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Knowing the Heavens 2

This chapter discusses the nature of constellations and the appearance of the daytime and nighttime skies. The changes in the appearance of the sky that accompany changes in observer location on the Earth, as well as changes that occur with the passage of time, are described. The physical explanations of these changes are provided in the context of the spherical shape of the Earth and its motions in space. The origins of naked-eye astronomy are discussed.

2-1 Naked-eye astronomy had an important place in ancient civilizations
The astronomical knowledge of ancient peoples is the foundation of modern astronomy.

2-2 Eighty-eight constellations cover the entire sky
The constellations provide a convenient framework for stating the position of an object in the heavens.

2-3 The appearance of the sky changes during the course of the night and from one night to the next
By understanding the motions of the Earth through space, we can understand why the Sun and stars appear to move in the sky.

2-4 It is convenient to imagine that the stars are located on a celestial sphere
The concept of the imaginary celestial sphere helps us visualize the motions of stars in the sky.

2-5 The seasons are caused by the tilt of Earth's axis of rotation
The celestial sphere concept helps us visualize how the Sun appears to move relative to the stars.

Box 2-1 Celestial Coordinates
The coordinates of the equatorial coordinate system, right ascension and declination, enable astronomers to denote precise locations on the celestial sphere.

2-6 The Moon helps to cause precession, a slow, conical motion of Earth's axis of rotation
Precession causes the apparent positions of the stars to slowly change over the centuries.

2-7 Positional astronomy plays an important role in keeping track of time
Ancient scholars developed a system of timekeeping based on the Sun.

2-8 Astronomical observations led to the development of the modern calendar
Our calendar is complex because a year does not contain a whole number of days.

Box 2-2 Sidereal time
While sidereal time is extremely useful in astronomy, mean solar time is still the best method of timekeeping for most earthbound purposes.

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Why Astrology is Not Science by James Randi

Many students tend to associate astronomy with astrology and with learning the names of constellations. Few students understand that modern astronomy is a branch of physics. It is relatively easy to involve students in a test of the predicting powers of astrology. This might involve very general horoscopes published in the paper or more detailed predictions generated by computer programs. Such an approach might achieve a more lasting impression than a lecture citing results of specific studies. Ask students to compare their birth "sign" with the constellation in which the Sun is found on their birthday. Astrology does not allow for the very real phenomenon of precession. Students may suggest that the gravitational forces between the planets and you influence your life. To demolish this idea, you could calculate the force of a planet and compare it with the force of the Earth (i.e., the student's weight).

Teaching Hints and Strategies

This chapter covers much of what students associate with astronomy. It provides opportunities for a number of both short and long range observing projects that might be completed on one night or may extend over a few or several weeks or even the entire course. Because many students have very poor spatial reasoning skills, such projects can be very useful and are generally well received by the students.

Students may not have noticed the variation of the sunrise and sunset points (Section 2-1) during the year because the change is slow. An easy way to record the changes is to take photographs of the eastern and western horizons and post enlargements in the classroom. Occasionally have students observe where the Sun (also the Moon, planets, and bright stars) rises and sets and mark these points on the photograph.

Many archaeological sites of interest to archaeoastronomers show alignments with the solstice sunrise or sunset positions or the rising of stars. Students may be unaware of the existence of such sites in the United States. (See the Guest Essay in Chapter 3.) The Chaco Canyon Sun Dagger provides a good example of controversy and differing interpretations of data in science. Students could research the various interpretations of this site.

The nature of constellations is discussed (Section 2-2). Students invariably confuse constellations and star clusters, so stress the differences. Stars in a cluster have common distances, ages, and chemical composition, while stars in a constellation are not necessarily spatially related. An introduction to astronomical nomenclature can transform some of the mystery experienced by students when they read popular astronomy articles into a feeling of familiarity. It is helpful to relate the constellations to geographic regions such as countries and states to develop an appreciation for their value in locating celestial objects: Constellation boundaries are similar to county lines or state boundaries.

Patterns made by bright stars are generally called "asterisms." These patterns can be only a part of a constellation (e.g., the Big Dipper is part of Ursa Major), can be the entire constellation (e.g., the Northern Cross contains all the bright stars of Cygnus), or can involve stars from more than one constellation (e.g., the Summer Triangle).

