653-8012 LEARNING TO USE THE SIMPLIFIED CELESTISTIAL SPHERE

1.1 INTRODUCTION

The instrument that accompanies this guidebook is known as a *celestial globe*. One major component is an outer globe, which represents the *celestial sphere.* The celestial sphere is the domain of the fixed stats. It is not actually a sphere, since all the stars are at vastly different distances from the earth, but is appears to be a sphere when viewed from the Earth's surface. In the center of the instrument is a small globe representing the Earth. The celestial sphere rotates around this globe.

The purpose of this pamphlet is to describe the various features of the celestial globe and how they can be used to illustrate the effects Earth's rotation on its axis. At the end will be found a number of demonstrations and study problems that will assist the student to become familiar with the workings of this instrument. The ultimate purpose is to give the student an understanding of many common astronomical phenomena.

1.2 WHAT IS THE CELESTIAL SPHERE?

The night sky appears to us as a giant inverted bowl or hemisphere, with ourselves at the center. The stars and other celestial objects appear fixed on this sphere, only half of which is visible above our horizon. As the night passes, this sphere, which we call the *celestial sphere*, rotates around us. In ancient times people believed that the stars were the objects that were moving. These days, we know that it is not the stars that move, but ourselves. As the Earth rotates, the celestial sphere appears to move.

The celestial sphere is in fact fictional, because different stars are at vastly different distances from us. The position of a star on the imaginary celestial sphere represents the direction that star is located in, but not it's distance. For the purposes of this instrument, all that needs to concern us is that the distances are so great that the apparent direction of a given star is the same for all viewers on the Earth, regardless of where they might be. In other words, the Earth seems large to us, but its size is utterly negligible compared to the distances between earth and the stars.

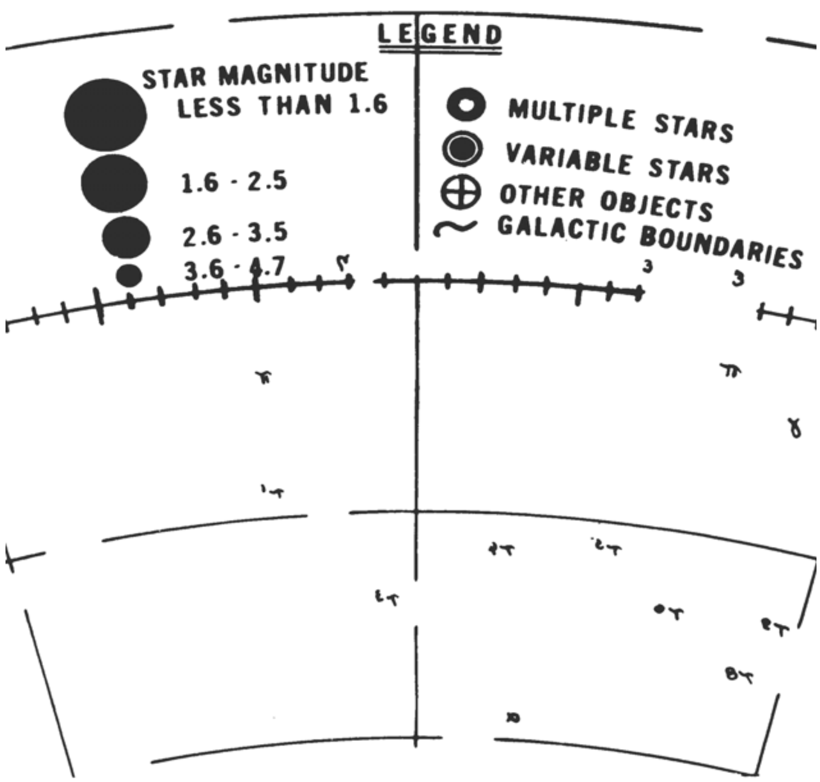
1.3 YOUR MODEL OF THE CELESTIAL SPHERE

The celestial sphere is made up of several parts. Let's first take a look at the outer globe, which is a model of the actual celestial sphere. The stars and certain other celestial objects are shown in fixed positions on this sphere. All but the faintest naked eye stars are shown, with dots sized to approximate brightness. In addition certain stars are identified by special symbols if they are multiple or variable. Some of the most conspicuous nebulae, galaxies, and star clusters are shown by a special symbol.

The boundaries of the Milky Way are also indicated. It is interesting to note that most of the bright stars are located near the Milky Way!

Many models of the celestial sphere are opaque, which means that everything appears backward compared to real life, due to the fact that the proper way to look at the celestial sphere is from the inside. This model, however, is transparent, so that one may look at the sphere from the inside by looking through to the opposite side of the sphere.

Since ancient times, people have tended to group the brighter stars into figures known as *constellations*, which resemble or named in honor of mythological figures. Constellations do not usually represent physical entities, because stars in a constellation may be at greatly different distances, and are grouped together only because they appear to be in the same direction. Today, scientists group stars into constellations to keep track of them. This has the effect of adding more stars to constellations than they originally had. To keep track of them, the constellations on your celestial globe have been separated by dotted black lines.



Your celestial globe emphasizes the appearance of the sky as seen from the position of the rotating earth. As a result, the Earth is at the center. However, due to manufacturing limitations, the Earth in this model does not rotate. Instead, the celestial sphere rotates around the Earth, which simulates the motions of the stars as seen by an Earthly observer.

1.4 OTHER TYPES OF PLANETARIUMS

Celestial globes have been made for **centuries**. Early ones were composed of glass and were very fragile. Our celestial globe is made of nearly unbreakable plastic.

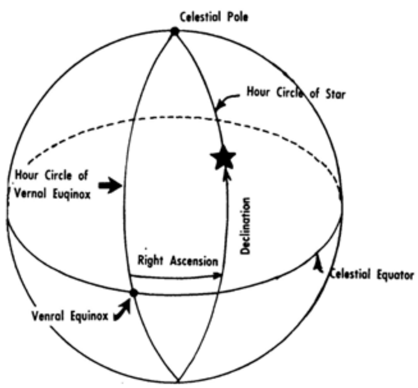
A *projector planetarium* is an instrument which projects an image of the sky onto the inside of a large dome, thereby simulating the experience of the sky as seen by an observer located at a fixed point on the earth's surface. The first projection planetarium ever built was by Zeiss in Germany in 1913. Science First sells a number of astronomy teaching aids. One of our flagship products is the Starlab® portable planetarium. Consisting of an opaque dome 5 or 7 meters in diameter, it can easily accommodate a classroom of students. A projector occupies the center of the dome, projecting stars, as one would see them in a night sky. It can also be used to display constellations, tectonic plates, animal migrations and more. Please visit www.starlab.com for more information.

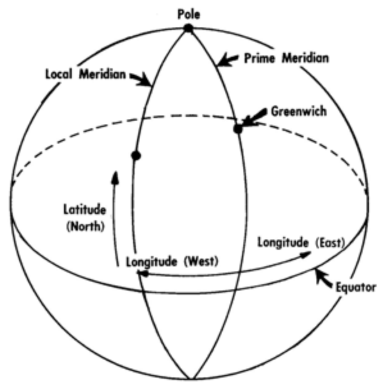
Science First also sells another type of planetarium, the orrey, such as the Trippensee model EL-500. An orrey shows the motions of the earth around the sun, and often the motions of the other planets and/or moon as well. As a result, the sun is at the center of the orrey and the planets are distributed around it.

It should be recognized that all three instruments – the celestial globe, the projection planetarium, and the orrey planetarium – are designed to illustrate many of the same astronomical phenomena, but in different ways. The projection planetarium is most useful for displaying the night sky as seen from Earth. The orrey planetarium demonstrates the actual motions involved. The celestial globe best demonstrates the relationship between Earth's rotation and the position of stars.

