

Chapter 4 How Earth and Sky Work -The Effect of Time

To this point, we have learned about what can be seen from various latitudes, provided that you wait long enough. How long, is long enough? Half a sidereal day would be long enough, if sunlight were no problem. After half a spin, the part of the sky that is seen changes entirely. There is NO difference in what can be seen over the course of the year (although there is a difference in which objects are up during the day). Solar and Sidereal Time tell the position of the observer compared to the Sun and stars respectively. They allow us to assess what can be seen at any time and date.

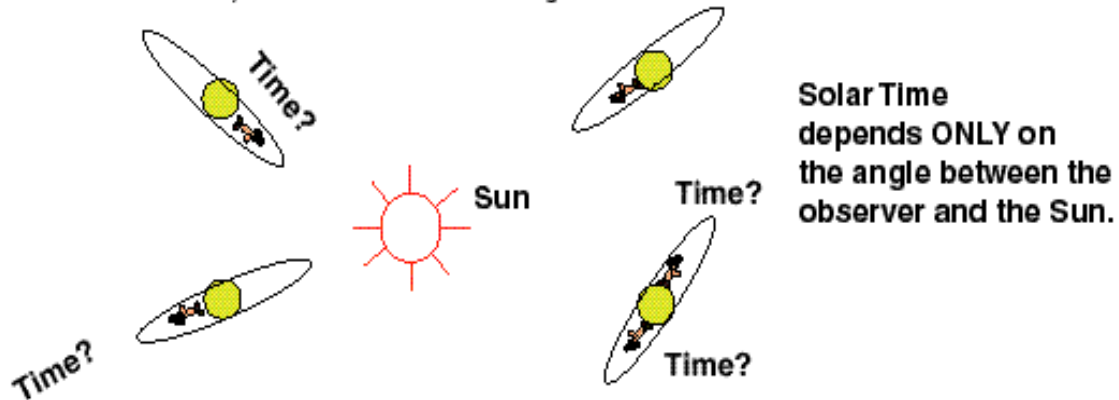
Solar Time tells the angle of the Observer's meridian with respect to the Sun. In the picture below, find some observers for whom it is noon.

Sun on the meridian =

Sun opposite the observer (on the meridian) =

PM post meridiem, PM times are hours since sun was on the meridian (at noon)

AM ante meridiem, AM times are between midnight and noon



When the Sun is in the eastern half of the sky, before it has crossed the meridian at culmination, it is Ante Meridiem (AM). When the Sun is in the western half, it is Post Meridiem (PM). So we divide the solar day by the time that the Sun passes the meridian, Noon.

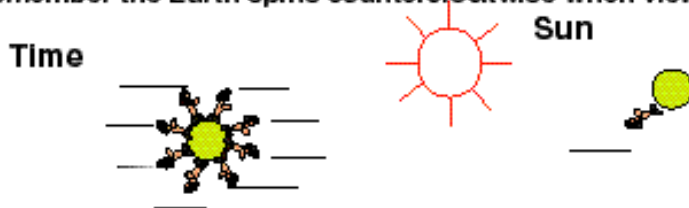
Draw another observer on the figure above. Make it an observer for whom it is midnight.

As seen from above the North Pole, the Earth spins and orbits Counterclockwise.

As we know, from Earth, we can observe only half of the Celestial Sphere at a time.

Fill in the Solar times for the observers (check! this is your reference)

(remember the Earth spins counterclockwise when viewed from above the North Pole)

