Homework Ch. 4 RQ 13-15, 17-20, Ch. 5 RQ 1,3,4,8

6. Color is usually related to wavelength; red is the longest wavelength and violet the shortest wavelength. Since wavelength and frequency are inversely proportional, red has the lowest frequency and energy; violet has the highest frequency and energy.

7. Each orbital has a precise energy, like in the Bohr model, but the electron is smeared out in an electron cloud or probability shell. The exact location of the electron can not be determined.

8. The hydrogen atom has one proton in its nucleus and one electron moving around it. The electron is found in one of many possible energy levels or orbitals.

9. When a physical quantity is quantized it means that it takes on only specific values rather than a continuous range of values.

10. The normal condition for atoms is one in which the number of electrons equals the number of protons in the nucleus. The electrons are in their lowest energy level. When an atom is excited, an electron is found in a higher energy orbital. The precisely-defined energy states or energy levels are referred to as orbitals. They are the regions occupied by electrons that surround the nucleus.

11. In order for a photon to be absorbed, it must have an energy that is precisely equal to the energy difference between two energy levels, the lower level which is occupied by an electron. The electron absorbs the photon and moves to the higher energy level. Very quickly thereafter the electron moves back down to the lower energy level by emitting a photon of equal energy to the energy difference between the two levels.

12. A star produces a continuous spectrum. However, this light passes through a cooler layer of gas that surrounds the star. Specific wavelengths are absorbed by this gas and the resulting spectrum appears as an absorption spectrum, a continuous spectrum with specific wavelengths missing. Emission lines are not normally found in a stellar spectrum because they are produced in a hot, low density gas. Most stars have a layer of a cool, low density gas forming an absorption spectrum. However, in some cases, a hot, low density layer can form or can be found in clouds of gas between stars and an emission spectrum is seen.

Information about the composition and temperature of the cool gas, along with its motions, can be determined from the absorption lines.

13. According to Kirchhoff's first law, a luminous solid liquid or dense gas will emit light of all wavelengths and produce a continuous spectrum.

14. When the spectrum of the light source is observed, an absorption spectrum is seen because the cloud has absorbed specific wavelengths. But if the cloud is observed, it is seen to emit specific wavelengths, as its atoms that absorbed the light now re-emit the energy.

15. The H-alpha absorption line of hydrogen results from electrons jumping from the second to the third atomic orbital. Because the Sun's lower atmosphere is rather cool, relatively few atoms have electrons in the second orbital; most are in the ground state. Hence, in the Sun, the H-alpha line is weak.

16. Molecules can rotate and they can vibrate. These two motions have quantized energy levels just like the electrons in an atom. Changes in the rotational or vibrational state of a molecule will produce specific spectral lines unique to each molecule.

17. The intensity of a spectral line depends primarily on two factors, the number of atoms of a particular element and the number of those atoms that are able to make the necessary transition between orbitals to produce that spectral line. The first factor gives information on the existence and abundance of an element. The second factor depends on the temperature of the gas. Astronomers are thus able to determine the abundance of an element and temperature of the gas from line intensity.

18. When an atom produces a spectral line, the wavelength observed depends on the motion of the atom. The Doppler effect tells us that an atom moving towards us will produce a line that is observed to be shifted to shorter wavelengths; an atom moving away will produce an observed wavelength that is longer. In any hot gas there are atoms moving in all directions; the hotter the gas the faster they move. The net result is a broadening of the spectral line. Mass motions of the gas and stellar rotation will also produce broadening of the line in much the same way.

19. If a star is rotating and is oriented so that its equator is approximately in our line of sight, then the light from one side will be approaching us and the other will be receding from us. The light from those two sides will be blue and red shifted, respectively. As the rotation increases, the amount of shifting increases. For a particular spectral line, coming from all parts of the star, a broadening of the line is observed.

20. Radial velocity of the star, elemental abundance, temperature, rotation, turbulence, magnetic field, atmospheric pressure.

such as this encourage students to build a community of learners by learning more about each other.

2. Observing New Stars in the Orion Region. Each group member should consider a different portion of the electromagnetic spectrum. In general, most groups will eventually decide on the infrared region as providing the most information but the decision is not a trivial task for most students.

3. Multiple-Wavelengths. Focus on helping students identify the subtleties of each wavelength image and clarifying their justifications for which band they find to have the most useful information.

ANSWERS TO CHAPTER 5 REVIEW QUESTIONS

1. The two reasons why larger telescopes are better than smaller telescopes are greater collecting area and better angular resolution. The primary purpose of a telescope is to make faint objects bright enough to detect. Larger telescope mirrors collect more light and bring it to a focus. It is also necessary to see detail in the image formed by the telescope, to resolve two objects that appear close to each other. Larger telescope mirrors produce less diffraction, which blurs an image and limits resolution.