1.5 THE EQUATORIAL COORDIANTE SYSTEM

It is convenient to have a procedure for locating objects on the celestial sphere. There are several systems, but by far the most common and most useful one is known as the *equatorial coordinate system.*

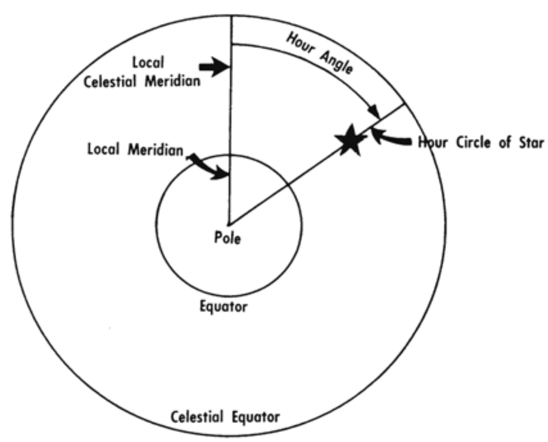


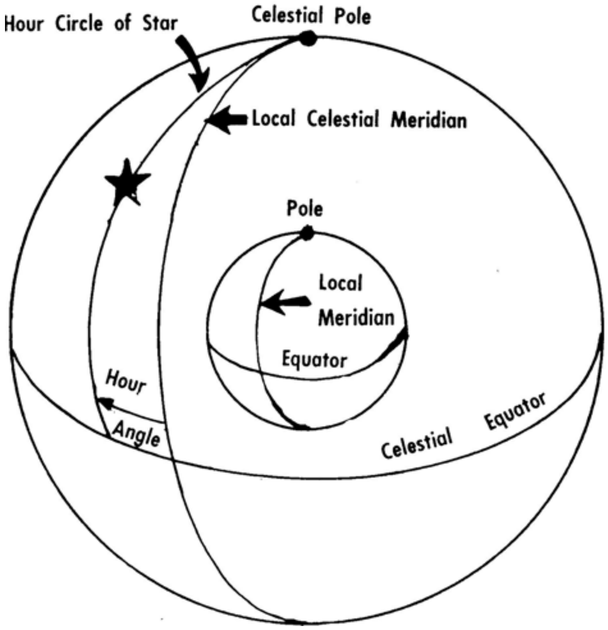


The equatorial coordinate system The Earth's coordinate system

It can be seen from the model that the Earth rotates on an axis that has a fixed orientation with respect to the celestial sphere. Hence, an extension of Earth's axis intersects the celestial sphere at a fixed point near the star appropriately called *Polaris*, or the *North Star*. This point is called the *north celestial pole*, and always appears directly overhead to a person standing on the north pole of the Earth. Halfway between the north celestial pole and its counterpart, the *south celestial pole*, lies a great circle on the celestial sphere known as the *celestial equator*. The celestial equator extends above the earth in an imaginary extension of the Earth's equator.

Because of the correspondence between the celestial poles, equator, and their Earthly counterparts, it is possible to use these as a basis for locating objects on the celestial sphere, in a manner analogous to the use of *latitude* and *longitude* on the Earth's surface. In the equatorial coordinate system, a star's angular distance (position) north or south of the celestial equator is called its *declination*, and is analogous to latitude on the Earth. All objects on the equator have a declination of 0°; those north of the equator have positive declinations (0° to +90°), while those south of the equator have negative declinations (0° to -90°).





Equal to longitude on Earth would be a Star's *right* ascension. A line on the celestial sphere that passes from the north celestial pole through some star and across the celestial equator to the celestial South Pole is called the star's *hour circle*. If some particular point on the celestial equator were chosen as a "starting point", then a star's ascension would be the angular measurement from the starting point along the celestial equator to the star's hour circle. All stars lying on the same hour circle would have the same right ascension.

On the Earth we measure longitude both east and west of the point on the equator that is crossed by the *prime meridian*, the meridian that passes through the town of Greenwich, England. In the sky we measure right ascension eastward from a point on the celestial equator known as the *vernal equinox*. A star's right ascension can thus be anywhere from 0° to 360°, but the measurement is customarily given in hours, minutes, and seconds. Hence, 360° = 24hr, or 15° = 1hr, or 1° = 4min. The significance of the point called the vernal equinox will be given later.

Lines of constant declination (10° intervals) and constant right ascension (1hr or 15° intervals) are present on your celestial globe. You will find 4 blue lines intersecting at the poles, which divide the globe into quadrants. On these lines are tick marks that are parallel to the equator and are spaced 10 degrees apart. On the equator itself, labeled in black, are the hour marks and their corresponding degree value.

1.6 THE EARTH'S ROTATION BENEATH THE CELESTIAL SPHERE

Our Earth rotates eastward beneath the celestial sphere, completing one rotation about every 23 hours and 56 minutes. As the Earth rotates, we can see that any giver meridian on the Earth's surface sweeps under successively different hour circles in the sky arriving back at the same circle every $23^h 56^m$.

One of the meridians on the Earth will be the meridian on which we stand, called the *local meridian*. At any given moment, our local meridian lies directly beneath an hour circle on the celestial sphere. This particular hour circle is called our *local celestial meridian*. Of course, people at different longitudes have different local celestial meridians. In addition, the local celestial meridian belonging to any one observer is constantly shifting eastward on the celestial sphere because of the Earth's eastward rotation, which carries our observer along with it. You can verify both of these points by examining the celestial globe.

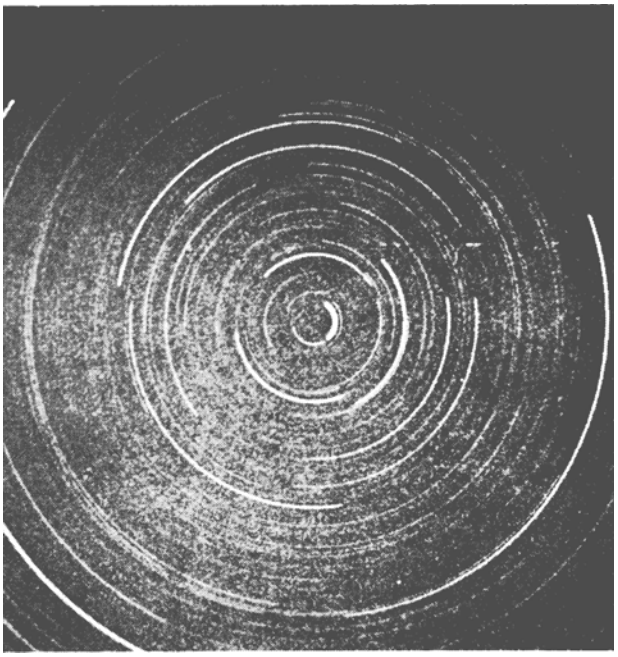
If we are to look into the night sky, our local celestial meridian will pass from the south point on our horizon up through the *zenith* (directly overhead) to the north celestial pole. The north celestial pole lies above our northern horizon by an angle equal to our latitude. As we are carried eastward with the rotating earth, all objects on the celestial sphere will cross the local celestial meridian from east to west. All objects lying on the same hour circle, i.e. those of the same right ascension will cross the local celestial meridian at the same time.

At any one time, the position of a star relative to the local celestial meridians can be specified quite easily, simply as the angle measured *westward* from the local celestial meridian to the star's hour circle. This angle, customarily measured in hours rather than degrees, is called the stars *hour angle*.

If a star is located on the local celestial meridian, its hour angle is naturally zero. Because of the Earth's eastward rotation, the star will appear to move westward with it's hour circle, and hence the star's hour angle will increase at a constant rate until exactly one rotation is completed, at which time the hour angle will have increased to $360° = 24^h$, and the star will be back on the local celestial meridian again.

1.7 THE EARTH'S REVOLUTION AROUND THE SUN

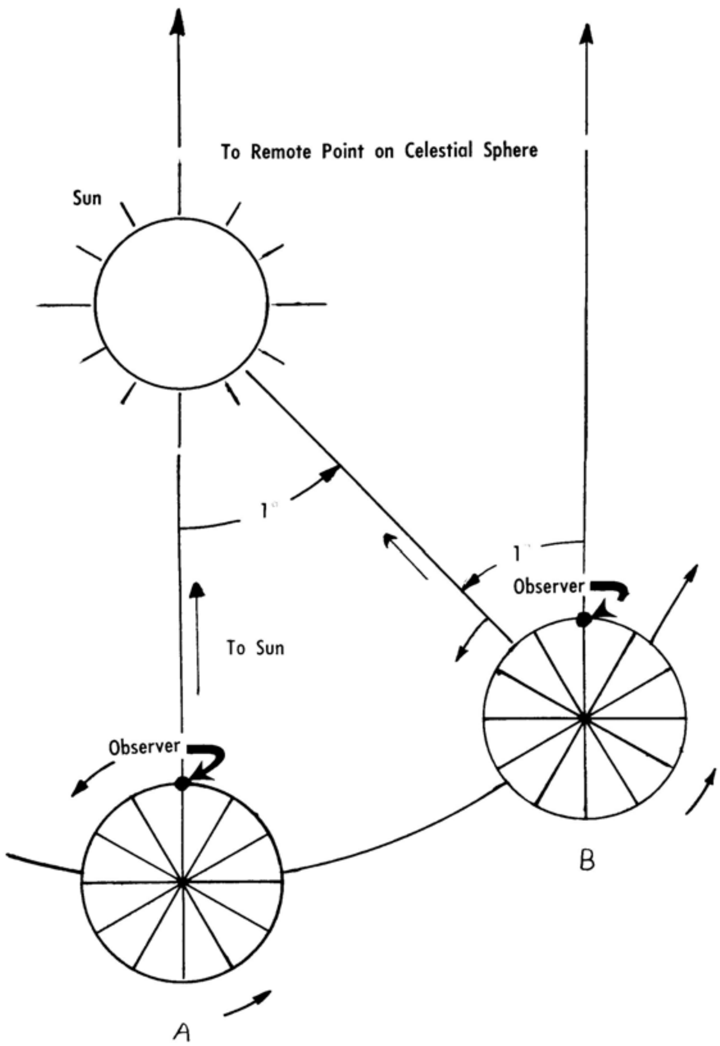
The Earth, as we know, revolves in an orbit around the sun with a period of one year. The result is that the stars above the horizon at midnight change as the year passes. For the same reason, as shown below, the sun appears in front of successively different groups of stars at different times of the year, or so it would appear if we could see the stars during the daytime. As a result, the sun appears to move slowly eastward among the stars, along a great circle on the celestial sphere, returning to its starting place in one year's time. This great circle is called the *ecliptic*. The ecliptic is the intersection of the plane of the Earth's orbit with the celestial sphere. Twelve constellations are distributed along the ecliptic around the sky and are known as the *constellations of the zodiac*.