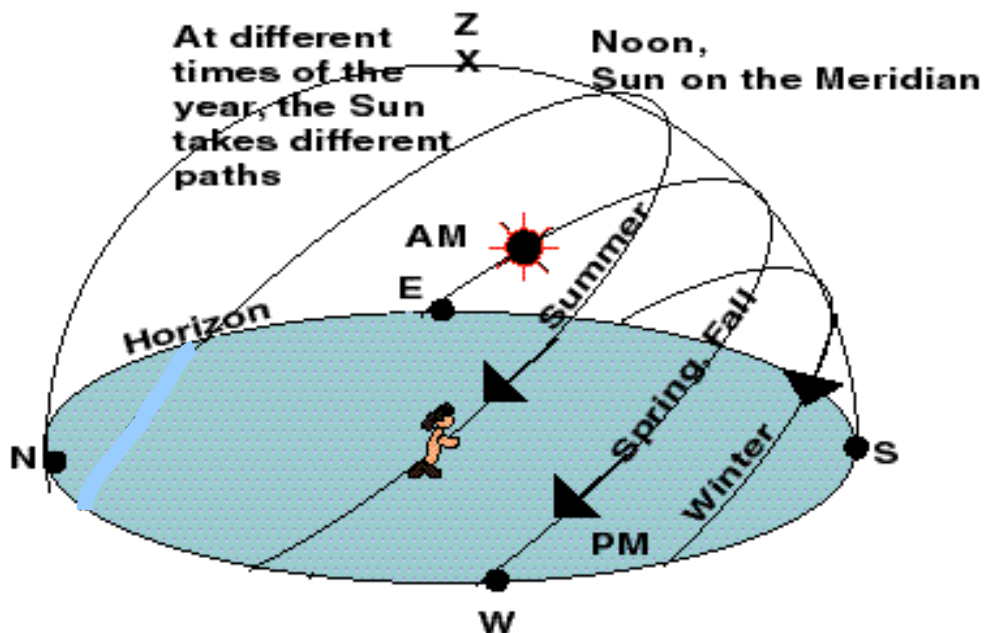


Draw additional Earth and observer pairs at 4 PM, 9 AM, 10 PM

Change of Solar time is due to Earth spinning on its axis.

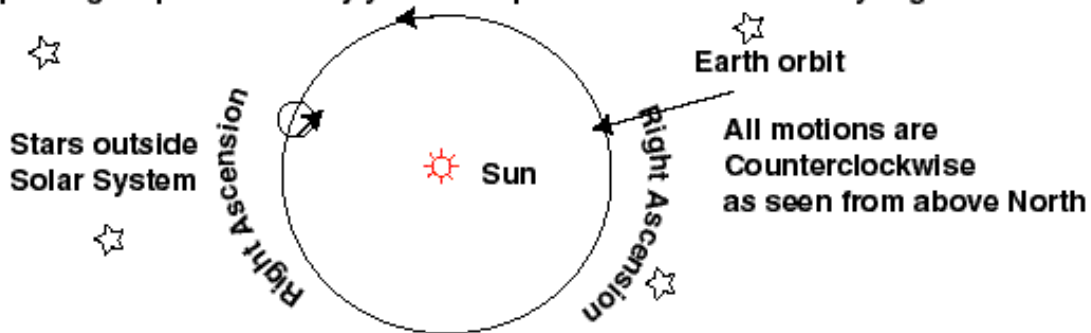
Can different people on the Earth have different Solar times at one instant?

The view of the Sun's path from the surface of the Earth is rather different. The Sun follows a path from east to west, as shown below. The figure is drawn for the northern hemisphere at mid latitudes, but the fact that the Sun rises in the East, sets in the West, is true for all places on earth. Similarly, the Sun rises furthest south on December 21 for everyone on Earth.

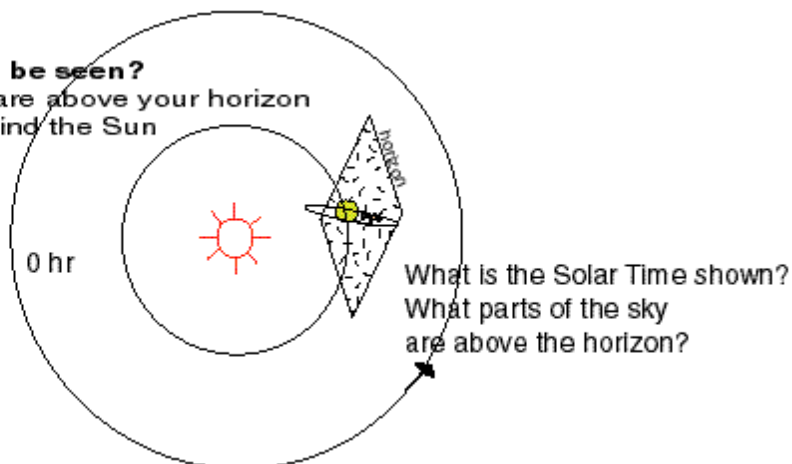


The Effect of Date and the Earth's Orbit

12. Viewing from above the North Pole, we see the Earth orbit the Sun, repeating its position every year. Star positions are identified by Right Ascension.



What stars can be seen?
The ones which are above your horizon and not right behind the Sun



The stars are located far far outside the Solar System. So Earth's motion is tiny compared to the distance to the stars. We will identify star positions by their Right Ascensions.

