CHAPTER 2: Patterns in the Sky—Motions of Earth

TRUE/FALSE

1. Constellations are arbitrary groupings of stars in the sky.

   ANS: T DIF: Easy REF: Excursion 2.1
   OBJ: Factual TOP: 1Ii

2. If a star rises on the eastern horizon, it will set on the Western horizon 6 hours later.

   ANS: F DIF: Medium REF: Section 2.2 OBJ: Applied
   TOP: 2IIIi

3. The meridian is half of a great circle in the sky that passes through an observer's zenith and the Earth's poles.

   ANS: T DIF: Medium REF: Section 2.2 OBJ: Factual
   TOP: 2Iiii

4. The equator is the only place on Earth where you can see the entire celestial sphere (day or night) over the course of 24 hours.

   ANS: T DIF: Easy REF: Section 2.2 OBJ: Factual
   TOP: 2IIi | 2IIIiii

5. The altitude of the Sun as it crosses the meridian changes during the year.

   ANS: T DIF: Medium REF: Section 2.3 OBJ: Factual
   TOP: 3IIIiv

6. Earth revolves around the Sun in the same direction Earth spins about its axis.

   ANS: T DIF: Easy REF: Section 2.3 OBJ: Factual
   TOP: 3Iii

7. Early astronomers were able to detect shifts in the apparent positions of stars even before the invention of the telescope, leading them to conclude that Earth revolves around the Sun.

   ANS: F DIF: Medium REF: Section 2.3 OBJ: Factual
   TOP: 3Iiii

8. The longest day of the year in the Northern Hemisphere occurs on the summer solstice.

   ANS: T DIF: Easy REF: Section 2.3 OBJ: Factual
   TOP: 3IIv

9. On the autumnal equinox, the lengths of both day and night are 12 hours.

   ANS: T DIF: Easy REF: Section 2.3 OBJ: Factual
   TOP: 3IIiv

10. A person who lives at the equator will see the Sun directly overhead at noon every day of the year.

    ANS: F DIF: Medium REF: Section 2.3 OBJ: Applied
    TOP: 3IIIiv

11. The seasons on Earth are caused by the change in distance between the Sun and Earth.

    ANS: F DIF: Medium REF: Section 2.3 OBJ: Factual
    TOP: 3IIIii | 3IIIiii

12. The fact that we always see the same side of the Moon indicates that the Moon does not rotate about an axis.

    ANS: F DIF: Medium REF: Section 2.4 OBJ: Conceptual
    TOP: 4IIIii

13. A new Moon will always be in the eastern sky at sunrise.

    ANS: T DIF: Medium REF: Section 2.4 OBJ: Applied
    TOP: 4Ii | 4IIiv

14. When a solar eclipse occurs, the Sun lies between the Earth and Moon.

    ANS: F DIF: Easy REF: Section 2.5 OBJ: Conceptual
    TOP: 5Iii

15. When a lunar eclipse occurs, on average more people will witness it as a partial eclipse than as a total eclipse.

    ANS: T DIF: Medium REF: Section 2.5 OBJ: Factual
    TOP: 5Ii | 5IIIiv

MULTIPLE CHOICE

1. The apparent path of the Sun across the celestial sphere during a year is called the
   a. prime meridian.
   b. ecliptic plane.
   c. circumpolar plane.
   d. celestial equator.

   ANS: B DIF: Easy REF: Section 2.2 OBJ: Factual
   TOP: 1Iii

2. What defines the position of the equator on Earth?
   a. The axis around which Earth rotates
   b. Where the ground is the warmest
   c. The tilt of Earth's equator relative to its orbit around the Sun
   d. All of the above

   ANS: A DIF: Easy REF: Section 2.2 OBJ: Factual
   TOP: 2Ii

3. If the star Polaris has an altitude of 35° then we know that
   a. our longitude is +55°.
   b. our latitude is +55°.
   c. our longitude is +35°.
   d. our latitude is +35°.

ANS: D DIF: Medium REF: Section 2.2 OBJ: Applied
TOP: 2Ii | 2Ivi

4. The meridian is defined as a great circle on the sky on which lie the
   a. celestial equator and vernal equinox.
   b. north and south celestial poles.
   c. zenith and the north and south celestial poles.
   d. zenith and east and west directions.

