Part I: Monthly Differences

Figure 1 shows a sun-centered, or heliocentric, perspective view of the Earth-Sun system indicating the direction of both the daily rotation of the Earth about its own axis and its annual orbit about the Sun. You are the observer shown in Figure 1, located in the northern hemisphere while facing south.

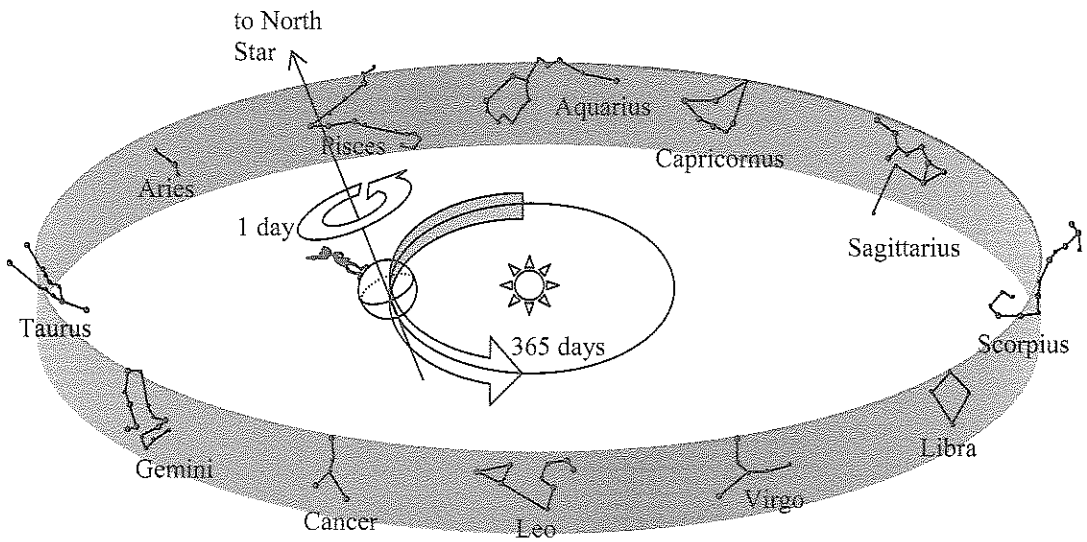

Figure 1

Figure 2 shows a horizon view of what you would see when facing south on this night at the same time as shown in Figure 1.

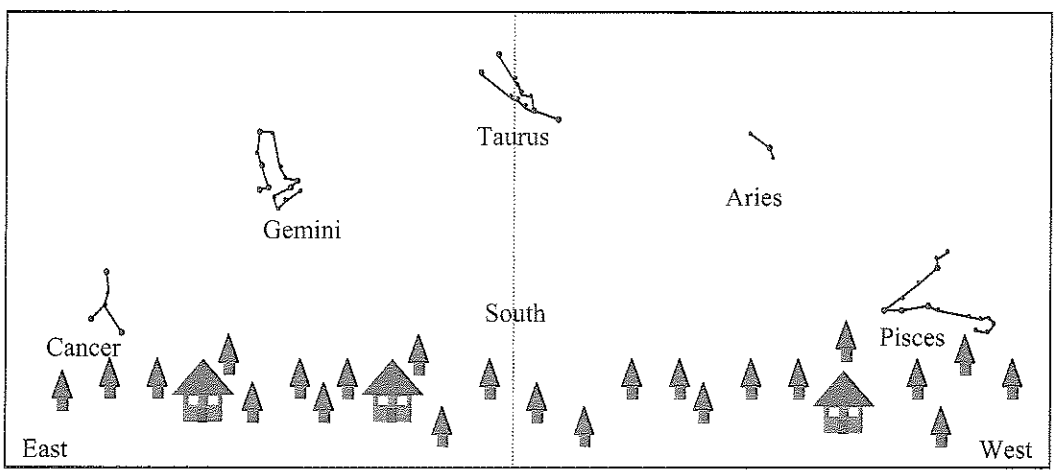

Figure 2

1) Which labeled constellation do you see highest in the southern sky?