The Earth orbits the Sun once per year, returning back to the same position in orbit more or less. The following diagram is your reference for combining the position with the position of the stars. Be sure to fill it in. The circles are positions of the Earth every 21st of the month (23rd of September). The lines tell the Right Ascension of the stars in that direction. There are 24 total hours

The date tells the Earth's position in orbit, which in turn determines the right ascension (and sidereal time) at midnight. Conversely, if we knew the sidereal time at midnight, it would be easy to find the date. The solar and sidereal times take every value every day.

There are only two motions, so only two different things can be specified. The Earth spins and orbits, and these two motions determine the date, the solar time and the sidereal time.

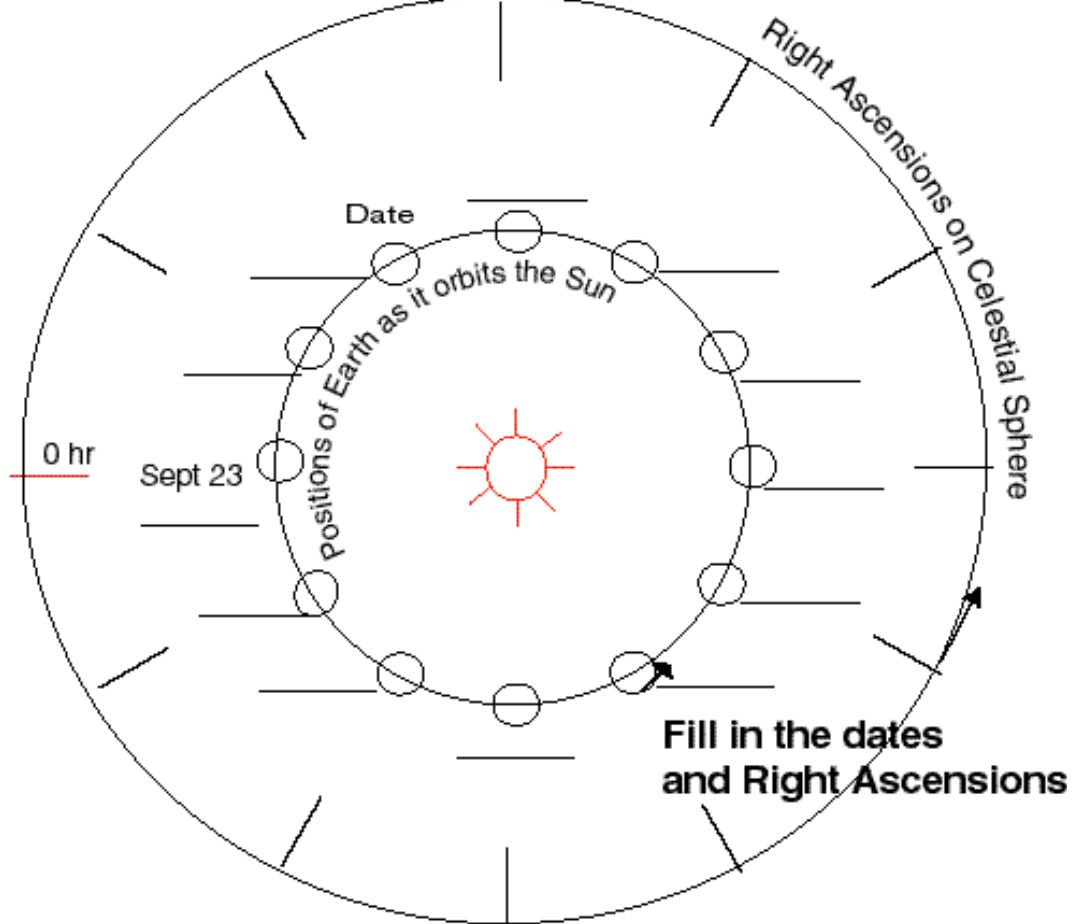
Solar Time tells the position of the observer's meridian compared to the Sun.
Date -Tells the position of the Earth in its orbit.
Sidereal Time equals the Right Ascension on the observer's meridian

Although all sidereal times and all solar times occur every day, the sidereal time corresponding to a given solar time depends on the date.

Observing from above the North Pole of the Earth's orbit

Earth orbits Sun yearly in a repeating pattern.

A date can be associated with each position.