Star Trails: time exposure by fixed camera pointed at Polaris

The Earth's axis of rotation is tilted, so that the plane of the Earth's equator lies at an angle of about 231/2° to the plane of Earth's orbit. Therefore, the ecliptic must lie at an angle of 231/2° to the celestial equator, and must intersect it at two fixed points on the celestial sphere.

The seasons we know are caused by the fact that the Earth's axis is tilted (See page 8). For example, summer in the northern hemisphere occurs when the Earth is at that part of its orbit where the North Pole is tilted toward the sun. In that position sunlight falls most directly on the northern hemisphere. Note that on about March 21, the sun shines down directly on the equator, which must mean that on that date the sun appears to lie on the celestial equator of the celestial sphere. Therefore, the sun is at that point on the ecliptic that intersects the celestial equator. As the year passes, the sun will move eastward along the ecliptic and also higher in the sky (northward of the celestial equator), a reflection of the Earth's motion.

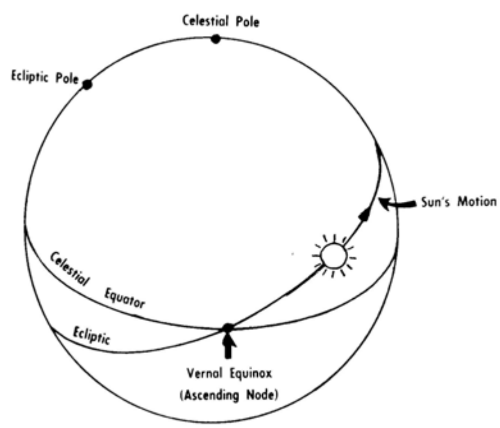


This point of intersection of the ecliptic with the celestial equator, which the sun passes on about March 21, is called the *vernal equinox*. This is the so-called *ascending node* of the ecliptic, because at this point the sun is "ascending" from south to north across the ecliptic. Spring starts in the northern hemisphere when the sun arrives at the vernal equinox. Six months later, the sun will arrive at the other node – the *descending node or autumnal equinox*. The ecliptic is marked on your celestial sphere in yellow.

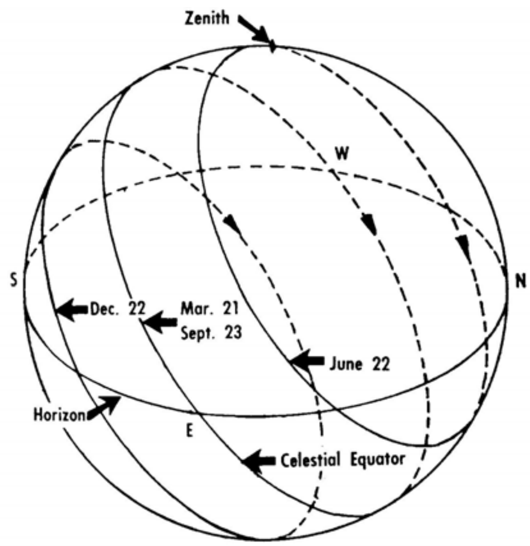
If the Earth's orbit were an exact circle, the sun would appear to move exactly uniformly along the ecliptic, and its position on the globe would correspond exactly to the large red tick marks. However, the Earth's orbit is elliptical, which means that the sun does not move uniformly. The actual position of the sun every five days is displayed by the small red tick marks.

In general, the sun moves about 1° per day. This is because there are 360° in a circle and 365 days in a year.

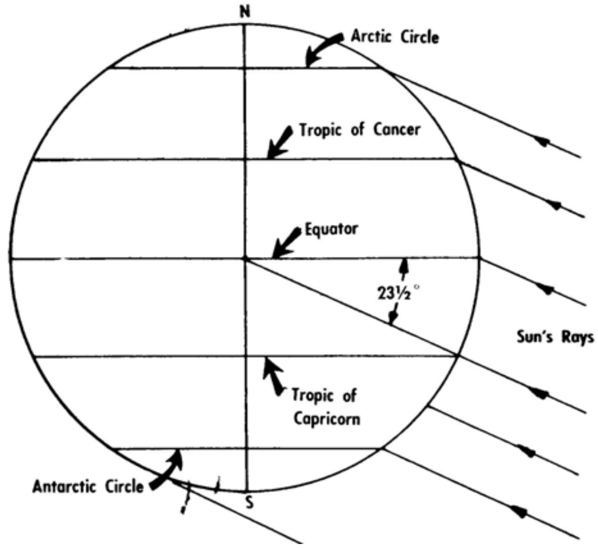
Please see the diagrams on the following page for diagrams regarding the origin of seasons.



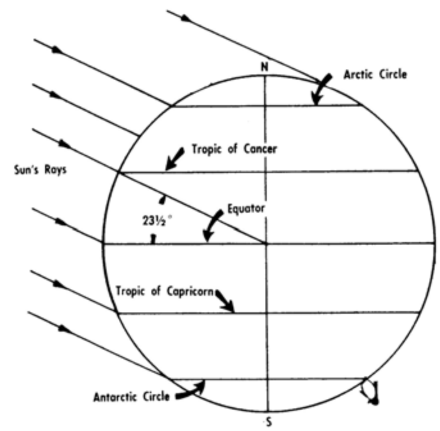
The Ecliptic on the celestial plane



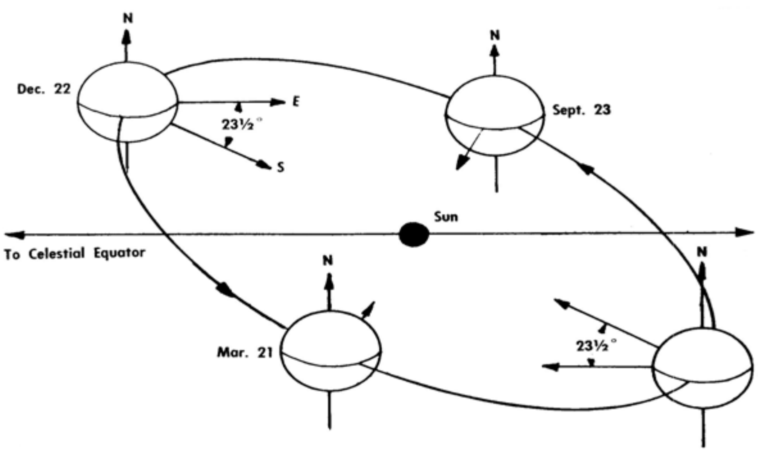
Sun's diurnal path on various dates.



The Earth on June 22nd



The Earth on December 22nd



1.8 APPARENT SOLAR TIME

We have already seen how it is possible to keep time by measuring the hour angles of a celestial object. Sidereal time in fact is defined as the hour angle of the vernal equinox. Therefore, a new sidereal day begins each time the Earth's rotation brings the vernal equinox to the local celestial meridian.