2) What constellation is just to the left (i.e., east) and what constellation is just to the right (i.e., west) of the highest constellation at this instant?

   left: right:

3) Noting that you are exactly on the opposite side of Earth from the Sun, what time is it?

4) In six hours, will the observer be able to see the Sun? If not, why not? If so, in what direction (north, south, east or west) would you look to see the Sun?

5) What constellation will be behind the Sun at the time described in question 4?

6) When it is noon for the observer, what constellation will be behind the Sun?

7) One month later, the Earth will have moved one-twelfth of the way around the Sun. You are again facing south while observing at midnight. Which constellation will now be highest in the southern sky?

8) Do you have to look east or west of the highest constellation that you see now to see the constellation that was highest one month ago?

9) Does the constellation that was highest in the sky at midnight a month ago now rise earlier or later than it rose last month? Explain your reasoning.

Part II: Daily Differences

Figure 3 shows the same Earth-Sun view as before and the bright star Betelgeuse, which is between Taurus and Gemini.

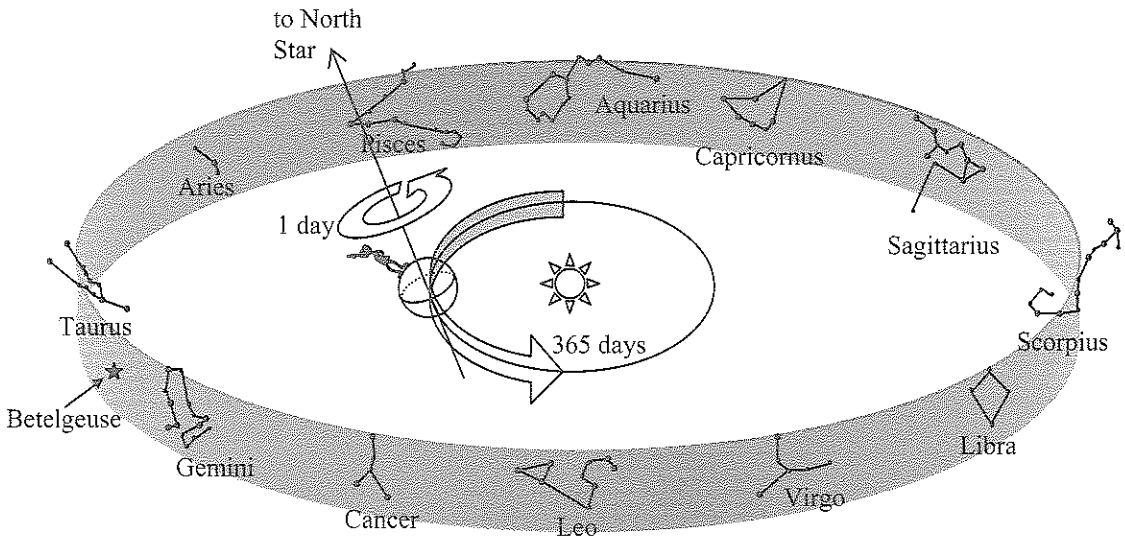

Figure 3

10) Last night you saw the star Betelgeuse exactly on your eastern horizon at 5:47 PM. At 5:47 tonight, will Betelgeuse be above, below, or exactly on your eastern horizon?

11) Two students are discussing their answers to question 10.

Student 1: *The Earth makes one complete rotation about its axis each day so Betelgeuse will rise at the same time every night. It will therefore be exactly on the eastern horizon.*

Student 2: *No. Because Earth goes around the Sun, the constellation Taurus rises earlier each month and so it must rise a little bit earlier each night. Betelgeuse must do the same thing. Tonight it would rise a little before 5:47 and be above the eastern horizon by 5:47.*

Do you agree or disagree with either or both of the students? Why?

Part I: Solar Day

Figure 1 shows a top-down view of the Earth-Sun system. Arrows indicate the directions of the rotational and orbital motions of Earth. For the observer shown, the Sun is highest in the sky at 12 noon.