On September 23, at midnight, Right Ascension 0 hr is on the meridian. As time progresses both solar and sidereal time increase together. Every day both solar and sidereal time go through all 24 hours.

Because the Earth orbits the Sun, the midnight direction changes. The Right Ascension on the meridian at midnight as changes (as does the sidereal time at midnight). It is easy to find the sidereal time at midnight by remembering how the diagram above works. Memorize that midnight on September 23 is 0 hr sidereal time and that:

The Sidereal Time at midnight, increases

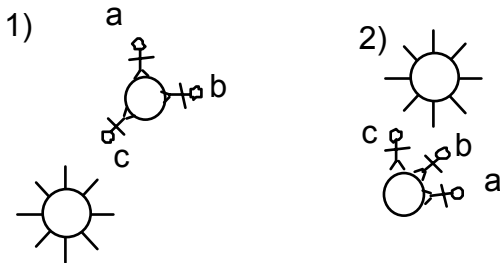
2 hours per month

1/2 hour per week

4 minutes per day

Orientation Practice Problems Set II

What is the Solar Time in the figure below for each observer?



3) Draw a picture with an observer who is at 6 AM

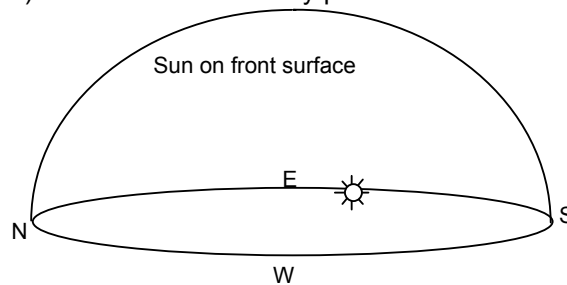
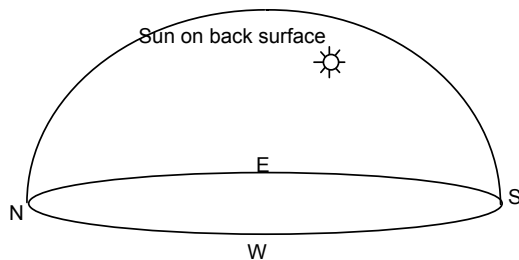
4) Draw a picture with an observer who is at 5 PM

5) Draw a picture with the Earth on Oct 21. Include the Sun, and the Right Ascension markers.

6) Draw a picture with the Earth on Aug 8, Include the Sun, and the Right Ascension markers.

7) What is the time of day shown in the next figure?

8) What is the time of day pictured in the next figure?



9) Draw the appearance of the sky (in the form shown in questions 7 and 8) for the times in question 2.

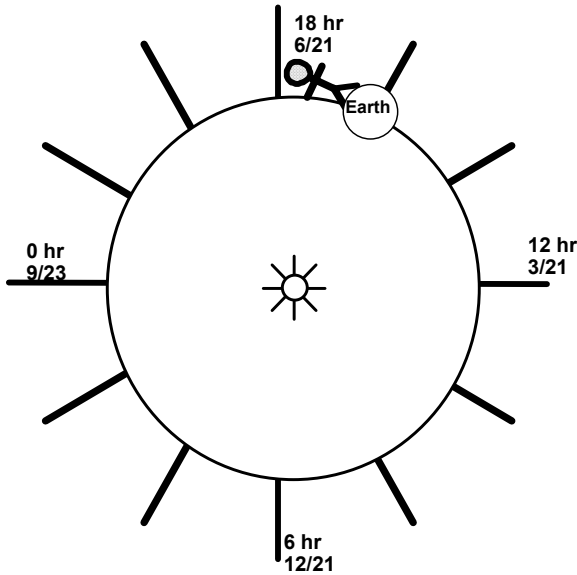
Solar Time, Sidereal Time and Date Given any two items from among Solar Time, Sidereal Time and Date, the third can be found. This is because there are only two motions; Earth spinning and Earth orbiting.

The date tells where to position the Earth and the time (solar or sidereal, whichever time you have) to determine the observer's position. From the drawing, it is possible to find the other time.

Example: What is the sidereal time at 6 AM on May 21?

The picture follows. The answer is 22 hr, but why? The observer's meridian points along the same direction as her body. The stars in that same direction are very far away, so it is important NOT to consider the printed numbers on the picture, but to think of the direction parallel to the body line starting from the Sun, as is shown below.

