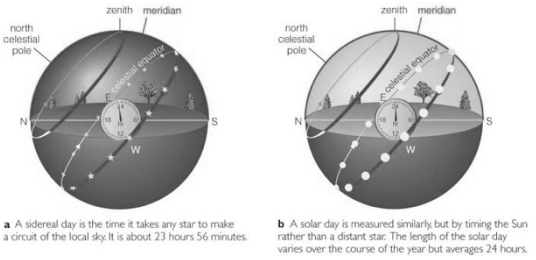
S1. Time and Coordinates

Closer look at time systems
Sky Coordinates
Sky visibility and Motion

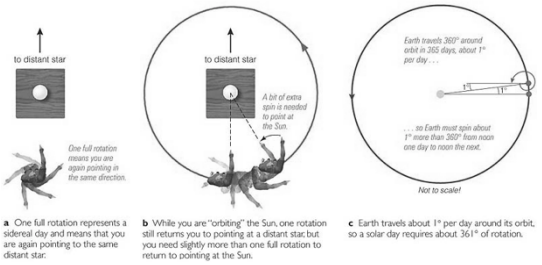
Time by Stars or Sun: Sidereal and Solar Time



a A sidereal day is the time it takes any star to make a circuit of the local sky. It is about 23 hours 56 minutes.

b A solar day is measured similarly, but by timing the Sun rather than a distant star. The length of the solar day varies over the course of the year but averages 24 hours.

Why are they different?

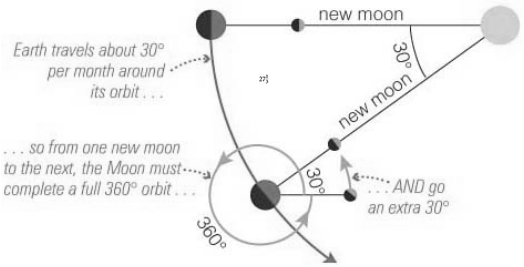


a One full rotation represents a sidereal day and means that you are again pointing to the same distant star.

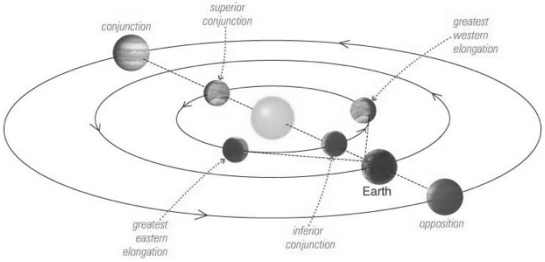
b While you are "orbiting" the Sun, one rotation still returns you to pointing at a distant star, but you need slightly more than one full rotation to return to pointing at the Sun.

c Earth travels about 1° per day around its orbit, so a solar day requires about 361° of rotation.

Moon's Orbit: Sidereal month = 27.3 days Synodic month = 29.5 days

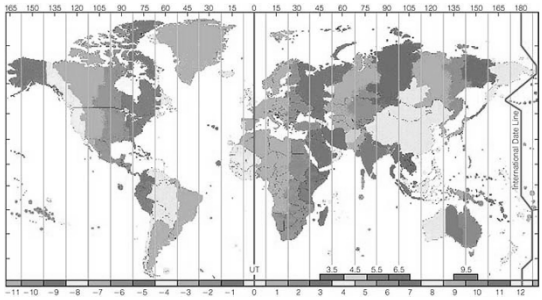


Planetary Synodic Periods: Time Between Crossings of Sun – Earth Line



Clock Time Based Upon Mean Solar Day

- 1 Mean Solar Day
  = 24 hours
  = 24 x 60 minutes
  = 24 x 60 x 60 seconds
- Based on the idea that Sun crosses meridian at noon (depends on longitude)
- Worked out in practice by constructing standard time zones of common time relative to Greenwich Mean Time (GMT) = Universal Time (UT)



- EST = UT – 5 hours Eastern Standard Time
- EDT = UT – 4 hours Eastern Daylight Time
- PST = UT – 8 hours Pacific Standard Time

International Date Line (IDL)

- Marks the boundary between the old and new days
- Crossing IDL going west, add one day
- Crossing IDL going east, subtract one day
- What happens when you fly west, crossing the IDL at midnight?