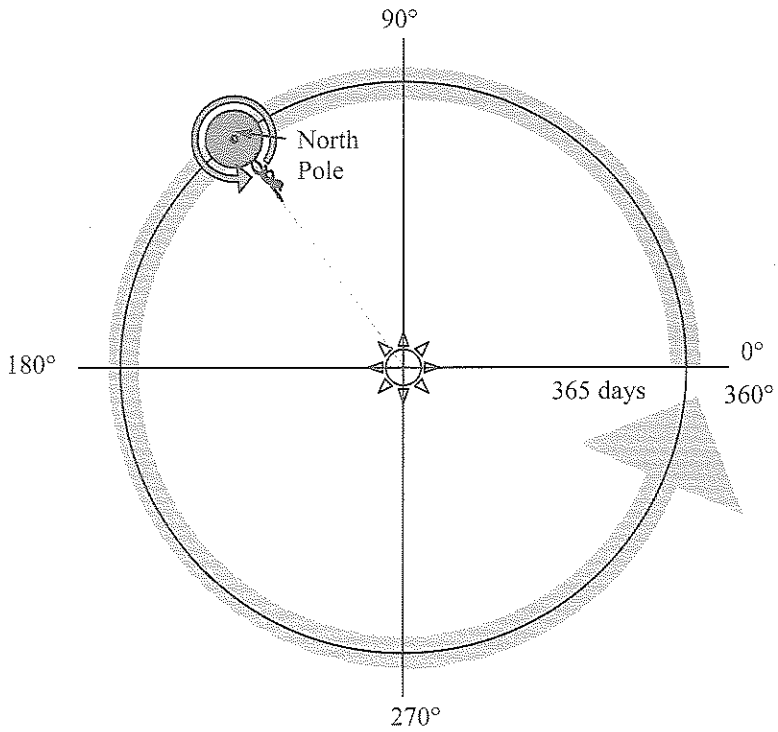

Figure 1

1) Earth orbits the Sun in a counterclockwise direction once every 365 days. Approximately how many degrees does Earth move along its orbit in one day?

2) As Earth orbits the Sun, it also rotates in a counterclockwise direction about its axis as shown in Figure 1. We define 24 hours as the time from when the Sun is highest in the sky one day to when it is highest in the sky the next day. How many degrees does Earth rotate about its axis in exactly 24 hours: 360°; slightly less than 360°; or slightly more than 360°?

3) How long does it take Earth to rotate exactly 360°: slightly less than 24 hours; 24 hours; or slightly more than 24 hours?

4) Two students are discussing their answer to questions 2 and 3.

Student 1: *Earth rotates about its axis once every 24 hours and one rotation equals 360°.*

Student 2: *No. When Earth has gone around 360° it has also moved a small amount counterclockwise around the Sun, which means the Sun is not yet at its highest point. Earth must spin a little bit more for the Sun to reach its highest point.*

Do you agree or disagree with either or both of the students? Why?

Part II: Sidereal Day

We define a **solar day** as the time it takes for the Sun to go from its highest point in the sky on one day to its highest point in the sky on the next day and we divide that time into 24 hours.

A **sidereal day** is defined as the time it takes for Earth to rotate *exactly* 360° about its axis with respect to the distant stars.

5) When does Earth rotate a greater amount, during a solar day or during a sidereal day?

6) Which takes a shorter amount of time, a solar day or a sidereal day?

Note: Since Earth rotates more than 360° in a solar day, a sidereal day is about 4 minutes shorter than a solar day.

Imagine that some time in the future the direction that Earth orbits the Sun is somehow reversed so that Earth now orbits the Sun approximately 1° *clockwise* each day. However, the rotation about its own axis remains counterclockwise at the same rate.

7) In the space below, create a sketch similar to Figure 1 to depict this imaginary situation.

8) Through how many degrees will Earth now rotate in a sidereal day?

9) Through how many degrees will Earth now rotate in a solar day?

10) Which is now longer, the solar or the sidereal day?

11) Is a sidereal day now longer, shorter, or the same length as a sidereal day was before we changed Earth's orbital direction?

12) Is a solar day now longer, shorter, or the same length as a solar day was before we changed Earth's orbital direction?

For all parts of this activity, it is helpful to imagine that the stars are so bright (or our Sun so dim) that the stars can be seen during the day so that your sky might appear as in Figure 1.