Rotation, revolution, and precession of the Earth should be defined and attributed to the observations described in these sections. A planetarium presentation can be very helpful here, if one is available. Students should be encouraged to go out at night and observe diurnal motion (Section 2-3). The rotation of the Earth on its axis should be identified as the basis for the geographic coordinate system. A brief discussion of the system provides a natural lead-in to the celestial sphere and celestial coordinates.

Rotation can be defined as motion of a body around an axis passing through the body, while revolution is the motion around an axis or point not passing through the body. It is usually said that the Earth rotates in 24 hours. Be sure that students know that this is relative to the Sun. The actual rotation period of the Earth is a sidereal day, about 23 hours and 56 minutes, which corresponds to a rotation of exactly 360° using the fixed (for all practical purposes) stars as a reference.

Point out that the location of every point on the Earth's surface can be specified by only two numbers—the longitude and latitude. Students are amused by the fact that all directions are due south if one is standing at the North Pole. Ask if anyone has used a Global Positioning System receiver. Consumer GPS units for outdoor recreational use will give the coordinates of a location to within 3 meters. Because the celestial sphere (Section 2-4) is an apparent spherical surface, a similar system can be used in the sky.

The causes of seasons (Section 2-5) are misunderstood by a very large number of students. The effects of the varying altitude of the Sun at noon can be demonstrated by using a flashlight held at different angles to a wall. The variation in the length of day is well-known to everyone. However, many students look at elliptical orbits and conclude that seasons are caused by the varying distance of the Earth from the Sun. Be sure to point out that the Earth is closest to the Sun in January and farthest away in July. Also point out that the northern and southern hemispheres have opposite seasons. Note that the traditional names of the equinoxes and solstices are for *northern* hemisphere observers.

A description of the astronomical origins of tropics and circles can be valuable in the context of causes of seasons. You might also discuss the cultural importance of the date of zenith transit of the Sun for the pre-Columbian civilizations in the western hemisphere at latitudes between the Tropics of Cancer and Capricorn.

The discussion of celestial coordinates (Box 2-1) notes that right ascension is measured in hours. Explain that this convention was established because the Earth is like a giant clock. The diurnal motion of heavenly objects is due to the rotation of the Earth. Just as a watch tells us the position of the Sun in the sky, astronomers think of the celestial sphere as a clock that is keeping sidereal time. Remind students that celestial coordinates are slowly changing due to precession and thus are exactly true for only one instant in time. Provide examples of the epochs indicated on star charts, star catalogs, or *Starry Night* to reinforce this point. (For example, *Starry Night* uses Julian Day 2451545.0000, the year 2000, for comet data.) Archaeoastronomers use precession to date ancient structures and artifacts. The Web site of the Center for Archaeoastronomy at the University of Maryland provides useful information: terpconnect.umd.edu/~tlaloc/archastro/index.html.

Precession (Section 2-6) can be illustrated using a simple toy top in the classroom. When the top is spinning upright, the tendency of the axis to point in a fixed direction can be seen. When the top begins to fall over due to the gravitational force of the Earth exerting a torque on the top, the resulting precession can be attributed to the compromise the top makes between falling over and not falling over. The necessity of rotation for precession is easy to show and the precise nature of the motion is obvious. Point out that the rate of spin is greater than the rate of precession for both the top and the Earth. It is instructive to discuss summer and winter constellations, how they are defined, and how they will appear in 13,000 years. Programs like *Starry Night* make an adjustment for pre-Gregorian calendar dates, giving those dates in the Julian calendar when necessary.

The role of astronomers in the development of our time systems (Section 2-7) and their connection with the Earth's rotation should be noted here as an example of an early application of astronomy. Astronomers can use WWV broadcasts to set clocks to the correct time. Many watches, clocks, and electronic weather stations receive WWVB and automatically set the date and time. Similar information is available from the U.S. Naval Observatory Web site. If you have access to a GPS receiver, take your class outside and show them the time on the receiver—this is the most accurate time available to the ordinary person. Some software products such as Garmin's MapSource can use a GPS clock to reset the clock on a personal computer.

The practical applications of sidereal time (Box 2-2) by astronomers should be stressed. You might discuss the problems that were encountered, for example, by the telescope operators of the International Ultraviolet Explorer who worked shifts determined by sidereal time rather than solar time. If your college has an observatory, it probably has a 24-hour sidereal clock.

