to a stop and begin retrograde motion? _______________________

Continue running time forward and watch as Mars stops **retrograde** motion and resumes **direct** motion. Again, you may have to step back and forth in time to find the exact day.

- What day does Mars resume direct motion? ____
- How long is Mars in retrograde motion? ____

<u>PART C</u>

Let's try to understand this odd retrograde motion by seeing what's happening from high above the Solar System. Make sure the **Ground** and **Atmosphere** are off. Use the **Search Window** to find and center **Solar System Observer**. Then press **CTRL-G** to go there. Then **Find** and center the **Sun**. Open the **View** window (use the menu or press **F4**) and, in the **Sky** sub-menu, put check marks next to **Solar System Objects**, **Show Planet Markers** and **Show Planet Orbits**. Also put a check in the box next to **Labels and Markers** and drag the **slider** next to it all the way to the right. Click on the **Colors** button next to **Show Planet Orbits**, and click on **Separate Colors of Major Planet Only** (this shows the orbits of the main planets in different colors, so that they're easier to see). Close the **View** window.

Change the **Date & Time** back to **October 1, 2007** (the time doesn't matter). Now **zoom in or out** until the orbit of **Mars** just fills the screen. The **Field Of View** (**FOV**) should be roughly about **0.4°.**

You are looking down at the orbits of most of the Solar System on **October 1, 2007** – the same day you started looking at Mars for the previous section. The positions of **Mercury**, **Venus**, **Earth** and **Mars** are labeled, along with the orbits of a number of small asteroids. Click on **Mercury**, **Venus**, **Earth** and **Mars** one at a time to see their orbits alone.

Tape a blank piece of transparency over your computer screen. Hold a ruler up to the screen and use it to gently draw a straight line from Earth, through Mars and down to the edge of the screen on the transparency. Make sure the ruler extends all the way to the edge of the paper. Label this line with the date (**10/1**).

Press the "**]**" (right square bracket) button to let one week pass. The right square bracket button should be two keys to the right of the letter **P** on your keyboard. Use the ruler again to make to make a second line from Earth to Mars and down to the edge of the screen. Label this one with new date (**10/7**). Press the right square bracket button again to let another week pass and repeat the procedure. Continue making lines on the paper once a week until **February 21, 2008**.

When you are done, examine the lines you printed on the transparency, with the dates marked. Remember, the spot where each line hits the edge of the paper indicates where Mars would appear that day against the distant stars from our point of view here on Earth. Call that spot "**Mars' apparent position**." Look at the spot carefully from day to day to determine how it moves from our point of view here on Earth. Compare the pattern of dots to the dates when Retrograde Motion began and ended, that you measured earlier. This should help you understand why retrograde motion occurs. Here's an online applet that might help you visualize things:

http://goo.gl/s3zNhr

- Describe how Mars' Apparent Position moves across the sky before, during and after retrograde motion starts, as you see it from Earth. Remember, we determined earlier when Retrograde motion begins and ends.

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- In your own words, then, explain what causes retrograde motion

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- Why do the Sun and Moon not show any retrograde motion?

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So retrograde motion has to do with the geometry of the planets' positions, and the relative speeds of the planets in their orbits. Like most things in science, what at first looks like a complicated, confusing idea turns out to be fairly simple, and easily understandable!

Write a conclusion explaining what you learned in this exercise.

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PLEASE ATTACH YOUR TRACING PAPER PAGE TO YOUR ASSIGNMENT WRITE-UP!