Part I: Daily Motion

On December 1, at noon, you are looking toward the south and see the Sun among the stars of the constellation Scorpius as shown in Figure 1.

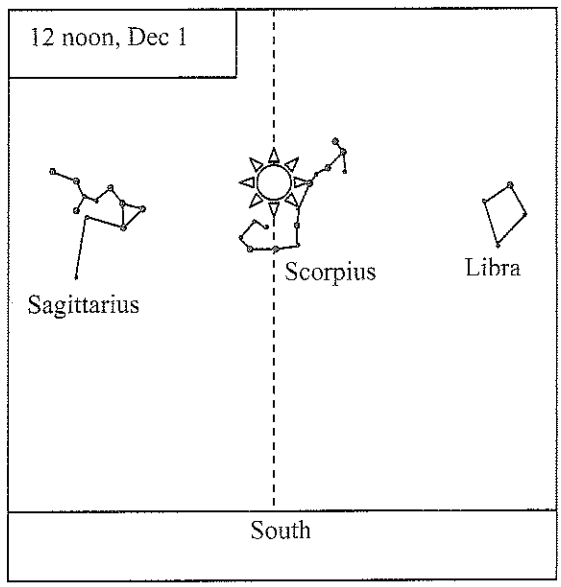

Figure 1

1) At 3 PM that afternoon, will the Sun appear among the stars of the constellation Sagittarius, Scorpius, or Libra?

2) Two students are discussing their answers to question 1.

Student 1: *The Sun moves from the east through the southern part of the sky and then to the west. By 3 PM it will have moved from being high in the southern sky to the west into the constellation Libra.*

Student 2: *You're forgetting that stars and constellations will rise in the east, move through the southern sky and then set in the west just like the Sun. So the Sun will still be in Scorpius at 3 PM.*

Do you agree or disagree with either or both of the students? Why?

Recall that in the celestial sphere model, the stars' daily motions result from the rotation of the celestial sphere.

3) Is it reasonable to account for the Sun's **daily motion** by assuming that the Sun is at a fixed position on the celestial sphere (in this case in the location of the constellation Scorpius) and is carried along its path across the sky by the sphere's rotation? Explain why or why not.

Part II: Monthly Changes

By careful observation of the Sun's position in the sky throughout the year, we find that the celestial sphere rotates slightly more than 360° every 24 hours. Figure 2 shows the same view of the sky (as Figure 1) but on December 2 at noon. For comparison, the view from the previous day at the same time is also shown in gray.

4) Draw the location of the Sun as accurately as possible in Figure 2.

5) Figure 3 shows the same view of the sky (as Figure 1) one month later on January 1 at noon. Draw the location of the Sun as accurately as possible in this figure.

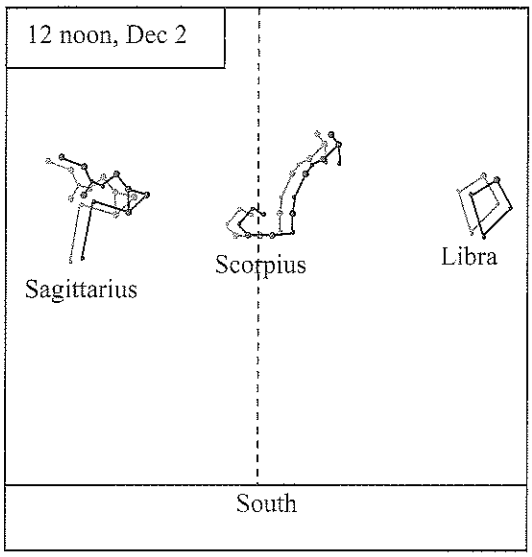

Figure 2

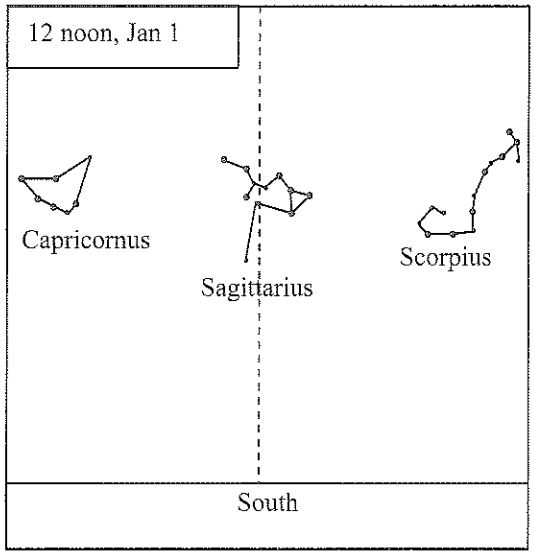

Figure 3

6) Two students are discussing their answers to questions 4 and 5.