Stress that the Gregorian calendar modifications were done in an attempt to preserve the synchronization of the calendar to the seasons (Section 2-8). It is said that when Pope Gregory XIII eliminated 10 days from the calendar, there were riots because the people felt that their lives were being shortened by those 10 days.

Ask students to imagine that they live at the extreme edge of a time zone, such as in the far northwestern corner of North Dakota, an area on Central Time. It is so far west that sunrise and sunset are about 50 minutes later, Central Time, compared to a city in northeastern Minnesota near Lake Superior. If you have students from widely separated areas in the same time zone, ask them to find the sunrise and sunset times for their hometown using the USNO Web site or computer software.
Several apps are available for smart phones that accurately give sunrise and sunset for a given location.

Review Questions

1. These structures, petroglyphs (a carving or etching in stone), and pictographs (a painting or staining on stone) are plentiful in the southwest United States, Mesoamerica, South America, and Egypt. The structures frequently are aligned with points on the celestial sphere or horizon. Petroglyphs and pictographs often depict astronomical events or concepts.

2. Constellations are useful to astronomers because they define small regions of the sky and indicate rough locations. The 88 constellations cover the entire sky, so there is no star that is not part of a constellation.

3. The constellation of Orion contains more stars than those connected by the blue lines shown in Figure 2-2b. The brightest stars connected that way correspond to what the ancients imagined. It would be like connecting cities of more than 100,000 people with lines on a state map and then claiming that those were the only cities in the state.

4. The Earth's rotation on its axis causes the hourly change in the sky. The Earth's revolution about the Sun causes the changes from month to month.

5. The celestial sphere is a large radius, imaginary sphere centered on the Earth. It is a useful concept today because the sky looks as if it were the inside surface of a large hollow sphere.

6. Since the celestial sphere is imaginary, such a traveler would never reach it and certainly could not land on an imaginary surface. It might, however, make for a fascinating science fiction plot.

7. The celestial equator is the great circle on the celestial sphere that is midway between the celestial poles. The plane of the celestial equator is the same as the plane of the Earth's equator. The north and south celestial poles are at the intersection of the celestial sphere with the extension of the Earth's axis of rotation. If you were at the Earth's equator, the celestial equator would pass through your zenith. If you were at one of the poles, the celestial pole would be at your zenith.

8. The zenith is directly overhead. If you were standing at the equator, the celestial equator would pass through your zenith. If you were at the South Pole Station, the south celestial pole would be at your zenith. If you see the north celestial pole at your zenith, watch out for polar bears!

9. The angle between the zenith and the horizon is 90° anywhere.

10. A person in Antarctica cannot use the Big Dipper to locate the north direction because at that location the Big Dipper is always below the horizon.

11. You would see the north celestial pole on the northern horizon from anywhere along the equator. There is no place on Earth where you would see the north celestial pole on the western horizon.

12. At the North Pole, all the stars are circumpolar. Stars on the celestial equator would make a 360º path, following the horizon. From the equator, all the stars rise and set. The 90º difference in latitude is responsible for the difference in appearance.

13. Look at Figure 2-12. The Earth's axis is in a fixed direction in space but not fixed relative to the Sun. Depending on which side of the Sun the Earth is in its orbit, the hemisphere whose pole is tilted toward the Sun is experiencing summer and vice versa.

14. It is warmer in the summer because the Sun's rays strike the ground more perpendicularly and the days are longer.

15. The ecliptic plane is the plane of the Earth's orbit around the sun. The ecliptic is the path of the Sun through the constellations.

16. The ecliptic is the intersection of the plane of the Earth's orbit and the celestial sphere. The ecliptic is tilted relative to the celestial equator because the Earth's equator is tilted relative to the Earth's orbit. Or, conversely, the Earth's rotation axis is tilted relative to the ecliptic. The Sun appears to move along the ecliptic approximately one degree per day.

17. The north celestial pole is seen directly overhead from the Earth's North Pole. From that location the Sun is never more than 23.5° above the horizon. This occurs on about June 21, when the sun makes a complete circle in the sky.

18. The vernal equinox occurs when the Sun appears to cross the celestial equator heading north. The autumnal equinox occurs when the Sun appears to cross the celestial equator heading south. The summer and winter solstices occur when the Sun is 23.5° north and south of the celestial equator, respectively. The equinoxes are the points where the ecliptic intersects the celestial equator and the solstices are 90° from the equinoxes along the ecliptic.