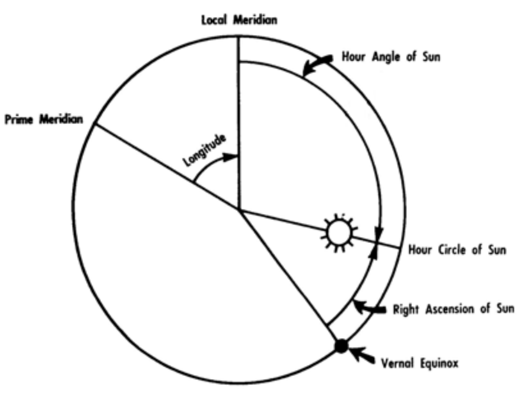
Clearly it would not be very convenient for us to use sidereal time in our daily lives, since zero o'clock would occur at various times of the day or night at different times of the year! (Why? Discuss) Naturally, we would prefer to keep time by the sun. Therefore, we can define *apparent solar time* as follows:

Apparent solar time = hour angle of the sun + 12 hours

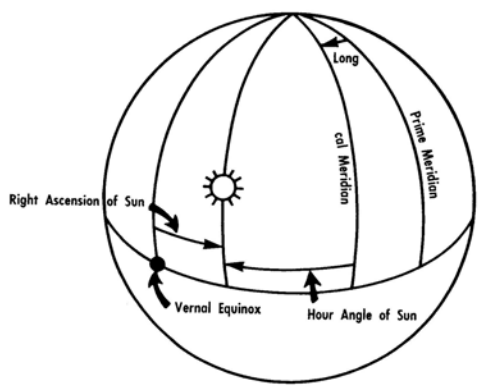
This means that at apparent solar noon (when the sun is on the local celestial meridian and its hour angle is therefore zero), the apparent solar time is 12:00, and at midnight is 24:00. The 12 hours are added only as a convenience; people usually prefer to have their days start and end at midnight rather than noon!

Our clocks run on *standard time*, which is based on *mean solar time*. The difference between the two is explained in the following section, for those who are interested.

Since the sun is moving constantly eastward on the celestial sphere by about 1° per day, we see that a solar day is not the same length as a sidereal day. One sidereal day, or 24 sidereal hours, passes during the time it takes the Earth to rotate 360°. However, during this time the sun has moved about 1° eastward, which means that the Earth must rotate an extra degree before the same meridian faces the sun again. It takes about 4 minutes for the Earth to complete this process. Therefore, a solar day is abort four minutes longer than a sidereal day. Thus, 24 sidereal hours is equivalent to about 23^h56^m in solar time.

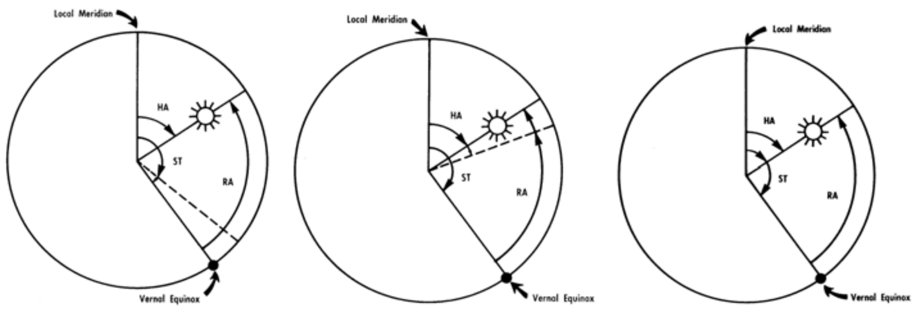


LOOKING DOWN ON POLE



LOOKING DOWN ON EQUATOR

APPARENT SOLAR TIME



RELATION BETWEEN SOLAR TIME AND SIDEREAL TIME FOR AN ARBITRARY DATE

	Initial	360° of Rotation	361° of Rotation
Date	Nov 20th	Nov 21st	Nov 21st
Solar time	5:00pm	4:56pm	5:00pm
Sidereal Time	8:00	8:00	8:04
Right Ascension of Sun	3^h0^m	3^h4^m	3^h4^m

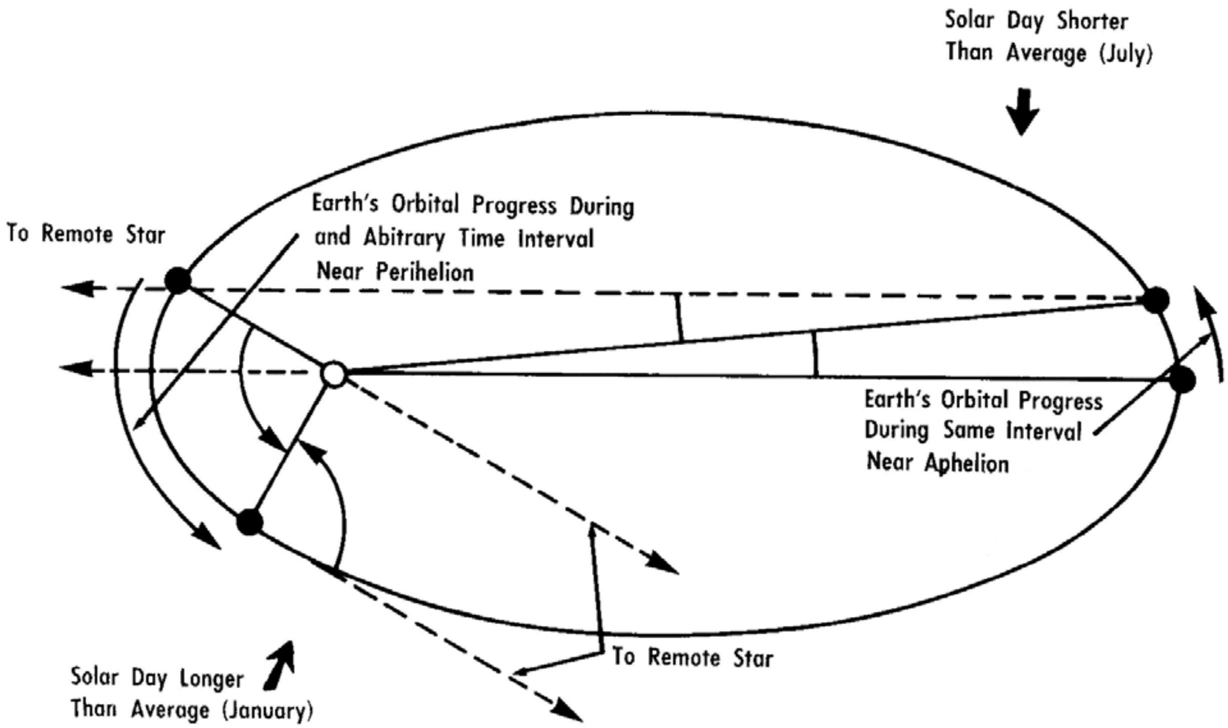
1.9 EQUATION OF TIME

For those who are interested, this section is devoted to showing the differences between apparent solar time and the time kept by our clocks. Apparent solar time, as described above, is unfortunately not a uniform measurement of time. This means that we would have to continuously readjust our clocks forward and backward if they are to keep apparent solar time, which would be most inconvenient! The only instrument that keeps apparent solar time without readjustment is, of course, a sundial! In addition to being unfashionable, sundials are not precise enough to use as timepieces today.

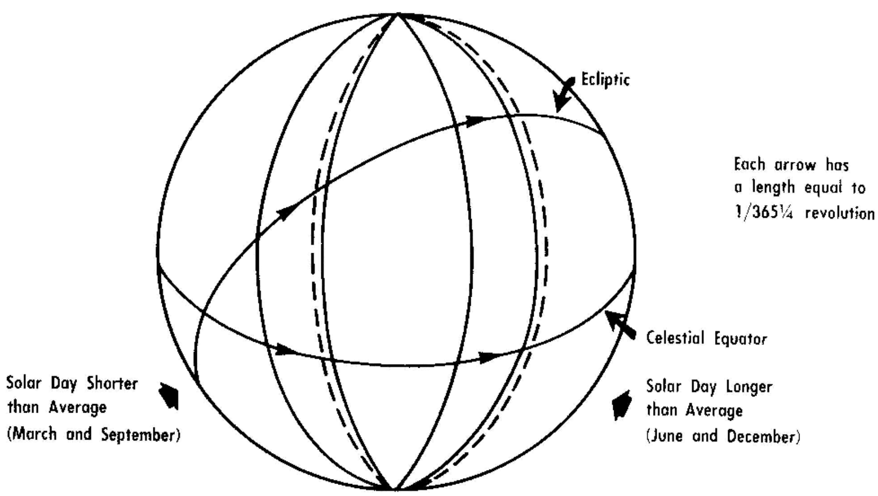
The apparent solar time is not uniform because the sun does not change its right ascension (or its hour circle) by the same amount every day. As a result, the time between the two successive passages of the sun across the local celestial meridian is not strictly the same for each day of the year.

There are two reasons why the sun does not change its right ascension by the same amount each day. One reason is that the movement of the sun on the ecliptic is not uniform, due to the variable motion of the earth on its elliptical orbit. This has already been mentioned in reference to the markings on the celestial sphere, and is illustrated below.