   Currently, there seems to be a sudden interest in building large telescopes. The last large telescope was built in 1948, the Palomar Observatory 5 meter telescope. For about 4 decades astronomers did not seem interested in building larger telescopes. Why did this suddenly change? The answer is that the detectors of light used by astronomers were very inefficient; they wasted most of the light received by the telescope. A photographic emulsion is no better than 5% efficient, 95% of the light is wasted. Other detectors were not much better than 10% efficient. Astronomers were not limited by the size of their telescopes but by the inefficiencies of their detectors. When CCD detectors became available, astronomers could use up to 75% of the light, so little light was wasted. Now, to see fainter objects, they had to start building bigger telescopes.

2. The largest telescopes are reflecting telescopes, primarily because of 3 distinct disadvantages of the refracting telescope. When light passes through a lens, light of different wavelengths focus at slightly different places. This is known as chromatic aberration and can produce seriously out of focus images. It is not easy to correct when making large lenses. Note, however, that camera lenses are quite successful in correcting this aberration, otherwise all your color photos would be rather blurry. A second problem is the glass lens absorbs certain wavelengths of light that the astronomers needs to observe. In the infrared, for instance, glass is not transparent like it is for visible light. In the infrared, the glass lens blocks light from entering the telescope. Lastly, it is difficult to keep a lens bigger than about one meter from bending in its support. Glass is flexible and lenses can only be supported around their edge. When a large glass lens bends due to its own weight, its curvature changes and so does the focus, thus ruining the image.

3. The Keck telescopes are 10-m reflectors and are the largest in the world. They are atop Mauna Kea in Hawaii, as are several other large telescopes.

4. The Earth's atmosphere smears out images seen in telescopes. "Seeing" is the blurring in the image of an object, such as a star, as its light passes through the Earth's atmosphere. Instead of the star image being very small, limited by the diffraction of the telescope, the image is blurred to many times this size. The atmosphere of the Earth is not homogeneous; it is turbulent and contains layers of varying temperatures and density. Light passing through

these layers is refracted into many slightly different paths. Fortunately for astronomers, the Earth's atmosphere is really rather thin and so the images are not completely blurred to uselessness.

5. The Hubble Space Telescope is not affected by seeing because it orbits above the Earth's atmosphere. It can also observe at wavelengths that are absorbed by the Earth's atmosphere. Its disadvantages are several; it is a very complex telescope to use and astronomers must use it remotely. If something goes wrong, they can not easily fix it. Since it orbits close to the Earth, half the sky is blocked by the Earth. Because it orbits quickly around the Earth, objects may be observable for only part of the time; the rest of the time they are blocked by the Earth.

6. A CCD is a charge-coupled device. It has thousands of individual detectors arranged in a grid, each much more sensitive than a photographic plate. The light level of each detector is read out by computer. A CCD's primary advantages are its high sensitivity to light, its linear response to light (twice as much light produces twice as much signal, unlike a photographic plate, which is highly non-linear), and the ease with which the image can be processed by computer software.

7. CCDs produce an electronic picture that is in digital form. The image is stored as a series of numbers in the memory of a computer. The raw data, however, can contain flaws produced by imperfections in the CCD chip, optical defects in the telescope, and unwanted light entering the CCD camera. Computer programs can remove most of these effects and produce clean images. This process is known as image processing.

8. A 2-m optical telescope's resolution is more affected by atmospheric turbulence than by diffraction. Its diffraction limit is about 0.05" but turbulence is about 10 times greater.

9. Active optics is a method in which the telescope's optical system is continually adjusted to compensate for effects like mirror distortion, temperature changes, and bad seeing.

10. Adaptive optics are just now being developed that change the shape of mirrors in the telescope in order to compensate for atmospheric distortions.

11. The resolution of a telescope depends on the wavelength of the light observed; the longer the wavelength, the lower the resolution. Radio waves are very long relative to visible light. Since larger telescopes produce higher resolution, radio telescopes must be very large, compared to optical telescopes, in order to have a useful resolving power.

12. Conditions in some objects produce radio waves but little or no visible light. Some objects produce both but by different mechanisms. Radio astronomy allows all these objects to be studied. The radio emissions reveal a great deal of information about the objects that could not be learned by observations in visible light.

13. Even large radio telescopes have poor resolution when compared to optical telescopes. To improve their resolution would require radio telescopes of enormous size; at least kilometers in diameter. The technique of interferometry synthesizes a telescope of this size by separating several radio telescopes by this distance and simultaneously observing the same object. Using some rather complex computer processing, the individual images are combined to synthesize what would have been observed by a telescope the size of the separation between the telescopes. Radio interferometry can now reach resolutions that are far better than optical telescopes.