19. The vernal equinox rises at a point due east on the horizon and sets at a point due west. This means the Sun rises due east and sets due west at the equinoxes.

20. The daily path of the Sun moves north and south with the seasons because the celestial equator is tilted relative to the ecliptic.

21. To see the Sun at the zenith, your latitude must be within 23.5° of the Earth's equator. It will appear at the zenith twice per year except at the Tropic of Cancer and Tropic of Capricorn, where the Sun will appear at the zenith only once per year.

22. The gravitational pull of the Moon and the Sun on the Earth's equatorial bulge causes the precession of the equinoxes. It takes about 72 (26,000/360) years for the vernal equinox to move 1° along the ecliptic. Likewise, the vernal equinox moves from one constellation to the next about every 2000 years. (There actually are 13 constellations on the ecliptic. Ophiuchus is omitted by astrology.)

23. The "mean Sun" is a point that moves along the celestial equator at a uniform rate. It is a better timekeeper than the actual Sun because the motion of the actual Sun varies from day to day.

24. It is convenient to divide the Earth into time zones so that noon according to the clock is close to the upper meridian crossing by the Sun.

25. The time given by a sundial is the apparent solar time, while the time given by a wristwatch is the mean solar time. These are not the same because the apparent motion of the Sun is not constant while the motion of the mean Sun is constant.

26. The sidereal year is the time for the Sun to appear to move exactly 360° around the ecliptic relative to the stars, while the tropical year is the time for the Sun to appear to move exactly 360° around the ecliptic relative to the vernal equinox. These two years are slightly different because precession causes the vernal equinox to move relative to the stars. The calendar is based on the tropical year so that the first day of spring occurs approximately on the same date each year.

27. The next leap year after the publication of the 10th edition of *Universe* will be 2016. The year 2000 was a leap year but 2100 will not be a leap year.

Advanced Questions

28. A star rises 4 minutes earlier each evening, so in one week Bellatrix rises $7 \times 4 = 28$ minutes earlier, at 8:02 P.M.

29. Andromeda arrives at a position in the sky 4 hours later than Cygnus. Therefore on July 21, Andromeda will be highest in the sky at 4 A.M.

30. You would not be able to see Perseus at midnight on May 15 because the Sun would appear in the direction of that constellation, as can be inferred from Figure 2-5.

31. (a) At 8 P.M. the diagram would look the same as in Figure 2-6 except rotated 45° (i.e., $3 \times 15°$) clockwise. At 2 A.M. the diagram would look the same as in Figure 2-6 except rotated 45° counterclockwise.

32. A star rises 4 minutes earlier each evening, or about an hour every two weeks. So one month earlier on July 1, the sky will have this appearance two hours later at 1 A.M., or two hours earlier at 9 A.M. on September 1.

33. (a) The arcs made by the stars cover about 1/3 of a circle, or about 120°, so the exposure took about (24 h)/3 = 8 hours. (b) North celestial pole, counterclockwise. (c) South celestial pole, clockwise.

34. (a) For an observer at the north pole, Figure 2-10 would have the Earth's North Pole and the north celestial pole at the top of the diagram. (b) For an observer at the equator, Figure 2-10 would have the Earth's poles and the celestial poles at the sides of the diagram 90° away from the top. (c) Since the North Pole is at 90° N latitude and the north celestial pole is 90° above the horizon there (part a), and since the equator is at 0° latitude and the north celestial pole is 0° above the horizon, the rule is justified. (d) In the southern hemisphere, one's latitude is equal to the angle between the south celestial pole and the horizon.

35. (a) The angular distance between the horizon and the north celestial pole is the same as the latitude, that is, about 20°. On the photograph, this is measured to be 7.45 cm. Thus, 20°/7.45 cm = 2.69 degrees per cm. The width of the picture is 11.45 cm so the angular width is 2.69°/cm × 11.45 cm = 30.8°. The height of the picture is 13.35 cm so the angular height is 2.69°/cm × 13.35 cm = 35.9°. (b) No stars in the southern sky will be circumpolar for Mauna Kea because the south celestial pole is below the horizon. However, because the south celestial pole will be 20° below the southern horizon, any star within 20° of the south celestial pole will rise and set. That is, the star must have a declination less than –70°. Stars with declination greater than +70° will be north circumpolar.

