CH02 End of Chapter Answers

Review Questions

1. According to Figure 2-7, the following wavelengths fall within the following ranges of the electromagnetic spectrum:

a. 2.6 μm – Infrared

b. 34 m – Radio

c. 0.54 nm – X-rays

d. 0.0032 nm – Gamma rays

e. 0.620 μm – Visible

f. 310 nm – Ultraviolet

g. 0.012 m – This lies right near the border between microwave and radio waves. Since the figure is not accurate to two decimal places, it is not possible to determine within which wavelength regime this falls.

2. Since radio waves are a form of electromagnetic radiation, they travel at the speed of light. The wavelength and frequency of any wave is related by the formula: $\lambda f = c$, where c is equal to the speed of light, or 3×10^8 m/s. Using this formula, and knowing the values for both c and f (880.65 MHz, or 8.8065×10^8 Hz), we can solve for the wavelength: $\lambda = 3 \times 10^8$ m/s / 8.8065×10^8 Hz = 0.341 meters.

3. According to the Stefan-Boltzmann law, hotter objects radiate more intensely than cooler objects. According to Wien's law, that energy is not radiated uniformly at all wavelengths, but mostly at a wavelength that is inversely proportional to the temperature of the object. As a hot, glowing object becomes hotter, it radiates more intensely at all wavelengths, becoming brighter, and shifts the peak wavelength (at which it radiates the most energy) to shorter wavelengths, becoming bluer.

4. According to the Stefan-Boltzmann law, the intensity of a blackbody object is related to the temperature of an object to the fourth power. If the temperature of the object doubles, then its intensity increases by a factor of 2^4, or 16. Therefore, it will radiate 16 times as much energy per second than it did before.

5. According to Wien's law, the wavelength of maximum emission is inversely related to the temperature of the object based on the formula:

$$\lambda_{max} = 0.0029 \text{ (K m)}/T$$

If we plug in the temperature, we get: $\lambda_{max} = 0.0029$ K m/(21,500K) = 1.35×10^{-7} m, or 135nm. While this falls within the ultraviolet portion of the electromagnetic spectrum, Bellatrix will appear blue since within the visible portion of the spectrum, it gives off more blue light than red.

6. According to Wien's law, the wavelength of maximum emission is inversely related to the temperature of the object based on the formula:

$$\lambda_{max} = 0.0029 \text{ (K m)}/T$$

If we plug in the wavelength of maximum intensity, we get: 853 nm = 8.53×10^{-7} m = 0.0029 K m/T; T = 0.0029 K m/8.53×10^{-7} m = 3400 K. While the greatest intensity of radiation that Antares emits lies within the infrared portion of the electromagnetic spectrum, it will appear red since it gives off more red light than blue.

7. The Bohr model of an atom suggests that electrons orbit around the nucleus of an atom much like planets orbit around a star. According to the Bohr model, electrons are not allowed to orbit at simply any distance it wants, but rather there are only certain allowable distances, or levels. In order for an electron to pull itself further away from the nucleus, jumping to a higher level, it must absorb energy. In order for an electron to move closer to the nucleus, jumping to a lower level, it must release energy. Specific jumps from one level to another correspond to specific energy values. These specific energy values correspond to specific wavelengths. Therefore, when we look at the spectra of an element, we see the wavelengths that its electrons like to emit or absorb in order to jump up and down various levels.

8. Different elements display different patterns of lines in their spectra because they have different permitted levels where the electrons can reside, which means that the electrons of different elements have different "favorite" wavelengths that they can absorb or emit to jump from one permitted level to another.

9. The Doppler effect occurs when an object that is emitting waves radially moves relative to the observer. This can occur due to the motion of the object or the motion of the observer. This radial motion (motion towards or away from one another) causes the detected wavelengths from the object to be shifted relative to the wavelengths it is emitting. If the radial motion is towards one another, then the detected wavelengths will be shorter than that which is emitted; if the radial motion is away from one another, then the detected wavelengths will be longer than that which is emitted. Astronomers can use this information to observe objects in space and tell if they are moving radially relative to us by looking to see if characteristic spectral lines that they are emitting are shifted relative to their rest positions. The direction of their shifts indicate in which direction they are moving, and the magnitude of their shifts indicate how fast they are moving.

10. The color of a star is independent of its motion through space. The color of a blue star depends on its temperature, telling us that it is a hot star. While the motion of a star toward us may shift its spectral lines towards the bluer end of the spectrum, this shift is not appreciable enough to cause a change in the color of a star.

11. A refracting telescope uses lenses to alter the path of light from a distant object such that they converge at a focal point. See Figure 2.21 for details.

12. A reflecting telescope uses mirrors to alter the path of light from a distant object such that they converge at a focal point. See Figure 2.22a for details.

13. The amount of light that a telescope can gather in a given amount of time simply depends on how large of an opening it has, which is equal to the area of the telescope lens or mirror.

14. The purpose of the telescope eyepiece is to magnify the image for easier viewing.

15. While the magnifying power is important in order for the observer to view the object, this can be adjusted by changing the eyepiece. The best criterion for evaluating telescopes is the size of the opening. The larger the opening, the more light the telescope can gather in a given amount of time, and the fainter the object an observer can see.