   ANS: C DIF: Medium REF: Section 2.2 OBJ: Factual
   TOP: 2Iiii | 2Iiv | 2Iv

5. The direction directly overhead of an observer defines his/her
   a. meridian.
   b. celestial pole.
   c. circumpolar plane.
   d. zenith.

   ANS: D DIF: Easy REF: Section 2.2 OBJ: Factual
   TOP: 2Iiv

6. No matter where you are on Earth, stars appear to rotate about a point called the
   a. zenith.
   b. celestial pole.
   c. meridian.
   d. equinox.

   ANS: B DIF: Easy REF: Section 2.2 OBJ: Factual
   TOP: 2Iv

7. At a latitude of +50°, how far above the horizon is the north celestial pole?
   a. 0°
   b. 40°
   c. 50°
   d. 90°

   ANS: C DIF: Medium REF: Section 2.2 OBJ: Applied
   TOP: 2Ii | 2Iii | 2Iv

8. At what latitude is the north celestial pole located at your zenith?
   a. 0°
   b. +30°
   c. +60°
   d. +90°
   e. This occurs at every latitude.

   ANS: D DIF: Medium REF: Section 2.2 OBJ: Applied
   TOP: 2Ii | 2Iiv | 2Iv

9. At what latitude is the north celestial pole at your horizon?
   a. 0°
   b. +30°
   c. +60°
   d. +90°
   e. This can never happen.

   ANS: A DIF: Medium REF: Section 2.2 OBJ: Applied
   TOP: 2Ii | 2Iii | 2Iv

10. The ecliptic plane is defined by the motion of _____ in the sky.
    a. the Moon
    b. the Sun
    c. Polaris
    d. the stars

    ANS: B DIF: Easy REF: Section 2.3 OBJ: Factual
    TOP: 3IIiii

11. How far away on average is the Earth from the Sun?
    a. 8.3 million kilometers
    b. 45 million kilometers
    c. 93 million kilometers
    d. 150 million kilometers

    ANS: D DIF: Easy REF: Section 2.3 OBJ: Factual
    TOP: 3Ii

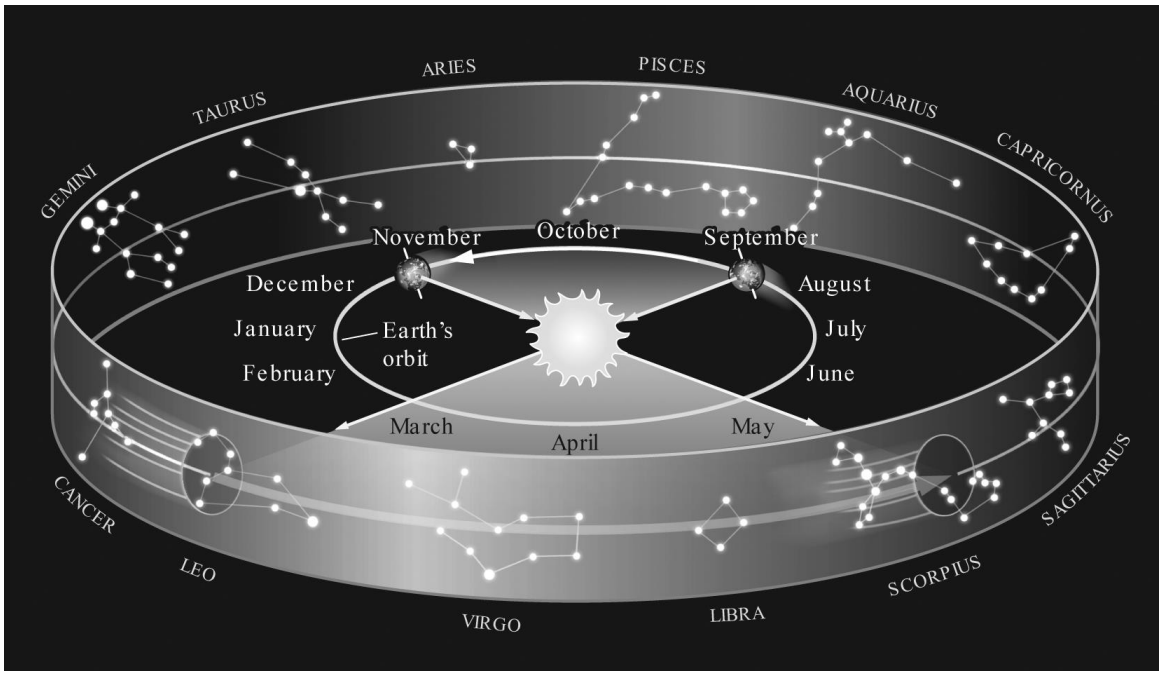
12. If you went out tonight and looked at the sky at midnight, at what time would you have to observe 6 months from now in order to find the stars in exactly the same position in the sky? Assume that you could see the stars at any time, day or night.
    a. 6 A.M.
    b. Noon
    c. 6 P.M.
    d. Midnight