The other reason is due to the fact that the ecliptic is inclined to the celestial equator. Therefore, even if the sun's motion along the ecliptic were uniform, its right ascension would not change by the same amount each day, as illustrated below.



VARIATION IN THE LENGTH OF THE SOLAR DAY DUE TO THE EARTH'S VARIABLE MOTION ALONG ITS ELLIPTICAL ORBIT



VARIATION IN THE LENGTH OF THE SOLAR DAY DUE TO THE INCLINATION OF THE ECLIPTIC

Since we would obviously prefer to have a uniform basis for time, we would like to keep time with a sun that moves *uniformly* along the *celestial equator,* rather than one that moves *non-uniformly* across the *ecliptic.* A fictitious sun that can be though to move in this way is the *mean sun*. The only requirements are that the mean sun should complete exactly one revolution around the equator in exactly the same time the real sun takes to move around the ecliptic, and that *on* *the average* the two suns remain near each other's hour circle. We can then define uniform time as *mean solar time* or *local mean time* as follows:

Mean solar time = hour angle of the sun + 12 hours.

The apparent and mean solar times can be out of step with each other by various amounts over the course of the year, up to 17 minutes. The difference between these two measurements of time is a quantity called the *equation of time*, which is defined as follows:

Equation of time = apparent solar time – mean solar time

A graph showing the variation of the equation of time throughout the year is displayed toward the right. Although mean solar time runs uniformly, it would not be very convenient to keep time in this fashion, since every longitude would keep a different time.

Consider the cities of Nashville and Memphis, which are about 200 miles apart. If both kept time according to their local celestial meridian, the time difference between the two would be approximately 15 minutes. This simply will not do. Instead, the earth has been divided into 24 *time zones*; each centered and based on a *standard meridian*. The 24 standard meridians are the prime meridian, or 0°, and longitudes 15°, 30°, 45° etc, both east and west. By convention, everyone in a given time zone goes by a *standard time* that equals the local mean time on the standard meridian. For example, Central Standard time is the local time on the meridian 90° W longitude. Local time can be found by subtracting longitude from Greenwich Mean Time. The prime meridian runs through Greenwich, England.

Time zones are not uniform in size. All of China falls under one time zone. Some areas, such as Svalbard or Newfoundland, posses time zones half of an hour different from bordering zones.

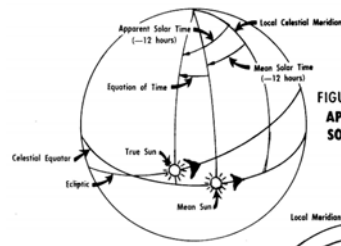
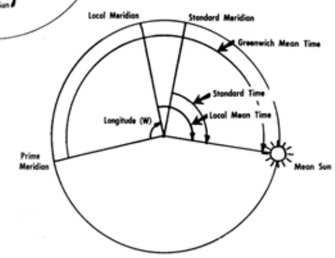
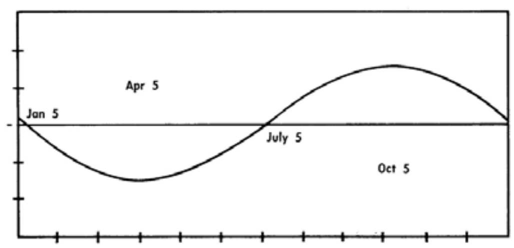
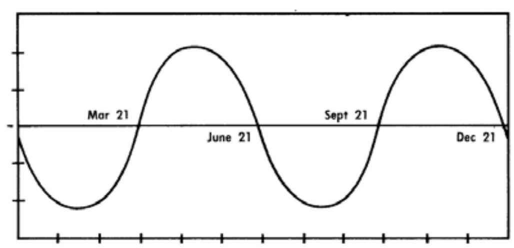


FIGURE 25 COMPARISON OF APPARENT AND MEAN SOLAR TIME



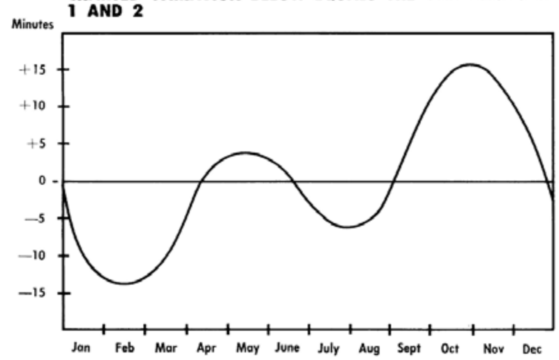


VARIATION CAUSED BY ELLIPTICAL ORBIT OF EARTH



VARIATION CAUSED BY THE 23½° TILT OF EARTH'S ORBIT

CHARTED VARIATION BELOW EQUALS THE VARIATIONS OF 1 AND 2



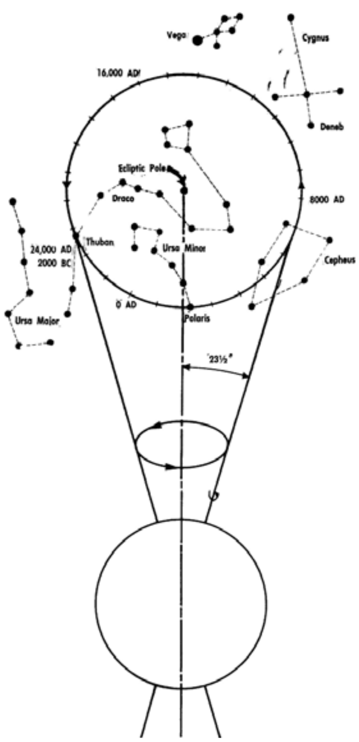
1.10 PRECESSION OF THE EARTH'S AXIS

The Earth's axis is not really perfectly fixed in space but slowly moves (*precesses*) in a cone perpendicular to the Earth's orbit. It takes about 26,000 years for one revolution of this motion, likened to the motion of a precessing top. The axis perpendicular to the Earth's orbital plane is perpendicular to the ecliptic, therefore intersecting the celestial sphere at two points. These points are called the *ecliptic poles*.

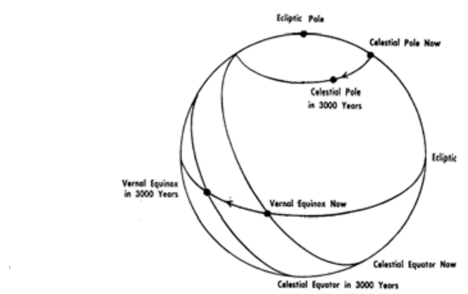
Because of the precessing of the Earth's axis, the north celestial pole will trace a circle around the north ecliptic pole; therefore, Polaris will not always be the North Star. When the Egyptian pyramids were being erected, Thuban had this honor, and in approximately 12,000 years the torch will be handed to Vega. This motion of the celestial poles naturally requires that the celestial equator move along with them, and as a result the equinoxes are shifting westward at a constant rate. Hence, this motion is often called the *precession of the equinoxes.*

About 2,300 years ago, the vernal equinox was situated on the ecliptic in the constellation Aries, and was given the name 'first point of Aries.' Since the sun arrives at the vernal equinox on about March 21 of each year, the month of March was associated with Aries. Each other month was assigned to other constellations when the sun arrived there.

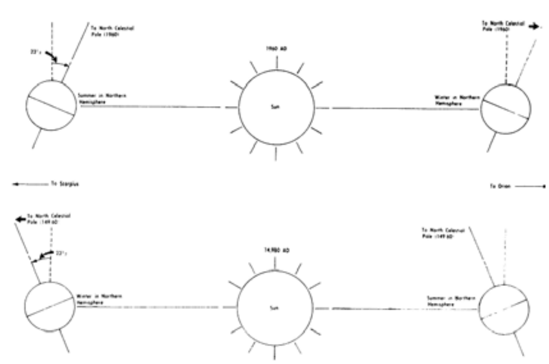
That was many years ago. Because of precession, the vernal equinox shifts 360° / 260, or 1.4° per century along the ecliptic. This means that it is located approximately 30° west of Aries, the adjacent constellation Pisces. For this reason, the constellations of the zodiac no longer correspond to the months they are assigned to.



THE EARTH'S PRECESSION



PRECESSION OF THE EQUINOXES



2.1 LOCATION OF STARS ON THE CELESTIAL SPHERE

The purpose of this activity is to learn how to designate the positions of stars or other bodies on the celestial sphere.

