1. Does it make sense? [Bennett, Chap 5, #15-24] Do these statements make sense (true) or not make sense (false)? Explain in one or two short sentences.
   a. If you could view a spectrum of the light reflecting off a blue sweatshirt, you’d find the entire rainbow of color (looking the same as a spectrum of white light).
      False. A blue sweatshirt only reflects blue light in the visible.
   b. Because of their higher frequency, X rays must travel through space faster than radio waves.
      False. All light travel through space at the same speed.
   c. Two isotopes of the element rubidium differ in their number of protons.
      False. An element is defined by the number of protons.
   d. If the Sun’s surface became much hotter (while the Sun’s size remained the same), the Sun would emit more ultraviolet light but less visible light than it currently emits.
      False. A hotter object emits more light at all wavelengths.
   e. If you could see infrared light, you would see a glow from the backs of your eyelids when you closed your eyes.
      True. Our body emits in the infrared.
   f. If you had X-ray vision, then you could read this entire book without turning any pages.
      False. The book does not emit X-ray, so you cannot read the book without turning pages.
   g. If a distant galaxy has a substantial redshift (as viewed from our galaxy), then anyone living in that galaxy would see a substantial redshift in a spectrum of the Milky Way.
      True. If we see a galaxy moving, observers in that galaxy would see us moving as well.
   h. Thanks to adaptive optics, telescopes on the ground can now make ultraviolet images of the cosmos.
      False. Adaptive optics works in the infrared.
   i. If you lived on the Moon, you’d never see stars twinkle.
      True. The twinkling is caused by the Earth’s atmosphere, and the Moon does not have an atmosphere.
2. [Bennett, Chap 5, #40] Energy Level Transitions. The following labeled transitions represent an electron moving between energy levels in hydrogen. Answer each of the following questions and explain your answers in one or two sentences.

a. Which transition could represent an atom that absorbs a photon with 10.2 eV of energy?

Transition B/C could represent an electron that gains 10.2 eV of energy because it jumps up from 0 eV to 10.2 eV.

b. Which transition could represent an atom that emits a photon with 10.2 eV of energy?

Transition B/C could represent an electron that loses 10.2 eV of energy because it jumps down from 0 eV to 10.2 eV.

c. Which transition represents an electron that is breaking free of the atom?

E because the electron is breaking free of the atom and getting ionized.

d. Which transition, as shown, is not possible?

D because electrons can only jump from one energy level to another.

e. Would transition A represent emission or absorption of light? How would the wavelength of the emitted or absorbed photon compare to that of the photon involved in transition C? Explain.

A represents emission if it is going from Level 3 → 1 by emitting a 12.1 eV photon and absorption if going from Level 1 → 3 by absorbing a 12.1 eV photon. This would be a higher energy photon and thus more energy than that in C.

3. [Bennett, Chap 5, #41] Orion Nebula. Viewed through a telescope, much of the Orion Nebula looks like a glowing cloud of gas. What type of spectrum would you expect to see from the glowing parts of the nebula? Why?

A glowing cloud of gas would have an emission spectrum. The gas is hot in the glowing parts and electrons are excited and at high energy levels. They will jump to lower levels and emit photons at certain wavelengths, creating an emission line spectrum.
4. [Bennett, Chap 5, #43] Spectral Summary. Clearly explain how studying an object’s spectrum can allow us to determine each of the following properties of the object.
   a. The object’s surface chemical composition can be determined by identifying specific spectral lines.
   b. The object’s surface temperature can be determined from the peak wavelength of the blackbody curve. [Bonus: In case where the spectrum is not a blackbody, it can be determined from the ionization states of elements found in the object.]
   c. Whether the object is a low-density cloud of gas or something more substantial — A low-density cloud will only have “pure” emission or absorption line spectrum. A denser object will have a thermal radiation spectrum (blackbody) superimposed with the line spectrum.
   d. The speed at which the object is moving toward or away from us can be determined by measuring the Doppler shift of the lines in its spectrum.

5. Suppose the surface temperature of the Sun were about 12,000 K, rather than 6000 K. 
   a. How much more thermal radiation would the Sun emit?

   We will use the Stefan-Boltzmann Law (energy emitted \(E = \sigma T^4\)):
   \[
   \frac{P_{\text{Hotter Sun}}}{P_{\text{Sun}}} = \left(\frac{12,000}{6000}\right)^4 = 2^4 = 16
   \]

   b. What would happen to the Sun’s wavelength of peak intensity?