    ANS: B DIF: Difficult REF: Section 2.3 OBJ: Applied
    TOP: 3IIi | 3IIii

13. If you go out at exactly 9 P.M. each evening over the course of one month, the position of a given star will move westward by tens of degrees. What causes this motion?
    a. The Earth's rotation on its axis
    b. The revolution of the Earth around the Sun
    c. The revolution of the Moon around the Earth
    d. The revolution of the Sun around the Earth

    ANS: B DIF: Easy REF: Section 2.3 OBJ: Applied
    TOP: 3IIi | 3IIii

14. Assume you are observing the night sky from a typical city in the United States at a latitude of +40°. Use the figure below to determine which constellation of the zodiac would be nearest the meridian at 6 P.M. in September.

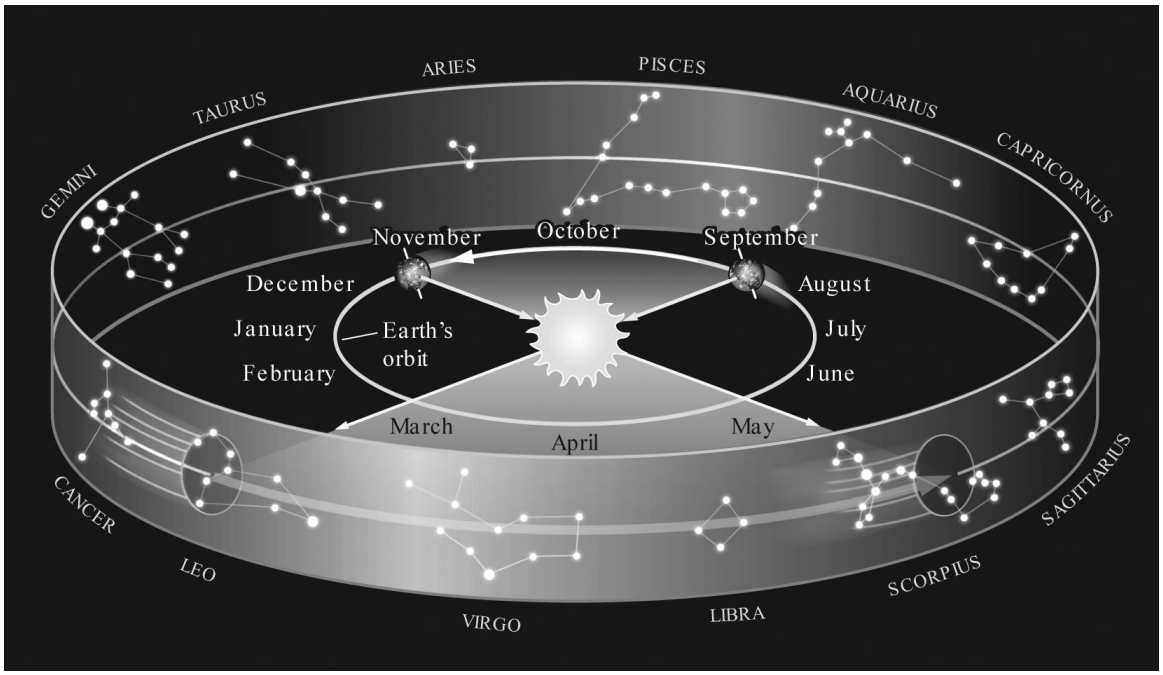


    a. Scorpius
    b. Gemini
    c. Aquarius
    d. Leo

    ANS: A DIF: Medium REF: Section 2.3 OBJ: Applied

TOP: 2Iiii | 2IIi | 2IIIi | 3Iii | 3IIiii

15. Assume you are observing the night sky from a typical city in the United States at a latitude of +40°. Use the figure below to determine which constellation of the zodiac would be rising at 10 P.M. in May.



a. Pisces
b. Virgo
c. Gemini
d. Sagittarius

ANS: D DIF: Difficult REF: Section 2.3 OBJ: Applied
TOP: 2Iiii | 2IIi | 2IIIi | 3Iii | 3IIiii

16. The shortest day of the year for a person living in the *Northern* Hemisphere is the
a. summer solstice.
b. vernal equinox.
c. winter solstice.
d. autumnal equinox.

ANS: C DIF: Easy REF: Section 2.3 OBJ: Applied
TOP: 3IIv

17. The shortest day of the year for a person living in the Southern Hemisphere is the
a. summer solstice (June 1).
b. vernal equinox (March 21).
c. winter solstice (Dec. 22).
d. autumnal equinox (Sept. 23).

ANS: A DIF: Difficult REF: Section 2.3 OBJ: Applied
TOP: 3IIv

18. On which day of the year does the Sun reach its northernmost point in the sky?
a. Vernal equinox
b. Summer solstice