Student 1: *The Sun will always lie along the dotted line in the figures when it's noon.*

Student 2: *But, we saw in question 3 that the Sun's motion can be modeled by assuming it is stuck to the celestial sphere. The Sun must, therefore, stay in Scorpius.*

Student 1: *If that were true then by March the Sun would be setting at noon. The Sun must shift a little along the celestial sphere each day so that in 30 days it has moved to the east into the next constellation.*

Do you agree or disagree with either or both of the students? Why?

7) Why is it reasonable to think of the Sun as attached to the celestial sphere over the course of a single day as suggested in question 3 even though we know from questions 5 and 6 that the Sun's position is not truly fixed on the celestial sphere?

Part III: The Ecliptic

The zodiacal constellations were of special interest to ancient astronomers because these are the constellations through which the Sun moves throughout the year. This was incorporated into their celestial sphere model by having the Sun loosely fixed to the celestial sphere but allowing it to slip a small amount each day. The Sun's position on the celestial sphere (among the stars in the constellation Scorpius) on December 1 is shown in Figure 4.

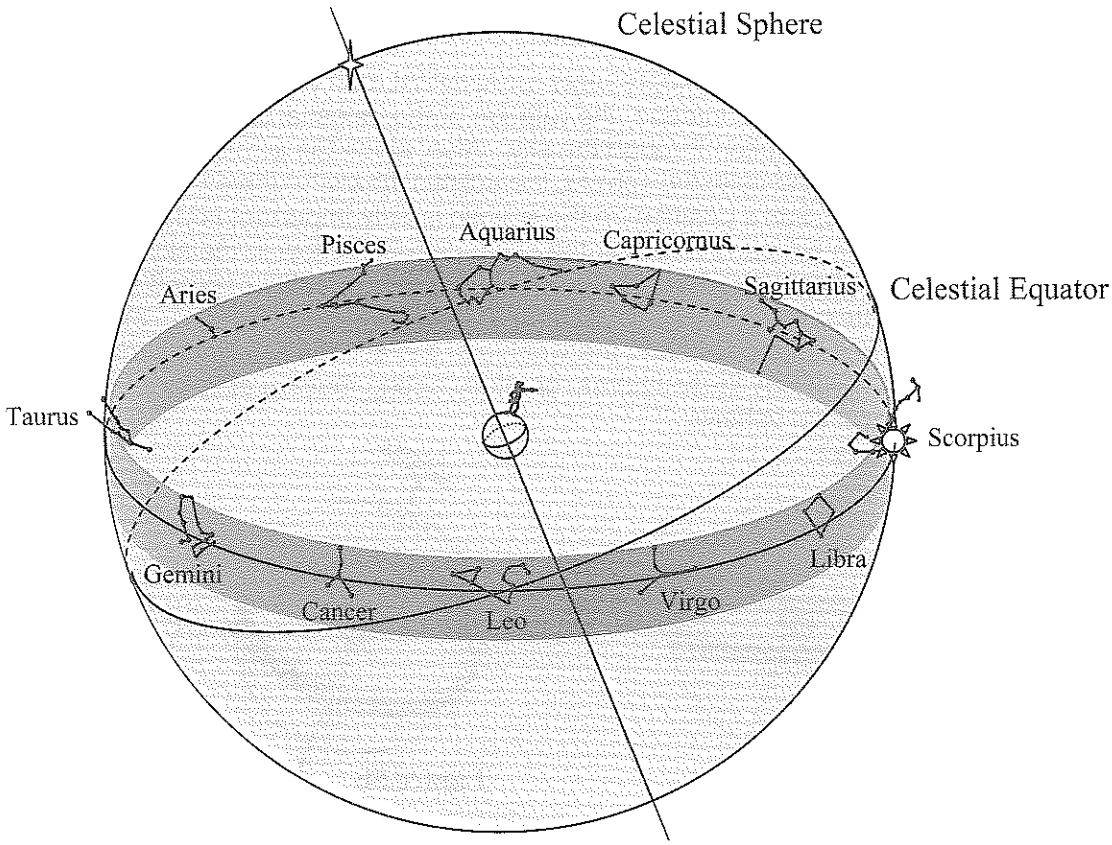

Figure 4

8) Draw where the Sun will be located on the celestial sphere on January 1. Label this position "Jan 1".

9) For the other constellations, draw in a Sun and label the constellation with the approximate date that the Sun will be located there.

The line drawn through these constellations, tracing out the Sun's annual path, is called the **ecliptic**.

10) Label the ecliptic in Figure 4.

11) About how many times does the celestial sphere rotate in the time it takes the Sun to move between two adjacent constellations (i.e., 1/12 of the way around) along the ecliptic?