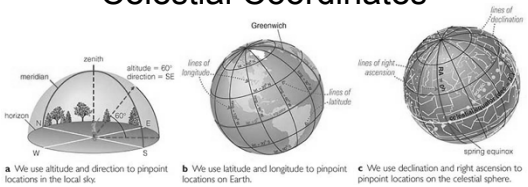
You miss a day!

- Example:
  It is 11:59 pm on September 12.
- At midnight the day increases by one
- Crossing IDL westbound increases the day by one
- Two minutes later it is 12:01 am on September 14.

Leap Years

- Spring equinox to spring equinox takes about 365 ¼ days
- Calendar is 365 days …not quite enough
- Every four years become a leap year where we add another day (Feb. 29) to make up the difference
- For best agreement, Leap Year is skipped when a century changes unless the century year is divisible by 400.

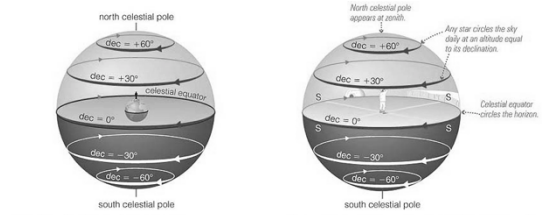
Celestial Coordinates



a We use altitude and direction to pinpoint locations in the local sky. **b** We use latitude and longitude to pinpoint locations on Earth. **c** We use declination and right ascension to pinpoint locations on the celestial sphere.

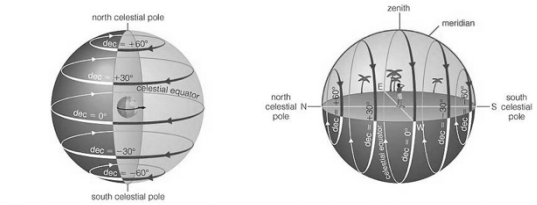
- RA = Right ascension (east-west)
- DEC = Declination (north-south)
- Sidereal time = RA of star crossing meridian at this instant

Daily (Diurnal) Motion: North Pole



a The orientation of the local sky, relative to the celestial sphere, for an observer at the North Pole. **b** Extending the horizon to the celestial sphere makes it easier to visualize the local sky at the North Pole. (Note: To understand the extension, think of Earth in part (a) as being extremely small compared to the celestial sphere.)

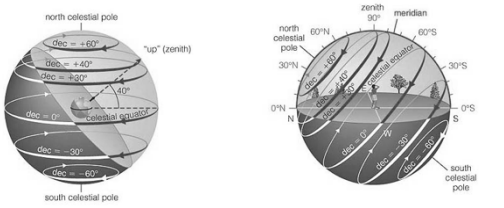
Daily (Diurnal) Motion: Equator



a The orientation of the local sky, relative to the celestial sphere, for an observer at Earth's equator.

b Extending the horizon and rotating the diagram make it easier to visualize the local sky at the equator.

Daily (Diurnal) Motion: 40 degrees north latitude

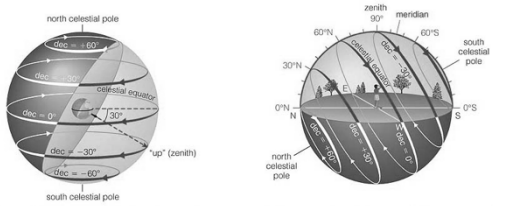


a The orientation of the local sky, relative to the celestial sphere, for an observer at latitude 40°N. Because latitude is the angle to Earth's equator, "up" points to the circle on the celestial sphere with declination +40°.

b Extending the horizon and rotating the diagram so the zenith is up make it easier to visualize the local sky. The blue scale along the meridian shows altitudes and directions in the local sky.

- Altitude of North Celestial pole = latitude
- DEC at zenith = latitude

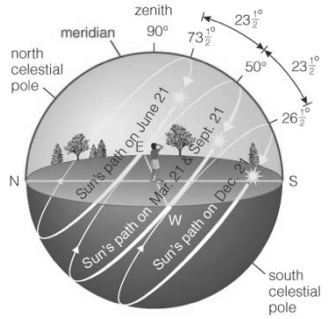
Daily (Diurnal) Motion: 30 degrees south latitude



a The orientation of the local sky for an observer at latitude 30°S, relative to the celestial sphere. "Up" points to the circle on the celestial sphere with declination −30°.