36. The telescope at latitude 20° N can only see to declination –70°. Because viewing near the horizon is always less than optimal, the actual southern limit would be less. So, in order to see the southern skies, it is helpful to have a telescope south of the equator.

37. If you were standing at either pole, the visible stars would all be circumpolar. At the equator none of the visible stars would be circumpolar. Circumpolar stars never rise or set. At the poles the diurnal circles of stars would be horizontal circles around the north celestial pole, and at the equator the celestial poles are on the horizon so that the diurnal circles must cross the horizon.

38. (a) Because Antarctica is fully illuminated, the most probable month of the picture is December. (b) The Earth is at perihelion in early January, so the picture shows the Earth near perihelion.

39. (a) For an observer at 35° south latitude, just rotate the horizon circle in Figure 2-15 by 180° so that south and north are reversed. (b) For an observer at the equator, just rotate the celestial sphere in Figure 2-15 35° clockwise so that the north celestial pole is on the horizon. (c) For an observer at the north pole, rotate the celestial sphere in Figure 2-15 55° counterclockwise so that the north celestial pole is at the top of the diagram.

40. Your latitude (40°) is the angular elevation of the north celestial pole above the northern horizon. Your latitude is also the angular distance, along the meridian, from the zenith to the celestial equator. (a) At noon on the day of the vernal equinox, the sun is at 0° declination. So the equinox is 90° – 40° = 50° above the southern horizon. (b) At noon on the date of the winter solstice, the Sun is 23.5°

south of the celestial equator. So the Sun is 40° + 23.5° = 63.5° from the zenith, which is 90° – 63.5° = 26.5° above the southern horizon.

41. In the northern hemisphere the Sun appears toward the south, and in the southern hemisphere the Sun appears toward the north. The houses are designed the way they are to admit as much sunlight as possible.

42. At Mumbai at 19° north latitude the Sun is at the zenith at midday twice during the year, once just before June 21, as the Sun moves northward, and once just after June 21, as the Sun moves southward. On June 21, the Sun is at the zenith at 23.5° north latitude.

43. Precession has caused the celestial sphere to appear to have moved by several degrees, causing the stars of the Southern Cross to no longer rise above the horizon as seen from Greece.

44. In 2600 B.C. the tunnel pointed toward the star Thuban. Now it points towards Polaris.

45. Archaeological artifacts and structures can be dated by applying the principle of precession of the equinox. If you go back in time to 129 B.C. with *Starry Night,* you can see what the sky looked like at that time.

46. By not dropping the 10 days, the date in Russia was earlier than the date in western Europe. However, an additional three days, for a total of 13, was dropped due to the accumulated effect of more than 300 more years of precession. Therefore the date of November 7, 1917, in Russia was October 25, 1917.

47. Midnight corresponds to 0:00 solar time. On the date of the autumnal equinox, sidereal time is nearly equal to solar time. The right ascension of a star on the meridian, which equals the sidereal time, is almost exactly $0^h\ 00^m\ 00^s$.

48. The winter solstice is located 180° away from the summer solstice along the ecliptic, so it is at R.A. 18^h and Decl. –23.5°.

49. The difference in R.A. is $11^h\ 20^m\ 00^s - 8^h\ 00^m\ 00^s = 3.33^h$. Each hour represents 15°, so
15 deg/hr × 3.33 hr = 50°.

50. The second star is $3^h\ 20^m$ to the east of the first star. Therefore if the first star passes through the zenith at 12:30 A.M. then the second star will pass through the zenith at 3:50 A.M.

51. Midnight sidereal time is defined to be when the vernal equinox crosses the upper meridian. If it is noon when the Sun is at the vernal equinox, that means the Sun and the vernal equinox are crossing the upper meridian, so it is sidereal midnight by definition.

52. (a) Sidereal time is the right ascension of any object on the meridian. The vernal equinox has a right ascension of 0^h, because it is the starting place from which right ascension is measured. The meridian is 90° (= 6 hours of time) from the east point, where the vernal equinox is located. Remembering the direction in which right ascension is measured, we see that the sidereal time is 18:00. (b) Sidereal time is the right ascension of any object on the meridian. The Sun is on the meridian at noon, which is 12:00 solar time. The autumnal equinox has a right ascension of 12^h because it is directly opposite the vernal equinox. Therefore, sidereal time is nearly equal to solar

time on the date of the autumnal equinox. They are exactly equal at high noon on that date (September 22).