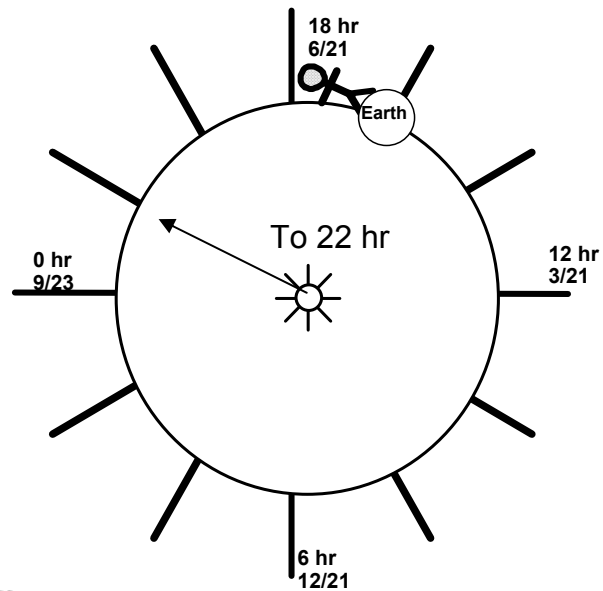
One way to find sidereal time for an observer is to estimate the direction of an arrow at the Sun, but parallel to the observer's body.



A better way to find the correct time is to use midnight as a reference and to count the number of hours midnight to get to the desired time. This method ensures that the result is independent of imperfections in drawing the figure.

In the example given, the solar time was 6 AM, six hours after midnight. The sidereal time at midnight was 16 hr, based on the date May 21. So 6 hr LATER than 16 hr is 16+6=22 hr. You get the same answer, but there is less dependence on the drawing.

Example: What is the sidereal time at 9 PM on Aug 21. The sidereal time at midnight is 22 hr and you could subtract three hours to get to 9PM. So 22 hr- 3 hr = 19 hr. The drawing shows the same thing. Here it feels natural to subtract 3 hours to go from midnight to 9pm (3 hours earlier). It is equally correct to add 21 hours going forward from midnight to 9PM. Adding the hours gives 22hr+21hr=43hr hours. Since there is no sidereal time of 43hr, the remedy is to realize that 24 hr is the same as 0 hours. Subtracting 43hr-24 hr=19hr.



This table is one way to organize the work. Arrows mean that one block determines the other.

Columns are true arithmetic problems when read downward.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight		↔
Hours to add		same	
Protagonist			

Data will be two from among

- Date
- Protagonist Solar Time
- Protagonist Sidereal Time

We have been counting hours away from midnight to get one kind of time if we know the other.

This computation can be organized with this table. Pretend there are two people involved. One is **Midnight Man**, for whom it is always midnight. The other is the **protagonist**, the one the problem is about. ALL of the data is about the protagonist, ALWAYS. The date is the same for the protagonist and the Midnight Man, so there is only one row for the date. The row and column headings tell what to enter.

Make two correct addition problems going DOWN. One is in the Solar Time column and the other in the Sidereal Time column. Read down the column to add the first two values and find the third. In each column

$$\boxed{\text{Midnight Man's time} + \text{Hours to Add} = \text{Protagonist's time}}$$

Problems are always read the same (going down) when complete, but the order in which they get filled in varies. The arrows indicate that data are related. In the case of the hours to add, the values are identical. In the case of date and midnight sidereal time, one determines the other.

The original motivation for making this table was to make it easier to find the DATE when the solar and sidereal times are known. It always works provided that no errors are made. However, it has no checks to indicate whether an error has occurred. Sketching the picture is useful for a check. If the table and picture disagree, there is **some** error.

Example: If it is 4 AM on November 21, what is the sidereal time? Ans. Fill in the block in the Solar Time/Protagonist block with 4AM, the solar time for the Protagonist. Fill in the Date block with the date, 11/21.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight		11/21
Hours to Add		same	
Protagonist	4AM		

Use your knowledge of the Sidereal Time at Midnight on November 21 to fill in 4 hr for Midnight Man's Sidereal Time. Use your knowledge of arithmetic to fill in 4hr to add to Midnight Solar Time to get to 4 AM. The same amount of time, 4 hr, is added to the Sidereal Time at Midnight.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	4hr	11/21
Hours to Add		same	
Protagonist	4AM		

Now add the 4hr to Midnight Man's Sidereal Time at Midnight to get the Protagonist's Sidereal Time.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	4hr	11/21
Hours to Add		same	
Protagonist	4AM	8hr	

So the answer is that the protagonist's sidereal time is 8 hr, but draw the picture to check.