The celestial equator is the path where the plane of the Earth's equator intersects the celestial sphere. On your celestial globe, the celestial equator corresponds to the seam where the two hemispheres are joined. Declination is an angle measure in degrees north or south of the celestial equator. Right ascension is an angle measured along the celestial equator from a point called the vernal equinox. It is usually measured in hors, minutes and seconds ($15° = 1^h$), but it can also be measured in degrees.

The position of a star on the celestial sphere can be designated by its declination and right ascension, just as the position of a city on Earth can be designated by latitude and longitude.

1. Verify in the following manner that the bright star Vega is near the right ascension 18^h35^m and declination +41°: First, find the vernal equinox – that point on the celestial equator where the right ascension is labeled 0^h and also 0°. Then move your attention eastward along the celestial equator through the right ascension 1^h, 2^h, etc until you reach 18^h. Then, move 35/60 (a little over half) of the way toward 19^h. Scan northward 4 divisions. You should find the star Vega near this location.
2. Likewise, verify that the star Antares is near the right ascension 16^h30^m and declination -25°. The minus sign indicates that the declination is south of the celestial equator. Antares shines red at night, and can be mistaken for Mars. Thus, the name Antares means not-Mars.
3. Verify that the spiral galaxy M31 is at right ascension 0^h30^m and declination +41°.
4. Find the star Betelgeuse in the constellation Orion (near the celestial equator). What are its coordinates?
5. What are the coordinates of Polaris, the North Star?
6. What object has a declination of +22° and a right ascension of 5^h35^m?
7. Locate the southern cross (the constellation Crux) on the celestial sphere by making use of approximate coordinates listed on the inside back cover.
8. Locate two or three additional objects of your own choosing, listed in various table of section three.

3.0 SCIENCE FIRST CELESTIAL GLOBE NIGHT ACTIVITIES

The four tables in this section enable you to compare the Science First Celestial Globe with the night sky! Look closely at the globe and sky, and compare. There are more color and double stars that you can see on a clear night with unaided eyes than you can imagine. Of course, a telescope will show you even greater wonders, but why wait? Go out tonight and see for yourself. The sky is a four dimensional marvel waiting to be explored.

For the planet locations, see your local newspaper, *Sky and Telescope,* or *Reviews of Popular Astronomy.* There are other manuals that will give you the same information, but the above are easily used.

3.1 TRIPPENSEE CELESTIAL GLOBE NIGHT ACTIVITIES

Name	Apparent Magnitude**	Right Ascen.	Decl.	Constellation	Distance in Light Years	Color*** and Class	Temp. (°K)	Intrinsic Luminosity (relative to sun)	Radius (relative to sun)
Barnard's Star	+9.5	17h55m	+4°33′	Ophiuchus	6.0	red main sequence	2500	0.0004	.12
Sun	—26.8	———	———	———	0.0000158	yellow main sequence	5800	1	1
Alpha Centauri	+0.1	14 37	—60 42	Centaurus	4.2	yellow main sequence	5800	1.4	1.2
Procyon	+0.5	7 38	+5 18	Canis Minor	11.4	white main sequence	6500	7	2.0
Sirius	—1.6	6 44	—16 40	Canis Major	8.8	blue main sequence	9000	23	2.0
Vega	+0.1	18 36	+38 45	Lyra	26	blue main sequence	10000	52	2.4
Arcturus	+0.2	14 14	+19 21	Bootes	36	orange giant	3800	110	24
Capella	+0.2	5 14	+45 58	Auriga	46	yellow giant	4700	160	19
Canopus	—0.9	6 23	—52 41	Carina	100	white supergiant	6500	1500	30
Betelgeuse	+0.5	5 53	+7 24	Orion	500	red supergiant	2700	14000	550
Rigel	+0.3	5 13	—8 14	Orion	800	blue supergiant	10000	45000	71

**Smaller or more negative magnitudes are brighter. The brightest star is Sirius(magnitude — 1.6), and the faintest naked-eye stars have a magnitude of about +6. A change of one magnitude represents a change in brightness by a factor 2.5. A change of 5 magnitudes represents a 100-fold brightness change.

***The colors of the bright stars are easily noticeable to the unaided eye!

3.2 SELECTION OF MULTIPLE STARS

Name	Right Ascen.	Decl.	Magnitude and Color: Brighter Star	Magnitude and Color: Fainter Star	Separation (in secs of arc)	Notes
Polaris (α UMi)	1h49m	+89° 2′	2.0 white	9.0 blu	18	1*
Almach (γ And)	2 1	+42 6	3.0 gold	5.0 blue	10	
Castor (α Gem)	7 31	+32 0	2.7 greenish	3.7 greenish	4.6	2*
γ Vel	8 8	—47 11	2.7 blue	3.0 blue	42	
Algeiba (γ Leo)	10 17	+20 6	2.6 gold	3.6 green-red	4.0	
α Cru	12 24	—62 49	1.6 white	2.1 white	5	
γ Vir	12 39	—1 11	3.6 yellow	3.7 yellow	5.7	
Mizar (ζ UMa)	13 22	+55 11	2.1 greenish	4.2 greenish	15	3*
ε Boo	14 43	+27 17	3.0 yellow	6.3 green	2.8	
Antares (α Sco)	16 26	—26 20	1.2 red	5.2 green	3.0	4*
E Lyr (E¹ + E²)	18 43	+39 37	4.6 greenish	4.9 bluish	208	5*
E¹ Lyr			5.1 greenish	6.0 bluish	2.9	
E² Lyr			5.1 greenish	5.4 greenish	2.3	
Albireo (β Cyg)	19 29	—14 56	3.0 yellow	5.3 blue	35	6*
β Cap	20 18	+27 51	2.5 yellow	6.0 blue	205	

*1. Very large magnitude difference, but not too close together.

*2. There is a third member of this system, a faint star of mag. 9.5 at a distance of 73″ arc. All three stars have been found spectroscopically to be binaries!

*3. First double discovered. Easy object for small telescopes. Also nearby is Alcor, a faint naked-eye star which is physically associated with Mizar. According to some, the attempt to see Alcor with the unaided eye is a test for good vision. It has been found spectroscopically that each component of Mizar, plus Alcor, are each themselves a close binary, so the system actually includes six stars!

*4. Very rewarding, but very difficult because of the small separation and large magnitude difference.

*5. A person with good vision may recognize this star to be double with the unaided eye. This is called the "double-double" because a telescope shows each component to be itself a double star, with characteristics as indicated in the table.

*6. One of the finest doubles in the sky. Colors very vivid. Easy object for small telescopes.

3.3 STAR CLUSTERS, NEBULAE AND GALAXIES

Special Name	M*	Right Ascen.	Decl.	Constellation	Type of Object	Comments
Great Nebula	31	0h40m	+41° 0'	Andromeda	spiral galaxy	Large and nearby. Thought to be similar to our own galaxy.
Small Magellanic Cloud	—	0 40	—73 0	Tucana	irregular galaxy	Satellite of our own galaxy. Looks like a detached piece of the Milky Way.
————	33	1 31	+30 24	Triangulum	spiral galaxy	Nearby.
h & chi Persei	—	2 15	+56 0	Perseus	open clusters	A fine double cluster.
Pleiades	45	3 44	+23 57	Taurus	open cluster	Also called the Seven Sisters (seven naked-eye stars). Contains reflection nebulosity
Hyades	—	4 20	+17 0	Taurus	open cluster	Nearby with many naked-eye stars. Forms the head of Taurus the Bull.
Large Magellanic Cloud	—	5 15	—73 0	Dorando	irregular galaxy	Satellite of our own galaxy. Looks like a detached piece of the Milky Way.
Crab Nebula	1	5 32	+22 0	Taurus	planetary nebula	Rapidy expanding remains of the supernova of 1054 A.D.
Orion Nebula	42	5 33	—5 25	Orion	emission nebula	One of the finest in the sky. Star formation is currently taking place here.
————	43	5 38	—5 19	Orion	emission nebula	A detached portion of the Orion Nebula.
Horsehead Nebula	—	5 33	—73 0	Orion	absorption nebula	
Praesepe	44	8 37	+20 10	Cancer	open cluster	A fine cluster. Also called the Beehive Cluster.
————	104	12 37	—11 21		spiral galaxy	
Omega Centauri	—	13 20	—47 0	Centaurus	globular cluster	Finest in the sky.
Whirlpool Galaxy	51	13 28	+47 27	Canis Venatici	spiral galaxy	
————	3	13 40	+28 38	Canis Venatici	globular cluster	
————	5	15 16	+2 17	Serpens	globular cluster	
————	13	16 40	+36 33	Hercules	globular cluster	Finest in the northern sky.
Lagoon Nebula	8	18 1	—24 23	Sagitarius	emission nebula	
————	16	18 16	—13 48	Serpens	open cluster	Contains emission nebulosity.
Ring Nebula	57	18 52	+32 58	Lyra	planetary nebula	Famous object.
Veil Nebula	—	21 0	+31 0	Cygnus	emission nebula	Remains of an expanding supernova
North American Nebula		21 0	+44 0	Cygnus	emission nebula	

* Catalog number in Messier's Catalog of fuzzy objects which might (at least according to Messier!) be mistaken for comets.