53. (a) They would become shorter and the solar day would become more nearly equal to the sidereal day in length. (b) They would both become longer and they would become less similar in length. (c) If the Earth's rotation were retrograde, the synodic day would be shorter than the sidereal day.

Discussion Questions

54. It is doubtful the ancients knew of telescopes (*Telescopium*) and microscopes (*Microscopium*), to name two. These constellations are generally located too far south to be seen from the Mediterranean area. Native American cultures had their own unique names for the constellations, as did Chinese astronomers.

55. If the tilt was 0° there would be no seasons and Earth would essentially have the climate we have at the time of the equinox. If the tilt was 90° each hemisphere would move in and out of total darkness. (Use a globe to visualize this.)

56. We assume that the bard was referring to Polaris. Polaris, the North Star, moves in a small circle around the north celestial pole. Polaris will not always be the North Star due to precession of the equinox. Although it makes for nice poetry, it's not good astronomy. Christopher Plummer's character, General Chang, utters the phrase "But I am constant as the northern star" in *Star Trek VI: The Undiscovered Country*. The film's subtitle, "The Undiscovered Country," comes from Hamlet's famous "To be or not to be" soliloquy, as do many of Chang's other quotes.

Web/eBook Questions

The USNO Web site has very useful information on time, calendars, seasons, and phases of the moon. One could have an entire assignment or lab activity devoted to exploring this site. If your course has a Web page or online learning platform, you might want to include a link to the USNO Web site: aa.usno.navy.mil.

In addition to using *Starry Night* to produce star charts customizable to any date, time, and location, the *Sky & Telescope* Web site has an interactive star chart: skychart.skyandtelescope.com/. Some weather sites such as www.wunderground.com/ also provide star charts.

Observing Projects

If you teach astronomy during a spring term, students may head south for spring break. Presumably they will be out late at night. Ask them to note the position of the North Star above the northern horizon. They may travel far enough south to see Canopus (Dec. –53°, probably visible south of about latitude 30° N). Travelers who are south of the equator will not be able to see Polaris.

63. a) Stars move counterclockwise.
    b) Answer is location-dependent. Observers at locations at mid-latitudes will see some circumpolar stars. Observers close to the equator will see very few if any circumpolar stars.
    c) Answer (ii). The limiting declination is equal to (90° – latitude).
    d) No circumpolar stars are seen in a direction opposite to the celestial pole in either.

64. a) The Sun appears to move eastward relative to the stars in the background.
    b) The Sun moves along the circular path called the ecliptic without changing the direction of its apparent motion.
    c) The Sun passes through the constellations Sagittarius, Capricornus, Aquarius, Pisces, Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpius, Ophiuchus. The first 12 of these are the signs of the Zodiac that are used in astrology.
    d) Time-dependent answer.
    e) Approximately six months.

65. a) On June 21st, the Sun is at its highest in the year, at 62° 26'.
    b) On December 21st, the Sun is at an angle above the S horizon of 15° 36'.
    c) The correct answer is (ii), Sun's elevation angle = (90° – Latitude)
    d) Of the selected dates, the Earth is closest to the Sun on December 21.
    e) Of the selected dates, the Earth is farthest from the Sun on June 21.

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Chapter 2: Stars and Constellations.

1. Crux, Sagitta, Circinus, (Equuleus)
2. Hydra, Ursa Major, Hercules, (Centaurus)
3. Hydra stretches almost 100° across the sky.
4. Bootes, Virgo, Leo and Canes Venatici.
5. Coma Berenices.
6. Spica, Arcturus, Cor Caroli, Denebola.
7. The Little Dipper, The W, Kids.
8. Big Dipper Stars: Alkaid, Mizar, Alioth, Megrez, Phecda, Merak, Dubhe.
9. Alkaid = HIP 67301 = Zeta Ursa Majoris = 85 Ursa Majoris.
10. (a) Upper-left corner, (b) Lower-right corner.
11. Merak and Dubhe.
12. 34º 04'.
13. Kochab, Pherkad
14. Caph, Schedar, Gamma Cassiopeiae, Ruchbah, Segin.
15. (a) Elnath (b) Taurus.
16. Delta Bootes, Nekkar, Seginus, Rho Bootes, Izar
17. Cor Caroli, Chara.
18. Coma Berenices and Canes Venatici
19. Leo Minor.

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