Example: Find the solar time at 6hr on April 21? You could draw it, or use the table
 So enter the protagonist's Sidereal Time (6 hr) and the Date. nYou know that 6hr is a sidereal time, because it doesn't say AM or Pm or noon or midnight.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight		4/21
Hours to Add	same		
Protagonist		6 hr	

Use your knowledge of sidereal time to fill in 14 hr for the sidereal time at midnight on 4/21.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	14hr	4/21
Hours to Add	same		
Protagonist		6 hr	

And use your knowledge of arithmetic to to subtract 8 hr from the sidereal time at midnight to get to the protagonist's sidereal time of 6 hr.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	14hr	4/21
Hours to Add	-8 hr	-8 hr	
Protagonist		6 hr	

Subtract the same 8 hr from Midnight to get to the Protagonist's Solar Time, 4 PM.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	14hr	4/21
Hours to Add	-8 hr	-8 hr	
Protagonist	4PM	6 hr	

Example: What is the date when Betelgeuse is on the meridian at 7 PM? It is not easy to draw this, because the position of the Earth is not known. On the other hand, the solar time (7 PM) is known and the sidereal time is known because you can look up the Right Ascension of Betelgeuse (6 hr) and since Betelgeuse is on the meridian, the sidereal time is 6 hr. So using the table

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight		↔
Hours to Add	same	↔	
Protagonist	7 PM	6 hr	

Now complete the arithmetic problem in the Solar Time column. So, reading down Midnight plus what gets you to 7 PM? The number of hours to add is -5. So fill the -5 hours into the solar time column and the sidereal time column.

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight		↔
Hours to Add	- 5 hr	same ↔ - 5 hr	
Protagonist	7 PM	6 hr	

Now complete the arithmetic problem for the Sidereal Time. What minus 5 gives 6? Eleven, of course. It is very common to make an error in this arithmetic. Try writing the number down in the top row. Then read aloud to yourself and see whether it sounds right. 11-5=6. OK

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	11 hr	↔
Hours to Add	- 5 hr	same ↔ - 5 hr	
Protagonist	7 PM	6 hr	

So what is the date when it is 11 hr Sidereal Time at midnight? Eleven hours is half way between 10 hours and 12 hours, so the position of the Earth along its orbit is half way between Feb 21 and Mar 21. We approximate each month as 30 days. So half way between Feb 21 and Mar 21 is 15 days before the 21st or the 6th of March. (Ignore the 28 days or 31 day months).

	Solar Time	Sidereal Time	Date
Midnight Man	Midnight	11 hr	↔ Mar 6
Hours to Add	- 5 hr	same ↔ - 5 hr	
Protagonist	7 PM	6 hr	

Now draw Mar 6 and one of the times. See whether the other time is consistent with the picture. If not, there has been some computational error.

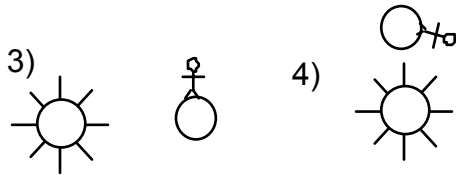
Orientation Practice Problems Set III

- 1) On April 7, what is the sidereal time at 11 PM?
- 2) On Aug. 21, what is the sidereal time at 9 AM?
- 3) If Orion is on the meridian, what is the sidereal time?
- 4) What time would you observe Gemini on the meridian on October 21?
- 5) If it is 13 hours on May 21, what is the solar time?
- 6) If it is July 4, and it is 10 PM, what is the sidereal time?
- 7) If you see Taurus, at 4 hours Right Ascension on the meridian and it is Feb. 21, what is the sidereal time? What is the solar time?
- 8) If it is 4 hr sidereal time and 12 noon, what is the date?
- 9) When you see Libra on the meridian at 3 AM, what is the date?
- 10) What is the Right Ascension of the Sun on Nov.7?