c. Autumnal equinox
d. Winter solstice

ANS: B DIF: Easy REF: Section 2.3 OBJ: Factual
TOP: 3IIv

19. For a person who lives at a latitude of +40°, when is the Sun directly overhead at noon?
a. Only on the summer solstice

b. Only on the vernal and autumnal equinoxes
c. Never
d. Always

ANS: C DIF: Difficult REF: Section 2.3 OBJ: Applied
TOP: 2Ii | 3IIIi

20. For a person living in Vancouver, Canada, at latitude of +49°, the Sun will reach a maximum height above the Southern horizon on winter solstice of
a. 41.0°.
b. 17.5°.
c. 37.0°.
d. 64.5°.

ANS: B DIF: Difficult REF: Section 2.3 OBJ: Applied
TOP: 2Ii | 3IIv | 3IIIi

21. When the Northern Hemisphere experiences summer, the Southern Hemisphere experiences
a. spring.
b. summer.
c. fall.
d. winter.

ANS: D DIF: Easy REF: Section 2.3 OBJ: Factual
TOP: 3IIIi

22. We experience seasons because
a. the Earth's equator is tilted relative to the plane of the solar system.
b. the Earth is closer to the Sun in summer and farther from the Sun in the winter.
c. the length of the day is longer in the summer and shorter in the winter.
d. the Earth moves with a slower speed in its orbit during summer and faster during winter.

ANS: A DIF: Medium REF: Section 2.3 OBJ: Applied
TOP: 3IIIii

23. Earth is closest to the Sun when the Northern Hemisphere experiences
a. spring.
b. summer.
c. fall.
d. winter.

ANS: D DIF: Difficult REF: Section 2.3 OBJ: Factual
TOP: 3IIIii

24. If the Earth's axis were tilted by 5° relative to the direction perpendicular to its orbital plane around the Sun, which would be *true*?
a. The seasons would remain the same.
b. Summers would be warmer.
c. Winters would last longer.
d. Winters would be warmer.

ANS: D DIF: Medium REF: Section 2.3 OBJ: Factual
TOP: 3IIIi | 3IIIii

25. The Earth's rotational axis precesses in space and completes one revolution every
a. 200 years.
b. 1,800 years.
c. 26,000 years.
d. 51,000 years.