3.4 STARS WITH INDIVIDUAL NAMES

Name	Designation*	Mag.	Color
Alpheratz	α And	2.1	blue
Mirach	β And	2.4	red
Almach	γ And	2.3	orange
Altair	α Aqu	0.9	blue
Hamal	α Ari	2.2	orange
Capella	α Aur	0.2	yellow
Mankalinan	β Aur	2.1	blue
Arcturus	α Boo	0.2	orange
Sirius	α CMa	—1.6	blue
Mirzam	β CMa	2.0	blue
Adhara	ε CMa	1.6	blue
Aludra	η CMa	2.4	blue
Procyon	α CMi	0.5	white
Canopus	α Car	—0.9	white
Miaplacidus	β Car	1.8	blue
Apidiske	ι Car	2.2	white
Caph	β Cas	2.4	white
Rigil Kentaurus	β Cen	0.9	blue
Menkar	α Cet	2.8	red
Deneb Kaitos	β Cet	2.2	orange
Alphecca	α Crb	2.3	blue
Acrux	α Cru	1.0	blue
Deneb	α Cyg	1.3	blue
Sadr	γ Cyg	2.3	white
Eltanin	γ Dra	2.4	orange
Achernar	α Eri	0.6	blue

Name	Designation*	Mag.	Color
Castor	α Gem	1.6	blue
Pollux	β Gem	1.2	orange
Regulus	α Leo	1.3	blue
Denebola	β Leo	2.2	blue
Algeiba	γ Leo	2.6	orange
Vega	α Lyr	0.1	blue
Rasalhague	α Oph	2.1	blue
Betelgeuse	α Ori	0.5	red
Rigel	β Ori	0.3	blue
Bellatrix	γ Ori	1.7	blue
Alnitak	ζ Ori	2.0	blue
Alnilam	η Ori	3.4	blue
Saiph	κ Ori	2.2	blue
Mirfak	α Per	1.9	white
Fomalhaut	α PsA	1.3	blue
Antares	α Sco	1.2	red
Shaula	ε Sco	2.4	orange
Kaus Australis	ε Sgr	1.9	blue
Nunki	o Sgr	2.1	blue
Aldebaran	α Tau	1.1	orange
Elnath	β Tau	1.8	blue
Dubhe	α UMa	1.9	orange
Merak	β UMa	2.4	blue
Alioth	ε UMa	1.7	blue
Mizar	ζ UMa	2.4	blue
Alkaid	η UMa	1.9	blue
Polaris	α UMi	2.1	white
Kochab	β UMi	2.1	orange

*Naked-eye stars within a constellation are designated by a Greek letter (generally in order of brightness) followed by the genitive form of the Latin constellation name.

4. GLOSSARY

The following words are most important for an understanding of the phenomena illustrated by the celestial globe. Key terms are bolded.

Absorption nebula: an interstellar dust cloud obscuring stars behind it.
Altitude: angle measured upward from the horizon toward the zenith.
Apparent Solar Time: hour angle of the sun plus 12 hours
Arctic circle: the parallel at latitude 66.5°, above which the midnight sun may be seen. Its southern equivalent is the Antarctic Circle.
Ascending node: the node on the ecliptic at which the sun moves northward across the celestial equator.
Astronomical Twilight: the period lasting from sunset until the sun is 18° below the horizon. Although dusk technically ends when the sun passes 6° below the horizon, there still remains a slight glow in the sky, which can hinder the work of an astronomer.
Autumnal Equinox: The descending node of the ecliptic. It is called autumnal, because when the sun arrives at this point, autumn begins in the Northern hemisphere.
Azimuth: angle measured along the horizon from North through East.
Binary Star: a star, which upon close examination is found to be a physically associated group of two stars. It is believed that many stars are actually binaries.
Celestial Equator: the great circle that represents the intersection of the plane of Earth's equator with the celestial sphere.
Celestial Globe: a model of the celestial sphere.
Celestial Pole: one of two points where the extended axis of the Earth intersects the celestial sphere.
Celestial Sphere: a fictitious sphere of infinite radius, centered on the observer, upon which the stars appear fixed.
Circumpolar Stars: stars which never set.
Civil Twilight: the period of dusk lasting from sunset until the sun is 6° below the horizon.
Constellation: One of the 88 chance groupings of stars on the celestial sphere.
Constellations of the Zodiac: the twelve constellations situated along the ecliptic.
Declination: angle measured northward or southward from the celestial equator.
Descending Node: the node on the ecliptic at which the sun moves southward across the celestial equator.
Diurnal: daily, recurring each day.
Ecliptic: The sun's path on the celestial sphere; the intersection of the Earth's orbital plane with the celestial sphere.
Ecliptic Pole: one of two points where the axis of the Earth's orbit intersects the celestial sphere.
Emission Nebula: an interstellar cloud of gas excited to fluoresce by nearby hot stars.
Equation of time: the difference between apparent and mean solar time.
Equator: the great circle on the Earth's surface midway between the poles.
Equatorial Coordinate System: a system for specifying the position of a celestial object be means of its right ascension and declination.
Equinox: one of two points where the ecliptic intersects the celestial equator. The name comes from the fact that, when the sun arrives at this point, day and night have equal length all over the Earth.
Galactic Cluster: a small, loose cluster of stars near the plane of the Milky Way.
Galaxy: a huge assembly of billions of stars; an "island universe". Sometimes a galaxy is referred to as a nebula. There are hundreds of millions of known galaxies.
Globular Cluster: a large, dense spherically symmetrical cluster of about 100,000 stars, not confined to the plane of the Milky Way.

Great Circle: any circle drawn on a sphere, which passes through diametrically opposite points on the sphere.
Greenwich: a town in England, through which runs the Prime Meridian.
Greenwich hour angle: the hour angle as measured at the prime meridian.
Greenwich mean time: the standard time on the prime meridian.
Greenwich sidereal time: the sidereal time on the prime meridian.
Horizon Ring: a device used to indicate the horizon on the celestial sphere.
Hour Angle: angle measured westward along the celestial equator from the local celestial meridian.
Hour Circle: any great circle connecting the celestial poles.]
Latitude: angle measured north or south of the equator.
Local Celestial Meridian: the celestial meridian which passes through the zenith of the observer.
Local mean time: hour angle of the mean sun plus 12 hours.
Local Meridian: to an observer on Earth, it is a great circle perpendicular to the equator and connecting the poles.
Longitude: angle measured along the equator east or west from the prime meridian.
Mean Solar Time: hour angle of the mean sun plus 12 hours.
Mean Sun: a fictitious sun which moves uniformly along the celestial equator.
Meridian: any great circle connecting the north and south poles.
Milky Way: hazy path in the sky which is a dense grouping of stars, representing the plane of our galaxy.
Node: one of two points on a sphere where tow great circle intersect each other.
North Celestial Pole: the celestial pole directly over the north pole of the Earth.
North Star: the bright star near the north celestial pole.
Open Cluster: a small, loose cluster of stars near the plane of the Milky Way.
Orrey: an instrument used to demonstrate the motions of the Earth and other planets around the sun, as well as the moon and the Earth. Science First sells a number of orrey style planetariums.
Parallel: a line of constant latitude on the Earth' surface.
Planetarium: devices used to depict the heavens, in this case an orrey or projector.
Polaris: the name given to the bright star near the celestial North Pole.
Pole: one of two points where the Earth's axis of rotation intersects its surface.
Precession of the Earth's axis: a slow motion of the Earth's axis around a cone perpendicular to the ecliptic; causes the celestial poles to move in circles around the ecliptic poles.
Precession of the Equinoxes: the movement of the equinoxes along the ecliptic brought about by the precession of the Earth's axis.
Prime Meridian: the meridian from which longitude is measured.
Projection Planetarium: an instrument that projects the nighttime sky onto the inside of a dome; used to demonstrate the effects of the motion of the Earth and celestial objects. Science First proudly carries the Starlab line of portable planetariums.
Right Ascension: angle measured from the vernal equinox eastward along the celestial equator.
Setting Circles: devices used to facilitate setting a telescope to point at a desired declination and hour angle.
Sidereal Day: the time interval between two consecutive passages of the vernal equinox across the local celestial meridian.
Sidereal Hour: one twenty-fourth of a sidereal day.
Sidereal Time: the hour angle of the vernal equinox.
Solar Day: the time interval between two consecutive passages of the sun across the local celestial meridian.
Solar time: tike reckoned according to the sun.

