ANSWERS TO MATCHING QUESTIONS
a. 9  b. 19  c. 26  d. 10  e. 14  f. 24  g. 7 h. 2 i. 23 j. 17 k. 12 l. 5  m. 8
n. 22  o. 27   p. 4  q. 16  r. 20  s. 11  t. 15  u. 6  v. 25  w. 18  x. 13  y. 1  z. 21
aa. 3

ANSWERS TO MULTIPLE-CHOICE QUESTIONS
14. b 15. a 16. d 17. b 18. a 19. c 20 a

ANSWERS TO FILL-IN-THE-BLANK QUESTIONS
1. parallax 2. celestial equator 3. right ascension 4. 23.5° 5. sunspot 6. helium

ANSWERS TO SHORT-ANSWER QUESTIONS
1. The universe is the totality of all matter, energy, time, and space.
2. Declination, right ascension, distance.
3. The ecliptic and celestial equator are tilted by 23.5°. The reason for this is the 23.5° tilt of the Earth’s axis.
4. The vernal equinox is the point of intersection of the celestial equator and the ecliptic, where
the Sun is moving northward. The celestial prime meridian is the great circle passing from the
North Celestial Pole to the South Celestial Pole perpendicular to the celestial equator and
intersecting the celestial equator at the vernal equinox.
5. The parsec is larger. One parsec equals 3.26 ly.
6. The parallax angle gets too small to measure beyond about 325 ly.
7. 5800 K.
8. Over one solar cycle the latitude of the sunspots changes to lower values. They begin at high
latitudes and end at lower latitudes.
9. The Sun’s corona is visible only during a solar eclipse.
10. The Sun is approximately 100 times bigger than Earth.
11. The core, the radiation and convection layers, the photosphere ("surface"), the chromospheres, and the corona.

12. \[ ^4_1\text{H} \rightarrow ^4_2\text{He}^4 + 2(\gamma + \nu + v) + \text{energy} \]

13. A star is a giant ball of gas which is stable because of the balance of two forces. Pressure pushes the gas outward, but gravity pulls the gas inward.

14. Apparent magnitude is a measure of the brightness of a star as observed from the Earth. Absolute magnitude is a measure of the brightness a star would have if it were positioned 10 parsecs from the Earth.

15. Over one day, the Moon, the stars, and the constellations move across the sky from East to West. Because Earth rotates eastward, the objects in the heavens will move westward, rising in the East and setting in the West.

16. Proxima Centauri is 4.3 ly distant.

17. O, B, A, F, G, K, M.

18.

19. An emission nebula is a bright nebula in which hydrogen gas is ionized by the energy from nearby stars and glows by fluorescence. A reflection nebula is a bright nebula in which the energy of nearby stars us merely reflected and scattered.

20. A red giant.

21. Nucleosynthesis is the creation of nuclei inside stars.

22. The mass of a star determines its lifetime. The mass determines how big and hot the star will get during its life. The temperature is very important because the temperature determines how quickly the nuclear reactions take place in the core of the star. The faster these nuclear reactions take place, the shorter the lifetime of the star.
23. A brown dwarf is a failed star, one unable to sustain fusion long enough to move onto the main sequence. About 100 brown dwarfs have been identified.

24. Protostar, main-sequence star, red giant, planetary nebula, white dwarf.

25. A supernova is a much more powerful explosion than a nova.

26. Type I results from the destruction of a white dwarf, and Type II from the destruction of a red supergiant.

27. A pulsar is a rapidly rotating neutron star. It emits energy along its magnetic poles that are spinning around in space. When that pole is pointing directly toward Earth, we receive a burst of emission; the emission turns on and off as the pulsar rotates. This is similar to a lighthouse because the light in a lighthouse turns “on” and “off” as it rotates around.

28. (The sketch should resemble Fig. 18.22.)

29. A black hole does not emit energy so it cannot be “seen”. However, astronomers can detect the presence of a black hole by its gravitational influence on nearby objects. Typically the black hole is in a binary system so astronomers can observe the motion of the companion and infer the presence of the unseen object.

30. Spiral, elliptical, irregular.

31. Quasars are the cores of galaxies that were forming when the universe was young. They are the most distant objects observed.

32. The two types of spiral galaxy are the normal and barred type galaxies. The normal types have a round nuclear region with spiral arms that curve out from the nucleus. The barred spiral galaxies have an elongated nucleus (shaped like a rectangular bar) with the spiral arms curving out from the ends of the nuclear bar.

33. Dark matter is unobserved matter hypothesized by astronomers to explain why a cluster of galaxies exists as a gravitationally bound system. Dark energy seems to be accelerating the expansion of the universe.

34. The Milky Way is a normal spiral galaxy about 100,000 ly in diameter. Its disk is about 2000 ly thick, and its nuclear bulge is about 20,000 ly thick.

35. In a halo around the Milky Way lie about 150 globular clusters, which are spherical collections of a few tens of thousands of stars. Their distribution led to the conclusion that our solar system was located in a spiral arm of the Galaxy, not at its center.
36. Dark matter is one of the greatest mysteries in astronomy. The composition of dark matter is unknown at this time, but it is believed to exist in two forms: ordinary matter and exotic matter. The ordinary matter is believed to be small, dense objects that we cannot see because they are too dim. The exotic matter is believed to be subatomic particles that we have and have not discovered.