ANS: C DIF: Easy REF: Section 2.3 OBJ: Factual
TOP: 3IVi

26. Leap years occur because
a. the Earth's orbital period around the Sun is decreasing.
b. the Earth's orbital period is 365.24 days.

c. the Gregorian calendar contains only 11 months.
d. the Earth speeds up in its orbit when it comes closest to the Sun.

ANS: B DIF: Easy REF: Section 2.3 OBJ: Conceptual
TOP: 3Vi

27. The Moon's sidereal period is 2.2 days shorter than the period during which the Moon's phases change because
a. the Moon always keeps the same side turned toward the Earth.
b. the Earth must rotate so an observer can see the Moon.
c. the Moon's orbit is tilted with respect to the Earth's rotational axis.
d. the Earth moves significantly in its orbit around the Sun during that time.

ANS: D DIF: Medium REF: Section 2.4 OBJ: Conceptual
TOP: 4IIiii

28. The Moon undergoes synchronous rotation, and as a consequence the
a. rotational period of the Moon equals the orbital period of the Moon around the Earth.
b. rotational period of the Moon equals the rotational period of the Earth.
c. rotational period of the Moon equals the orbital period of the Earth around the Sun.
d. Moon does not rotate as it orbits the Earth.

ANS: A DIF: Easy REF: Section 2.4 OBJ: Conceptual
TOP: 4IIIii

29. In regard to the phase of the Moon, the term *waxing* means
a. less than half-illuminated.
b. more than half–illuminated.
c. becoming smaller.
d. increasing in brightness.

ANS: D DIF: Easy REF: Section 2.4 OBJ: Factual
TOP: 4Ii

30. If tonight the Moon is in the waxing gibbous phase, in three days the Moon will most likely be in the
a. new phase.
b. full phase.
c. third quarter phase.
d. first quarter phase.

ANS: B DIF: Easy REF: Section 2.4 OBJ: Applied
TOP: 4Ii | 4Iii | 4IIii

31. If there is a full moon out tonight, approximately how long from now will it be in the third quarter phase?
a. Three to four days
b. One week
c. Two weeks
d. One month

ANS: B DIF: Easy REF: Section 2.4 OBJ: Applied
TOP: 4Ii | 4Iii | 4IIii

32. Which of the following is *false*?
a. Everyone on Earth observes the same phase of the Moon on a given night.
b. The phases of the Moon cycle with a period that is longer than its sidereal period.
c. In some phases, the Moon can be observed during the day.
d. The observed phase of the Moon changes over the course of one night.

ANS: D DIF: Easy REF: Section 2.4 OBJ: Applied
TOP: 4Iii | 4IIi | 4IIii | 4IIiii

33. At what time does a third quarter moon rise? (Hint: A third quarter moon occurs approximately 3 weeks after a new moon.)
    a. 12 midnight
    b. 12 noon
    c. 6 A.M.
    d. 6 P.M.

    ANS: A DIF: Medium REF: Section 2.4 OBJ: Applied
    TOP: 2IIi | 2IIIi | 4Ii | 4Iii | 4IIii | 4IIiv

34. What time does a third quarter moon rise?
    a. 12 midnight
    b. 12 noon
    c. 6 A.M.
    d. 6 P.M.

    ANS: A DIF: Difficult REF: Section 2.4 OBJ: Applied
    TOP: 2IIi | 2IIIi | 4Ii | 4Iii | 4IIii | 4IIiv

35. At what time does the waxing gibbous phase rise?
    a. 3 P.M.
    b. 9 A.M.
    c. 3 A.M.
    d. 9 P.M.

    ANS: A DIF: Difficult REF: Section 2.4 OBJ: Applied
    TOP: 2IIi | 2IIIi | 4Ii | 4Iii | 4IIii | 4IIiv

36. If a person on Earth currently views the Moon in a waxing crescent phase, in what phase would the Earth appear to a person on the Moon?
    a. Waxing crescent
    b. Waxing gibbous
    c. Waning gibbous
    d. Waning crescent

    ANS: C DIF: Difficult REF: Section 2.4 OBJ: Applied
    TOP: 4Ii | 4Iii

37. A partial lunar eclipse occurs when
    a. the Sun appears to go behind the Moon.
    b. the Moon passes through part of the Earth's shadow.
    c. the Moon shadows part of the Sun.
    d. the Earth passes through part of the Moon's shadow.