16. Refracting telescopes have a number of disadvantages compared to reflecting telescopes. First, lenses will refract different wavelengths of light by different amounts. This is known as chromatic aberration. While this can be corrected to some extent, the larger the telescope the harder it is to correct for this. Reflecting telescopes do not suffer from chromatic aberration. Second, as light passes through a lens, a small amount will be absorbed. Mirrors do not absorb light as it bounces off. Third, lenses can only be supported around the edges of the lens, and as lenses become bigger and bigger, they become heavier and can eventually deform due to their own weight. Mirrors can be supported along their entire backside and so don't suffer from this problem. Finally, in order to use a lens to focus light, both sides of a lens must be ground precisely. For a mirror, only one side must be ground precisely, requiring half of the work.

17. The angular resolution of a telescope is a measurement of how closely spaced two separate objects can be and still be observed as two objects, rather than as one blurry object.

18. Adaptive optics is the process by which astronomers can actively monitor the changing influence of Earth's atmosphere on telescope observations and correct for it as it is happening, effectively eliminating the blurring effect of the atmosphere.

19. A charge-coupled device (CCD) is a computer chip with millions of tiny cells that can register when a photon of energy hits it and store that energy. CCDs have replaced photographic film because 1) they are more efficient, registering over 99 percent of all the photons that hit it, 2) have better resolution, and 3) can transfer their data to a computer for analysis.

20. The Sun is not a strong emitter of radio waves, and the radio waves that it does emit are not scattered by the Earth's atmosphere. Therefore, during the day, the sky is not filled with radio waves, and it is possible to observe at these wavelengths day

or night. On the other hand, the Sun does emit optical light more strongly, and in addition, as this light enters Earth's atmosphere, the shorter-wavelength portion of this light is scattered across the sky, such that when we look up, we see this light wherever we look. Optical astronomers cannot observe during the daytime because the sky is too bright in this wavelength range.

21. X-rays and gamma rays cannot penetrate the Earth's atmosphere, and therefore if we want to observe at these wavelengths, we must places satellites in orbit above the atmosphere to detect these wavelengths.

Web Chat Questions

1. According to Wien's law, the wavelength at which an object emits most of its light is inversely related to its temperature. Therefore, a hotter star would emit most of its light at, and the vision of any life form evolving on a planet orbiting around that star would most likely be sensitive to, shorter wavelengths.

2. Ultraviolet light has a shorter wavelength than visible light. Since the wavelength of light is inversely related to its energy, ultraviolet light is more energetic than visible light and can do more damage to cellular structure.

3. Some factors that should be considered when choosing the site for a new observatory might be: Can the wavelength of light being observed penetrate the atmosphere that far? Is there anything within the atmosphere that can impede observations (such as high humidity)? Are there any surrounding impediments, such as buildings, mountains, light pollution, etc.? Is it possible to build the telescope elsewhere for less money yet have the same benefits?

4. Some of the advantages to using a small telescope in space are that the telescope won't suffer from atmospheric effects such as atmospheric seeing, refraction of light rays, or absorption by atmospheric gases. Some of the disadvantages are that it is more expensive to put a telescope in space than it is to build one on the ground, plus the fact that large telescopes gather more light in a given amount of time than small telescopes.

Collaborative Exercises

1. The students should demonstrate the following in each case:

   a. The student representing the light-emitting source should move toward the student representing the observer, who is standing still.

   b. The student representing the light-emitting source should stand still while the student representing the observer should move away.

c. The two students should move in the same direction, but the student in front should walk faster, such that the distance between the two students increases over time.

2. Answers will vary depending on the number of students in the circle.

3. The Keck telescopes have primary mirrors with diameters of 10 meters. While they are each made of 36 hexagonal mirrors, if we approximate the mirrors as circular mirrors, then the circumference of each mirror is equal to 10π meters, or approximately 31.4 meters. To determine if a class has enough students to recreate the sizes of the two Keck mirrors, simply measure the total arm span of every student and see if it adds up to 62.8 meters or more.

Observing Projects

1. The speed of light is 2.99980×10^5 km/s. The measured value for the speed of light should be close to this value. The 1-second precision with which the times of reappearance are measured is one reason why this measured speed will not be completely accurate.

2. a) Tau Ceti, Epsilon Eridani, Epsilon Indi, Lalande 21185.
b) Altair, Procyon.
c) Lalande 21185.

3. Capella is 1.7 times brighter than Delta Aurigae.

4. a) The Lagoon Nebula is a gas cloud with stars embedded within it. It will therefore show an emission line spectrum from the atoms in the gas cloud that have been excited by UV radiation from hot stars.
b) The light from M31, a spiral galaxy neighboring our own Milky Way galaxy, will be the combined light from the myriad of stars making up this galaxy and this light will show an absorption line spectrum, consisting of a continuous spectrum crossed by absorption lines.
c) The Moon will show the spectrum of the Sun, which is an absorption line spectrum consisting of a continuous spectrum from a 6000K star, crossed by thousands of (Fraunhofer) absorption lines.

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.