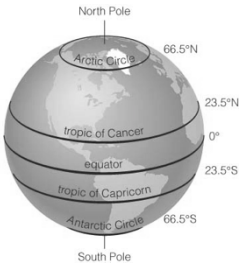
b Extending the horizon and rotating the diagram so the zenith is up make it easier to visualize the local sky. Note that the south celestial pole is visible at altitude 30° in the south, while the celestial equator stretches across the northern half of the sky.

Sun's Path in Sky: 40 degrees north latitude

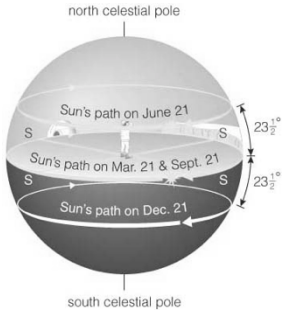


Special Latitudes for Sun Viewing

- Arctic circle = 66 ½ N where Sun never sets on summer solstice
- Tropic of Cancer = 23 ½ N where Sun is overhead at noon on summer solstice

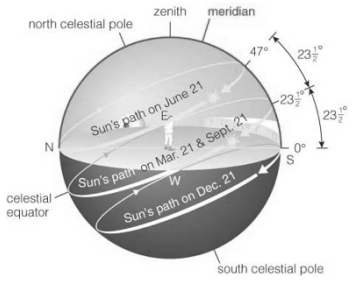


Sun's Path at North Pole



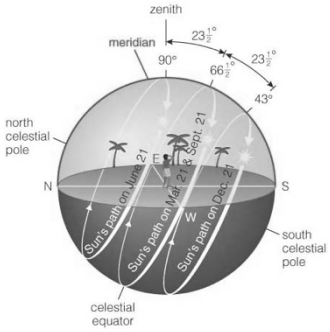
24 hours daylight from Mar. 21 to Sept. 21

Sun's Path at Arctic Circle



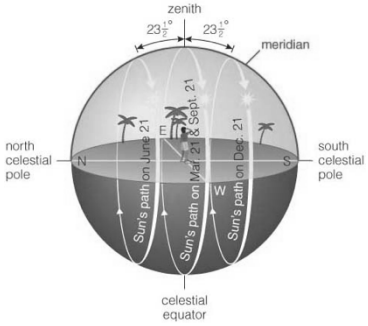
24 hours daylight on June 21

Sun's Path at Tropic of Cancer



Sun overhead at noon on June 21

Sun's Path at Equator



12 hours daylight every day

Celestial Navigation

- North-south positions of stars and Sun directly related to **latitude**
- Local noon depends on **longitude** (need a good clock)
- Done in practice using a sextant for several star/sun sightings
- Modern positions from satellites in the Global Positioning System (GPS)

Lost at Sea

- During an upcoming vacation, you decide to take a solo boat trip. While contemplating the universe, you lose track of your location. Fortunately, you have some astronomical tables and instruments, as well as a UT clock. You thereby put together the following description of your situation:
- It is the spring equinox.
- The Sun is on your meridian at altitude 75° in the south.
- The UT clock reads 22:00.

a. What is your latitude?
b. What is your longitude?

Latitude

- Spring equinox: Sun is at DEC = 0
- Altitude of Sun is 75 degrees above southern horizon
- Zenith is 15 degrees further north (altitude of 90 degrees)
- DEC at zenith = 0 + 15 = 15 degrees N
- Observer's latitude = DEC at zenith = 15 degrees N

Longitude

- When the Sun crosses the meridian the UT clock reads 22:00
- Sun crossed meridian at Greenwich at 12:00 UT
- Earth has rotated 10 hours to cross over observer (who is west of Greenwich)
- Longitude = (10/24) x 360 = 150 deg W
- You are south-east of Hawaii!

Next time:

- Chapter 4:
  Motion, gravity, tides
  please read pages 111 – 131 in text.