   We will use Wien’s Law: \(\lambda_{\text{peak}} = \frac{2,500,000}{T}\) mm

   For 12,000 K, \(\lambda_{\text{peak}} = \frac{2,500,000}{12,000}\) mm = 242 nm

   c. Do you think it would still be possible to have life on Earth? Explain.
   It is doubtful that life could exist on Earth. Earth would be too hot because of the larger amount of energy coming in.
6. [Bennett, Chap 5, #49] Doppler Calculations. In hydrogen, the transition from level 2 to level 1 has a rest wavelength of 121.6 nm. Find the speed and direction (toward or away from us) for a star in which this line appears at wavelength.
   a. 120.5 nm. b. 121.2 nm. c. 121.9 nm. d. 122.9 nm.

   a. We use the Doppler shift formula to find the speed of the star:
   \[ V = \frac{\Delta \lambda}{\lambda_0} \times c = \frac{120.5 \text{ nm} - 121.6 \text{ nm}}{121.6 \text{ nm}} \times 300000 \text{ km/s} = -2714 \text{ km/s} \]
   The negative value indicates that Star A is moving toward us.

   b. \[ V = \frac{\Delta \lambda}{\lambda_0} \times c = -387 \text{ km/s} \]
   The negative value indicates that Star B is moving toward us.

   c. \[ V = \frac{\Delta \lambda}{\lambda_0} \times c = 740 \text{ km/s} \]
   The positive value indicates that Star C is moving away from us.

   d. \[ V = \frac{\Delta \lambda}{\lambda_0} \times c = 3207 \text{ km/s} \]
   The positive value indicates that Star D is moving away from us.

7. [Bennett, Chap 5, #50] Hubble's Field of View. Large telescopes often have small fields of view. For example, the Hubble Space Telescope's (HST's) advanced camera has a field of view that is roughly square and about 0.06° on a side.
   a. Calculate the angular area of the HST's field of view in square degrees.
   \[ \text{angular area} = 0.06^\circ \times 0.06^\circ = 0.0036 \text{ sq. deg.} \]

   b. The angular area of the entire sky is about 41,250 square degrees. How many pictures would the HST have to take with its camera to obtain a complete picture of the entire sky?
   \[ N = \frac{\text{total area}}{\text{one field's angular area}} = \frac{41,250 \text{ sq. deg.}}{0.0036 \text{ sq. deg.}} = 11.5 \text{ million} \]
I would recommend typing answers to the following questions, especially if your handwriting is hard to read.

8. [Bennett, Chap 5, #51] The Changing Limitations of Science. In 1835, French philosopher Auguste Comte stated that science would never allow us to learn the composition of stars. Although spectral lines had been seen in the Sun’s spectrum at that time, it wasn’t until the mid-19th century that scientists recognized (primarily through the work of Foucault and Kirchhoff) that spectral lines give clear information about chemical composition. Why might our present knowledge have seemed unattainable in 1835? Discuss how new discoveries can change the apparent limitations of science. Today, other questions seem beyond the reach of science, such as the question of how life began on Earth. Do you think such questions will ever be answerable through science? Defend your opinion.

9. [Bennett, Chap 5, #52] Science and Technology Funding. Technological innovation clearly drives scientific discovery in astronomy, but the reverse is also true. For example, Newton made his discoveries in part because he wanted to explain the motions of the planets, but his discoveries have had far-reaching effects on our civilization. Congress often must decide between funding programs with purely scientific purposes (“basic research”) and funding programs designed to develop new technologies. If you were a member of Congress, how would you try to allocate spending for basic research and technology? Why?

10. What we can learn from the spectrum of Mars shown in Fig 5.16? List each feature and describe how you infer the properties?

   When younger, Mars probably had an atmosphere similar to Earth’s. Would Mars’ spectrum have looked any different then? If yes, list at least three features that would be different.

   1) The visible light we see from Mars is actually reflected light from the Sun, which is spread throughout the visible spectrum.

   2) Mars reflects the sunlight preferentially in the blue, which is why it appears red to us.

   3) The emission lines in the UV tell us that there is hot gas in the Martian atmosphere.

   4) The absorption lines in the IR tell us that there is carbon dioxide in the Martian atmosphere.

   5) The spectral lines are shifted from their rest wavelengths. This tells us the direction and speed at which Mars is moving toward or away from us.

   6) Peak of the blackbody spectrum in the IR tells us that the Martian surface temperature is about 225 K.

Mars with an atmosphere would definitely have looked different. We would have seen the following differences:

   1) more absorption lines (for e.g., nitrogen and oxygen)

   2) more emission lines (for e.g., nitrogen and oxygen)

   3) Mars might have been a bit warmer, shifting the peak of blackbody spectrum to bluer wavelengths.

   4) Depending on the content of the atmosphere, the sunlight that Mars absorbs would have been different. Mars would have been a different color.