    ANS: B DIF: Easy REF: Section 2.5 OBJ: Conceptual
    TOP: 5Ii | 5IIi

38. During which lunar phase do solar eclipses occur?
    a. New
    b. First quarter
    c. Full
    d. Third quarter

    ANS: A DIF: Easy REF: Section 2.5 OBJ: Conceptual
    TOP: 4Iii | 5Iii

39. Solar and lunar eclipses are rare because
    a. the Moon's orbital plane is tipped by 5.2° relative to the plane defined by the Earth's equator.
    b. the Moon's orbital plane is tipped by 5.2° relative to the Earth's orbital plane.
    c. the Moon's orbital plane is tipped by 23.5° relative to the plane defined by the Earth's equator.
    d. the Moon's orbital plane is tipped by 23.5° relative to the Earth's orbital plane.

    ANS: B DIF: Medium REF: Section 2.5 OBJ: Concept
    TOP: 5IIIi | 5IIIiii

40. Approximately how often do lunar eclipses occur?
    a. Twice every year
    b. Once per month
    c. Twice every 11 months
    d. Once every 11 years

    ANS: C DIF: Difficult REF: Section 2.5 OBJ: Factual
    TOP: 5IIIiii

SHORT ANSWER

1. On what place(s) on Earth can you stand and have the great circle of the celestial equator be at the same height relative to your horizon for all 360° of its circumference?

   ANS:
   You can stand at either the North Pole or the South Pole.

   DIF: Medium REF: Section 2.2 OBJ: Applied TOP: 1Iiii | 2Iii | 2Iv

2. How is the observed height of Polaris above the horizon related to an observer's latitude? (Hint: Consider three cases of observers located at the equator, the North Pole, and $\text{latitude} = +45°$.)

   ANS:
   The observed height of Polaris above the horizon is equal to an observer's latitude. For an observer at the equator $(\text{latitude} = 0°)$, Polaris is on the horizon. For an observer at the North Pole $(\text{latitude} = +90°)$, Polaris is at the zenith or 90° above the horizon. For an observer at $\text{latitude} = +45°$, Polaris is 45° above the horizon.

   DIF: Medium REF: Section 2.2 OBJ: Applied TOP: 2Ii | 2Iii | 2Ivi

3. Earth has an average radius of approximately 6.4×10^3 km. What is the average speed of the ground due to the rotation of Earth at its equator in km/s if there are 8.64×10^4 seconds per day?

   ANS:
   Here the students need to convert the radius of Earth to its circumference:
   $C = 2\pi r = 2 \times 3.14159 \times 6.4 \times 10^3 = 4.02 \times 10^4$ km. Divide this distance by 8.64×10^4, and we get a speed of $0.465 \text{ km/s} = 1{,}676 \text{ km/hr}$.

   DIF: Difficult REF: Section 2.2 OBJ: Applied TOP: 3Ii

4. Consider an observer located on the equator. If the observer sees a star directly overhead at 8 P.M., where will that star be located in the night sky at midnight? How far above the horizon will it be or will it have set?

   ANS:
   The star will move westward by an amount that is equal to $(12 \text{ hr} - 8 \text{ hr}) \times 360°/24 \text{ hr} = 60°$, and the star will be $90° - 60° = 30°$ above the western horizon.

   DIF: Easy REF: Section 2.2 OBJ: Conceptual TOP: 2IIIi | 2IIIiii

5. The center of the Milky Way lies approximately 30° south of the celestial equator. From what latitudes on the Earth is it impossible to view the center of our galaxy?

ANS:
At $\text{latitudes} > 90° - 30° = 60°$, it would be impossible to see the center of our galaxy because it would lie below the horizon.

DIF: Easy REF: Section 2.3 OBJ: Applied TOP: 1Iiii | 2Ii

6. Explain how the aberration of starlight provides a compelling demonstration that Earth revolves around the Sun.

ANS:
As Earth revolves around the Sun, light from stars appears to hit Earth from slightly different directions over the course of one full orbit. Measurements in the deviations of the path of light over time can give us the speed of Earth's motion as it orbits the Sun.

