ASTR 220 Homework #5 Solutions
Spring 2005

1. *Ch. 5, Does It Make Sense, #18.* This statement does not make sense. All light must travel at the same speed: the speed of light. Therefore, x-rays and radio waves travel at the same speed.

2. *Ch. 5, Problems, #31.*

   (a) **Composition:** If an object has an emission or absorption spectrum, we can match up the spectral lines to catalogs of spectral lines of known elements. If an element is in the object, all of its spectral lines should be apparent in the spectrum. (Note: for an object with an absorption spectrum, we are really finding the composition of the cool gas between us and the object emitting the continuous spectrum.) We cannot determine the composition of an object emitting a continuous spectrum.

   (b) **Temperature:** If an object emits an absorption or continuous spectrum, we can apply Wien's law. We plot the spectrum on a wavelength vs. intensity and determine what wavelength has the highest intensity (and therefore is the brightest). Then we use this wavelength in Wien's law to calculate the temperature. We can't find the temperature of an object emitting an emission spectrum.

   (c) **Density:** If an object is emitting an emission spectrum, we know that it must have a low density. Only a low density object can give off an emission spectrum. If an object gives off a continuous spectrum, we know that it has high enough density to be opaque. If an object emits an absorption spectrum, we know that two "objects" are involved: a high density hot object and a low density cool object. They may be parts of the same object, such as a star and its atmosphere.

   (d) **Speed:** If an object gives off an emission or absorption spectrum, we can determine its speed. The spectral lines are shifted in proportion to the objects velocity, according to the Doppler Effect: large shift in wavelength, then large velocity. We know if an object is moving away from us because the wavelength of the spectral lines will be shifted toward longer wavelengths; if the object is moving toward us, the wavelength will be shifted toward shorter wavelengths. We can't determine the speed of an object emitting a continuous spectrum.

3. *Suppose a star has a surface temperature of 20,000 K.*

   (a) *What is the wavelength at the peak of the star's thermal radiation curve?* We can use Wien's law:
   $$\lambda_{max} = \frac{0.0029m \cdot K}{T}$$
   Plug in the temperature:
   $$\lambda_{max} = \frac{0.0029m \cdot K}{20,000K} = 1.45 \times 10^{-7}m$$

   (b) *What type of light is this? (Such as radio, visible, etc.)* From Figure 5.2, we can see that this wavelength falls in the ultraviolet range of light.

4. *Suppose we observe a star with a hydrogen absorption line in the red part of the star's spectrum. In the star's spectrum, the line has a wavelength of* $6.565 \times 10^{-7}m$. *However, in the laboratory, we measure the wavelength of this line to be* $6.563 \times 10^{-7}m$.

(a) *What is the shift in the wavelength of the spectral line?* The shift in wavelength is defined as: $\Delta\lambda = \lambda - \lambda_\circ$. $\lambda_\circ$ is the wavelength of the spectral line for the object at rest. That would be the laboratory object. λ is the wavelength of the spectral line of the moving object. Consequently: $\Delta\lambda = 6.565 \times 10^{-7} m - 6.563 \times 10^{-7} m = 2 \times 10^{-10} m$.

(b) *What is the velocity of the star?* We can use the Doppler Effect equation to determine the velocity.

$$v = \frac{\Delta\lambda}{\lambda_\circ} c$$

We calculated $\Delta\lambda$ in the previous part, so we can plug in the numbers.

$$v = \frac{2 \times 10^{-10} m}{6.563 \times 10^{-7} m}(3 \times 10^8 m/s)$$

$$v = (3.0 \times 10^{-4})(3 \times 10^8 m/s) = 9 \times 10^4 m/s$$

(c) *Is the star moving toward us or away from us?* The velocity is positive, so that means that the star is moving away from us. We can confirm this by comparing the non-moving and moving wavelengths of the spectral line. The moving wavelength is longer than the non-moving wavelength, which means that the object is moving away from us.

5. *Ch. 10, Sensible Statements, #18.* This statement does make sense. The solar thermostat described on pgs. 264 - 265 keeps the Sun's core temperature relatively constant. If the Sun's core temperature went up a bit, the rate of fusion in the core would increase. That would create more thermal pressure, which would cause the Sun to expand a bit. The increase in size of the core would cause it to cool off, which would bring the rate of fusion back to its normal level.

6. *Ch. 10, Sensible Statements, #19.* This statement does not make sense. Fusion only happens in the Sun's core. Energy that is produced (as light) must travel outward from the core through the Sun's outer layers. We know that this can take about 1 million years, mostly because of the random walk process in the Sun's radiation zone. So if the Sun turned off today, we wouldn't know about it for 1 million years.

7. *Ch. 10, Review Questions, #2.* The two forces balanced in gravitational equilibrium are the force of gravity inward and the pressure of the Sun's gas outward. The weight of the Sun's mass on the core of the Sun compresses it and makes the core smaller. We know that compressing a gas increases its thermal energy, which makes the Sun's core hotter. This compression also naturally makes the core denser than the outer layers of the Sun.

8. *Ch. 10, Review Questions, #4. Only do the layers from the core up to (and including) the photosphere.*

   - Core: The Sun's core is the hottest and densest part of the Sun. Fusion occurs here, converting hydrogen to helium and releasing energy in the form of light.
   - Radiation Zone: This layer is right above the Sun's core. It's not as hot or dense as the core. However, it is hot enough that light cannot travel straight out through it. Instead, light "bounces" between electrons randomly and can take about 1 million years to escape.
   - Convection Zone: This layer is just underneath the "surface" of the Sun. Heat is transferred from the bottom of the convection zone to the top through the convection of gas in this layer. The gas at the top cools off, losing radiative energy into space.
   - Photosphere: This is the "surface" of the Sun, where the Sun becomes opaque. It's the coolest layer of the Sun and where sunspots appear. Even though we call this the surface of the Sun, it's considered the lowest layer of the Sun's atmosphere.

9. *Explain why fusion in the Sun only occurs in the core and not in the outer layers or surface.* Thermonuclear fusion can only occur at very high pressures and temperatures. The PP chain starts by fusing two hydrogen nuclei - hydrogen nuclei are just protons. Protons have a positive charge, so they repel each other normally. However, at very high pressures and temperatures, protons start moving so quickly that the collide and fuse together before their charge repulsion can take effect. In the other layers and surface of the Sun, the temperature and pressure is not high enough for this to happen.

10. *When we observe the Sun through a spectroscope, we see an absorption spectrum. However, if we observe **only** the Sun's **atmosphere** through a spectroscope (during a solar eclipse), we see an emission spectrum. Explain why we see two different kinds of spectra, even though we are looking at the Sun in both cases. Relate your explanation to how each type of spectrum is created.*

    When we look at the Sun normally, we see an absorption spectrum. That means that we are seeing an object that gives off a continuous spectrum through a cooler cloud of gas. That cloud of gas is the Sun's atmosphere, specifically the photosphere. The photosphere absorbs some light from the continuous spectrum light that is produced in the Sun's interior.

    When we look at the Sun's atmosphere only, during a solar eclipse, we are only seeing a cloud of gas. Since we see it against the background of space, which is cold, the gas now appears hot. Consequently, it fulfills the conditions of an emission spectrum: a hot, thin object.