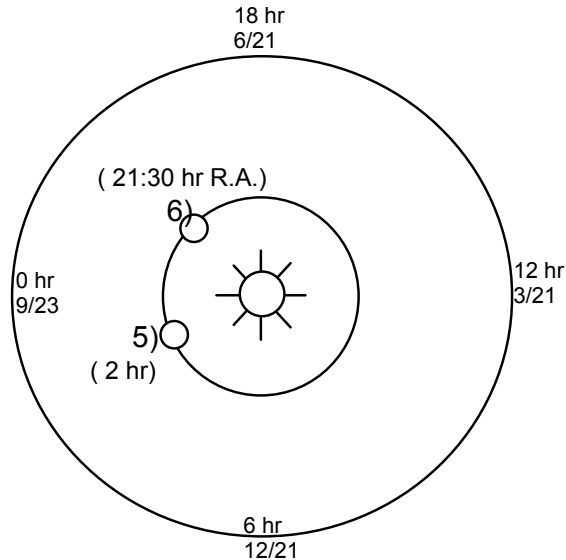
Answers

Set II Get within an hour or so. Be sure to get the AM and PM correct.

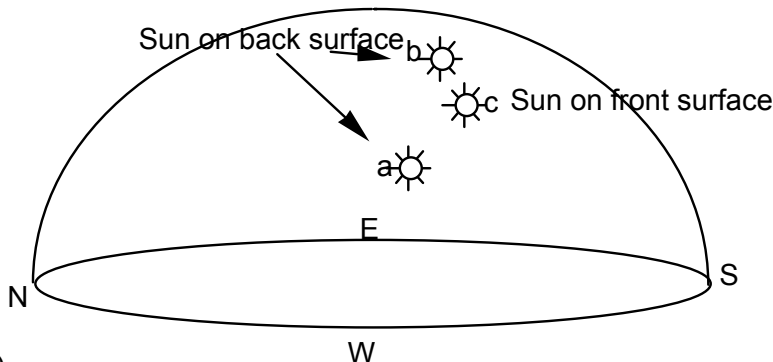
- 1) a 3 AM b 10 PM c 11:30 AM 2) a 7 AM b 10 AM c 2PM



The direction of the Earth with respect to the Sun doesn't matter for the answer. There is no solar or sidereal time specified, so there is no protagonist to draw



- 7) About 10 AM 8) Between 5 PM and 7 PM, depending on the season. You cannot tell exactly from the picture, but it is past late afternoon



9)

Set III 1) 12 hr 2) 7 hr 3) 6 hr approx. 4) 5AM 5) 9 PM 6) 17 hr 7) 4 hr, 6 PM 8) May 21 9) Libra is at about 15 hr, you can look this up on a map, so the sidereal time is 15 hr, the date is Mar 21 10) 15 hr

Putting Latitude and Time Together

As we consider what can be seen at any time, it is necessary to know the sidereal time, and the latitude. We have been computing the sidereal time and the range of declinations visible separately. To combine the two, use the horizon plot provided.

This curve is meant to be overlaid on the mercator projection map of the entire sky. The heavy curve is the horizon. The values of marked near the curves distinguish the view from different latitudes. Diablo Valley College is at about $+38^\circ$. The rectangular grid on the page is the right ascension and declination grid; the same as on the map. The vertical line is the meridian.

To use the curve for the Northern Hemisphere, match the **bottom boundaries** (not the edge of the paper, but the straight line at the bottom) of the map and the sheet with the curves. Match the meridian with the value of **Right Ascension = Sidereal Time**. Everything above the curve will be visible. Usually the curve will hang off to either the right or left edge and will leave the other side uncovered. To find the horizon on the uncovered side, remember that the map is supposed to be the surface of a sphere, so the right and left edges (Right Ascension 0 hr) really should be connected. The part of the horizon overlay which is hanging off will be on top of the rest of the map, where it is needed.

Using the Visibility Curve

We have been considering the effect of latitude separate from the effect of time. If you want to know exactly what can be seen, at any particular time, it is a little more complex. The curves on the next page are designed to be used to block the parts of the sky, on the mercator project, that you cannot see at a given moment.

Each curve is labeled with the latitude for which it applies. It is easiest to copy the page and cut along the line for your latitude with a scissor. This embodies the effect of your latitude. Be careful to follow the curve accurately, they cross.

Compute the Sidereal Time for whenever you want to observe. Align the meridian on the visibility curve up on the Right Ascension equal to the Sidereal Time .

Line up the edge of the grids on the mercator star map and the bottom of the visibility curve. For observing in the Northern Hemisphere, line up the bottom of the visibility curve grid with the -90° line on the star map. For observing in the Southern Hemisphere, turn the sheet with the visibility curve upside down and line up the bottom of the curve with the $+90^\circ$ line on the map.