DIF: Medium REF: Section 2.3 OBJ: Conceptual TOP: 3Iiii

7. Earth experiences seasons due to the tilt of its axis. What are the two consequences of this tilt that contribute to the seasons?

ANS:
(1) Variation in the length of day
(2) Variation in the directness of the Sun's rays

DIF: Medium REF: Section 2.3 OBJ: Applied TOP: 3IIIii

8. What would be the effect on the seasons if the tilt of the Earth's axis were 10° rather than 23.5°?

ANS:
If the tilt of the Earth's axis were smaller, there would be a less dramatic temperature shift between the seasons because the angle of the Sun's rays would vary less and the length of day/night would be more equal throughout the year.

DIF: Easy REF: Section 2.3 OBJ: Applied TOP: 3IIIii

9. For an observer in Seattle, Washington, which is located at $\text{latitude} = +47°$, what is the minimum height above the southern horizon that the Sun will have throughout the year and approximately when will this occur?

ANS:
The Sun will be at its minimum height above the southern horizon at noon on the winter solstice (Dec. 22). In Seattle at a latitude of +47°, the celestial equator will have a height of $90° - 47° = 43°$ above the southern horizon. Because the Earth's axis is tilted by 23.5° relative to the direction perpendicular to its orbital plane around the Sun, the Sun will reach a height of $43° - 23.5° = 19.5°$ above the Southern horizon at noon on the winter solstice.

DIF: Difficult REF: Section 2.3 OBJ: Applied TOP: 2Ii | 2Iii | 3IIv

10. On which great celestial circle(s) on the celestial sphere would you find the position of the autumnal equinox?

ANS:
On both the celestial equator and the ecliptic planes.

DIF: Difficult REF: Section 2.3 OBJ: Factual TOP: 1Iii | 1Iiii | 3IIiv

11. What makes the equinoxes and solstices special?

    ANS:
    The equinoxes occur when the Sun is directly above the equator; the entire world experiences a 12-hour day and a 12-hour night. The solstices occur when the Sun is farthest from the equator (north or south). On these days, one hemisphere experiences its longest day and shortest night, while the other hemisphere experiences its shortest day and longest night.

    DIF: Easy/Medium REF: Section 2.3 OBJ: Factual
    TOP: 3IIiv | 3IIv

12. Explain why we always see the same side of the Moon from Earth.

    ANS:
    The amount of time it takes for the Moon to rotate once about its axis is exactly equal to the amount of time it takes to orbit once around Earth.

    DIF: Easy REF: Section 2.4 OBJ: Conceptual TOP: 4IIIii

13. Explain why the Moon appears to rise later and later from one day to the next.

    ANS:
    In general, objects appear to rise and set due to Earth's rotation. While Earth rotates once every 24 hours, the Moon also orbits around Earth roughly once a month in the same direction as Earth's rotation. Therefore, over 24 hours, the Moon has moved slightly from its original position, and Earth has to rotate a little more before the Moon appears to rise again the next day.

    DIF: Medium REF: Section 2.4 OBJ: Applied TOP: 4IIiv

14. If the Moon was full three days ago, what phase will it be tonight and when will it rise and set?

    ANS:
    The Moon's phase cycles on a 29.5 day period. Therefore the Moon tonight will be approximately halfway between the full and third quarter phases, and thus it will be in the waning gibbous phase. It will be on an observer's eastern horizon and rising halfway between 6 P.M. and midnight, which is 9 P.M. It will set 12 hours later at 9 A.M.

    DIF: Medium REF: Section 2.4 OBJ: Applied TOP: 4Ii | 4Iii | 4IIiv

15. Explain why the eclipse seasons occur roughly twice every 11 months, rather than twice per year.

    ANS:
    This happens because the plane of the Moon's orbit slowly wobbles, completing one full "wobble" every 18.6 years. Because the wobble is in the opposite direction from the Moon's orbit, the eclipse seasons occur less than six months apart.

    DIF: Difficult REF: Section 2.5 OBJ: Applied TOP: 5IIIi | 5IIIii | 5IIIiii