12) How long does it take the Sun to make one complete trip around the ecliptic (i.e., from Scorpius to Scorpius)?

Part IV: Wrap Up

It is important to realize that the ecliptic represents an ANNUAL drift of the Sun and does not represent the daily path of the Sun. Instead, the rotation of the celestial sphere is responsible for the Sun's daily motion through the sky. Also, since the ecliptic is tilted with respect to the rotation axis of the celestial sphere, the ecliptic slowly "wobbles" as the celestial sphere rotates. The Sun's position on the ecliptic is only important in deciding whether the Sun's daily path will carry it high in the sky (summer) or low in the sky (winter). In Figure 5a, the Sun's position along the ecliptic and its path for one day (dashed line) are shown for two different dates: December 1 (in Scorpius), and June 1 (in Taurus). Figures 5b, 5c, and 5d show the path of the Sun and the wobble of the ecliptic at 6-hour intervals as the celestial sphere rotates. Study these figures, carefully noting that the ecliptic and Sun are both carried by the celestial sphere.

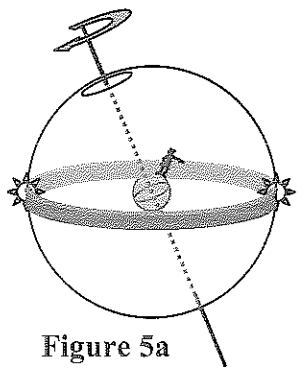

Figure 5a

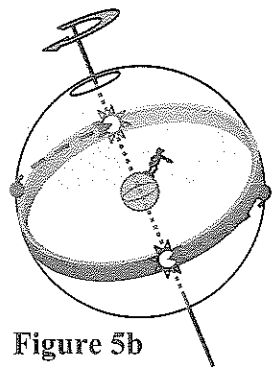

Figure 5b

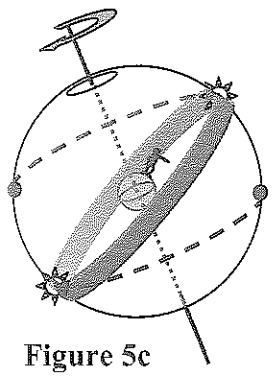

Figure 5c

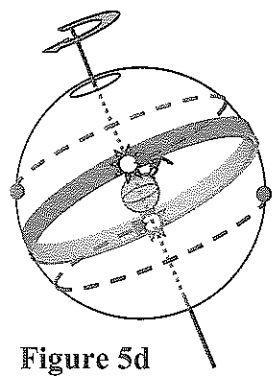

Figure 5d

13) On Figure 5d, label the ecliptic (Sun's annual path) and the Sun's daily path for December 1 and June 1.

14) Which Figure (5a, 5b, 5c, or 5d) shows the Sun at noon, low in the southern sky, when it would be among the stars of the constellation Scorpius?

15) Which Figure (5a, 5b, 5c, or 5d) shows the Sun at noon, high in the southern sky, when it would be among the stars of the constellation Taurus?