Solstice: one of two points on the ecliptic midway between the equinoxes, corresponding to the positions of the greatest possible positive or negative declination of the sun. The name comes from the fact that the sun momentarily "stands still" in its northward or southward journey before apparently reversing direction.
Spiral Galaxy: a galaxy characterized by a flattened disc consisting of spiral arms.
Standard Meridian: any one of 24 meridians placed at intervals of 15° around the Earth, used as a basis for standard time.
Standard Time: the local mean time on a standard meridian.
Star Cluster: a physically associated group of stars with a common origin and age.
Subsolar Point: that point on the Earth's surface at which the sun appears at its zenith.
Substellar Point: that point on the Earth's surface at which the corresponding star appears at its zenith.
Summer Solstice: the point on the ecliptic corresponding to the position of maximum possible north declination of the sun. When the sun arrives at this point, summer begins in the northern hemisphere.
Supernova: a violent explosion of a star, often billions of times the energy of our sun. It amy produce a planetary nebula.
Time Zone: a region of the Earth's surface centered on a standard meridian and using the corresponding standard time.
Tropic of Cancer: the parallel at 23.5° N, where the noon sun appears at the zenith on about June 22nd, when it reaches maximum positive declination. About 2000 years ago, the sun would have appeared in the constellation Cancer on this date, but due to precession now appears between Taurus and Gemini.
Tropic of Capricorn: the parallel at 23.5° S, where the noon sun appears at the zenith on about June 22nd, when it reaches maximum negative declination. About 2000 years ago, the sun would have appeared in the constellation Capricorn on this date, but due to precession now appears between Sagittarius and Scorpius.
Universal Time: the standard time on the prime meridian, also known as Greenwich Mean Time.
Variable Star: a star whose luminosity undergoes fluctuations with time.
Vernal Equinox: the ascending node of the ecliptic. It is called vernal because when the sun arrives at this point, spring begins in the northern hemisphere.
Winter Solstice: the point of the ecliptic corresponding to the position of maximum possible south declination of the sun. When the sun arrives at this point, winter begins in the northern hemisphere.
Zenith: the point directly overhead on the celestial sphere.
Zodiac: a path on the celestial sphere centered on the ecliptic.

The 88 Constellations on the TRIPPENSEE CELESTIAL SPHERE

Constellation	Genitive	English name or description	Abbreviation	Approximate Position† α (h)	δ (°)
Andromeda	Andromedae	Princess of Ethiopia	And	1	+40
Antlia	Antliae	Air pump	Ant	10	—35
Apus	Apodis	Bird of Paradise	Aps	16	—75
**Aquarius	Aquarii	Water bearer	Aqr	23	—15
Aquila	Aquilae	Eagle	Aql	20	+5
Ara	Arae	Altar	Ara	17	—55
**Aries	Arietis	Ram	Ari	3	+20
Auriga	Aurigae	Charioteer	Aur	6	+40
Bootes	Bootis	Herdsman	Boo	15	+30
Caelum	Caeli	Graving tool	Cae	5	—40
Camelopardus	Camelopardis	Giraffe	Cam	6	—70
**Cancer	Cancri	Crab	Cnc	9	+20
Canes Venatici	Canum Venaticorum	Hunting dogs	CVn	13	+40
Canis Major	Canis Majoris	Big dog	CMa	7	—20
Canis Minor	Canis Minoris	Little dog	CMi	8	+5
**Capricornus	Capricorni	Sea goat	Cap	21	—20
*Carina	Carinae	Keel of Argonauts' ship	Car	9	—60
Cassiopeia	Cassiopeiae	Queen of Ethiopia	Cas	1	+60
Centaurus	Centauri	Centaur	Cen	13	—50
Cephus	Cephei	King of Ethiopia	Cep	22	+70
Cetus	Ceti	Sea monster (whale)	Cet	2	—10
Chamaeleon	Chamaeleontis	Chameleon	Cha	11	—80
Circincs	Circini	Compasses	Cir	15	—60
Columba	Columbae	Dove	Col	6	—35
Coma Berenices	Comae Berenices	Berenice's hair	Com	13	+20
Corona Australis	Coronae Astralis	Southern crown	CrA	19	—40
Corona Borealis	Coronae Borealis	Northern crown	CrB	16	+30
Corvus	Corvi	Crow	Crv	12	—20
Crater	Crateris	Cup	Crt	11	—15
Crux	Crucis	Cross (southern)	Cru	12	—60
Cygnus	Cygni	Swan	Cyg	21	+40
Delphinus	Delphini	Porpoise	Del	21	+10
Dorado	Doradus	Swordfish	Dor	5	—65
Draco	Draconis	Dragon	Dra	17	+65
Equuleus	Equulei	Little horse	Equ	21	+10
Eridanus	Eridani	River	Eri	3	—20
Fornax	Fornacis	Furnace	For	3	—30
**Gemini	Geminorum	Twins	Gem	7	+20
Grus	Gruis	Crane	Gru	22	—45
Hercules	Herculis	Hercules, son of Zeus	Her	17	+30
Horologicm	Horologii	Cloak	Hor	3	—60
Hydra	Hydrae	Sea serpent	Hya	10	—20
Hydrus	Hydri	Water snake	Hyi	2	—75
Indus	Indi	Indian	Ind	21	—55
Lacerta	Lacertae	Lizard	Lac	22	+45
**Leo	Leonis	Lion	Leo	11	+15
Leo Minor	Leonis Minoris	Little lion	LMi	10	+35
Lepus	Leporis	Hare	Lep	6	—20
**Libra	Librae	Balance	Lib	15	—15
Lupus	Lupi	Wolf	Lup	15	—45
Lynx	Lyncis	Lynx	Lyn	8	+45
Lyra	Lyrae	Lyre or harp	Lyr	19	+40
Mensa	Mensae	Table Mountain	Men	5	—80
Microscopium	Microscopii	Microscope	Mic	21	—35
Monoceros	Monocerotis	Unicorn	Mon	7	—5
Musca	Muscae	Fly	Mus	12	—70
Norma	Normae	Carpenter's level	Nor	16	—50
Octans	Octanis	Octant	Oct	22	—85
Ophiuchus	Ophiuchi	Holder of serpent	Oph	17	0
Orion	Orionis	Orion, the hunter	Ori	5	+5
Pavo	Pavonis	Peacon	Pav	20	—65
Pegasus	Pegasi	Pegasus, the winged horse	Peg	22	+20
Perseus	Persei	Perseus, hero who saved Adromeda	Per	3	+45
Phoenix	Phoenicis	Phoenix	Phe	1	—50
Pictor	Pictoris	Easel	Pic	6	—55
**Pisces	Piscium	Fishes	Psc	1	+15
Piscis Austrinus	Piscis Austrini	Southern fish	PsA	22	—30
*Puppis	Puppis	Stern of the Argonauts' ship	Pup	8	—40
*Pyxis (=Malus)	Pyxidis	Compass on the Argonauts' ship	Pyx	9	—30
Reticulum	Reticuli	Net	Ret	4	—60
Sagitta	Sagittae	Arrow	Sge	20	+10
**Sagittarius	Sagittarii	Archer	Sgr	19	—25
**Scorpius	Scorpii	Scorpion	Sco	17	—40
Sculptor	Sculptoris	Sculptor's tools	Scl	0	—30
Scutum	Scuti	Shield	Sct	19	—10
Serpens	Serpentis	Serpent	Ser	17	0
Sextans	Sextantis	Sextant	Sex	10	0
**Taurus	Tauri	Bull	Tau	4	+15
Telescopium	Telescopii	Telescope	Tel	19	—50
Triangulum	Trianguli	Triangle	Tri	2	+30
Triangclum Australe	Trianguli Australis	Southern triangle	TrA	16	—65
Tucana	Tucanae	Toucan	Tuc	0	—65
Ursa Major	Ursae Majoris	Big bear	UMa	11	+50
Ursa Minor	Ursae Minoris	Little bear	UMi	15	+70
*Vela	Velorum	Sail of the Argonaut's Ship	Vel	9	—50
**Virgo	Virginis	Virgin	Vir	13	0
Volans	Volantis	Flying fish	Vol	8	—70
Vulpecula	Vulpeculae	Fox	Vul	20	+25

* The four constellations, Carina, Puppis, Pyxis, and Vela, originally formed the single constellation, Argo Navis.

**Constellation of the Zodiac.

† α=right ascension; δ=declination.

Warranty and Parts:

We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.