Physics 167 – Astronomy

Homework #6

Chapter 11

1. a. The Sun's average surface temperature is about 5800 K. Use Wien's law to calculate the wavelength of peak thermal emission from the Sun. What color does this wavelength correspond to in the visible light spectrum? Why do you think the Sun appears white or yellow to our eyes?

b. The typical temperature of a sunspot is about 4000 K. Use Wien's law to calculate the wavelength of peak thermal emission from a sunspot. What color does this wavelength correspond to in the visible-light spectrum? How does this color compare with that of the Sun?

2. Estimate how much mass the Sun will lose through fusion reactions during its 10-billion-year life. You can simplify the problem by assuming the Sun's energy output remains constant. Compare the amount of mass lost with Earth's mass. (Find the ratio of the mass lost to Earth's mass.)

3. The gas pressure in the photosphere changes substantially from its upper levels to its lower levels. Near the top of the photosphere, the temperature is about 4500 K and there are about 1.6×10^{16} gas particles per cubic centimeter. At the bottom of the photosphere, the temperature is about 7000 K and there are about 1.5×10^{17} gas particles per cubic centimeter. Compare the pressures of each of these layers and explain the reason for the trend in pressure that you find. How do these gas pressures compare with Earth's atmospheric pressure at sea level? (Hint: See Cosmic Calculations 11.1.)

4. The total mass of the Sun is about 2×10^{30} kg, of which about 75% was hydrogen when the Sun formed. However, only about 13% of this hydrogen ever becomes available for fusion in the core. The rest remains in layers of the Sun where the temperature is too low for fusion.
a. Based on the given information, calculate the total mass of hydrogen available for fusion over the lifetime of the Sun.
b. Combine your results from part (a) and the fact that the Sun fuses about 600 billion kg of hydrogen each second to calculate how long the Sun's initial supply of hydrogen can last. Give your answer in both seconds and years.
c. Given that our solar system is now about 4.6 billion years old, when will we need to start worrying about the Sun running out of hydrogen for fusion?

5. This problem leads you through the calculation and discussion of how much solar power can be collected by solar cells on Earth.
a. Imagine a giant sphere with a radius of 1 AU surrounding the Sun. What is the surface area of this sphere in square meters?

b. Because this imaginary giant sphere surrounds the Sun, the Sun's entire luminosity of 3.8×10^{26} watts must pass through it. Calculate the power passing through each square meter of this imaginary sphere in watts per square meter. Explain why this number represents the maximum power per square meter that a solar collector in Earth orbit can collect.
c. List several reasons why the average power per square meter collected by a solar collector on the ground will always be less than what you found in part (b).

6. Observations over the past century show that the Sun's visible-light output varies by less than 1%, but its X-ray output can vary by a factor of 10 or more. Explain why the changes in X-ray output can be so much more pronounced than the changes in visible-light output.

Chapter 12

7. Earth is about 150 million km from the Sun, and the apparent brightness of the Sun in our sky is about 1300 watts/m^2. Using these two facts and the inverse square law for light, determine the apparent brightness that we would measure for the Sun *if* we were located at the following positions:
a. Half Earth's distance from the Sun.
b. Twice Earth's distance from the Sun.
c. Five times Earth's distance from the Sun.

8. Alpha Centauri A lies at a distance of 4.4 light-years from Earth and has an apparent brightness in our night sky of 2.7×10^{-8} watts/m^2. Recall that 1 light-year = 9.5×10^{15} m.
a. Use the inverse-square law for light to calculate the luminosity of Alpha Centauri A.
b. Suppose you have a light bulb that emits 100 watts of visible light. How far away would you have to put the light bulb for it to have the same apparent brightness as Alpha Centauri A in our sky?

9. Use the inverse square law for light to answer each of the following questions.
a. Suppose a star has the same luminosity as our Sun (3.8×10^{26} watts) but is located a a distance of 10 light-years from Earth. What is its apparent brightness?
b. Suppose a star has the same apparent brightness as Alpha Centauri A (2.7×10^{-8} watts/m^2) but is located at a distance of 200 light-years from Earth. What is its luminosity?
c. Suppose a star has a luminosity of 8×10^{26} watts and an apparent brightness of 3.5×10^{-12} watts/m^2. How far away is it from Earth? Give your answer in both kilometers and light-years.

10. Use the parallax formula to calculate the distance to each of the following stars. Give your answers in both parsecs and light-years.
a. Alpha Centauri: parallax angle of 0.7420 arcsecond
b. Procyon: parallax angle of 0.2860 arcsecond

11. Sirius A has a luminosity of $26L_{Sun}$ and a surface temperature of about 9400 K. What is its radius?

12. Describe what would happen to the surface temperature of a star if its radius doubled in size with no change in luminosity.

13. Suppose you are observing two binary star systems at the same distance from Earth. Both are spectroscopic binaries consisting of similar types of stars, but only one of the binary systems is a visual binary. Which of these star systems would you expect to have the greater Doppler shifts in its spectra? Explain your reasoning.