37. The Large Magellanic Cloud and the Small Magellanic Cloud.

38. Hubble’s law states that the greater the recessional velocity of a galaxy, the farther away the galaxy. Hubble’s law indicates that the universe is expanding.

39. Galaxies are not evenly distributed in space but congregate in huge superclusters and long filaments that are separated from each other by huge voids containing very few galaxies.

40. The cosmological redshift, the cosmic microwave background, and the H/He ratio.

41. The most recent modification to the Big Bang model is called the inflation model. It differs from the standard model in that it includes a tremendous release of energy at $10^{-35}$ seconds after the big bang. This tremendous release of energy caused the universe to expand (inflate) very rapidly and thus flatten space-time. The release of energy is thought to be caused by the breakup of a unified force as the universe cooled slightly from the beginning.

42. 400 million years.

**ANSWERS TO APPLYING-YOUR-KNOWLEDGE QUESTIONS**

1. Astronomers took a long time to accurately measure the distances to stars because the distances are so far away. It took more modern technology and telescopes to provide precise enough measurements. Note however that the basic method to measure stellar distances was known very well by the Greeks over 2000 years ago.

2. If Sirius exploded into a supernova it would be a cataclysmic event for anything within about 50-100 light-years distant. The Crab supernova released so much energy from about 6000 light-years from Earth that it was brighter than the full Moon for two weeks. Sirius is only 8.7 light-years from Earth; it would release so much energy in the form of gamma rays and x-rays that it would probably destroy all life on the Earth.

3. Star A is blue, star B is yellowish, and star C is reddish. Because of the Stefan-Boltzmann law ($E \propto T^4$), higher temperature stars emit more light. Star A is the brightest star.
4. Follow a line through the stars Merak and Dubhe in the “bowl” of the Big Dipper. Look for an isolated, magnitude 2 star (Polaris). See Appendix IX.
5. Like the Sun, emission nebulae produce their own light. Like the Moon, reflection nebulae just reflect light given off by stars.
6. It will be several billion years before the Sun reaches the red giant phase.
7. Most of the atoms were forged in the cores of active stars and in the supernovas that destroyed some of the stars.

ANSWERS TO EXERCISES

1. \( d = \frac{1}{p} = \frac{1}{0.20 \text{ arcsec}} = 5.0 \text{ pc} \)
2. \( d = \frac{1}{p} = \frac{1}{0.38 \text{ arcsec}} = 2.6 \text{ pc} (=8.6 \text{ ly}) \)
3. \((365 \text{ d/y})(24 \text{ h/d})(60 \text{ min/h})(60 \text{ s/min}) = 3.15 \times 10^7 \text{ s/y} \)
4. \((1.86 \times 10^5 \text{ mi/s})(3.15 \times 10^7 \text{ s/y}) = 5.86 \times 10^{12} \text{ mi/y} \)
5. Betelgeuse: distance = 130 pc

Use \( d=1/p \), where distance, \( d \) is in parsecs and the parallax angle, \( p \) is in arcseconds. Thus \( p = 1/130 \text{ pc} = 0.008 \text{ arcseconds} \).
6. \((130 \text{ pc})(3.26 \text{ ly/pc}) = 420 \text{ ly} \)
7. –3 is 10 magnitudes brighter than +7, and so it is \( 100 \times 100 = 10,000 \) times brighter.
8. Venus is 5 magnitudes brighter than the star, so it is 100 times brighter
9. Ursa Major cluster recessional velocity, \( V_r = 15,000 \text{ km/s} \).

Use Hubble’s Law \( V_r = H d \), where \( H = 73 \text{ km/s/Mpc} \). The distance to the galaxy cluster can be determined from \( d = V_r/H = 15,000 / 73 = 205 \text{ Mpc (mega-parsecs)} \).
10. For the Hydra supercluster having a distance of 800 Mpc, the recessional velocity is calculated from \( V_r = H d \), \( V_r = 73 \times 800 = 58,400 \text{ km/s} \).
11. The age of the universe is calculated from Hubble’s constant, the rate of expansion of the universe. If \( H = 100 \text{ km/s/Mpc} \) then,

\[
\text{Age (in billions of years)} = \frac{1 \times 10^{12}}{H} = \frac{1 \times 10^{12}}{100} = 1 \times 10^{10} \text{ years} = 10 \text{ billion years.}
\]

If \( H = 50 \text{ km/s/Mpc} \) then,

\[
\text{Age (in billions of years)} = \frac{1 \times 10^{12}}{50} = 2 \times 10^{10} \text{ years} = 20 \text{ billion years.}
\]
12. If \( H = 75 \text{ km/s/Mpc} \), the age of the universe is
Age (in billions of years) = \((1 \times 10^{12})/75 = 1.33 \times 10^{10}\) years = 13.3 billion years.

**ANSWERS TO VISUAL CONNECTION**

a. Nuclear reactions  
b. Photosphere  
c. Chromosphere  
d. Solar Wind