Homework 2

AST 301, Section 44940, Spring 2004

NAME Student EID Score: /100

Due Tuesday, March 2, 2004

Questions A – C should help you to understand the properties of light. **Show your work. If you don't show your work, we will reluctantly have to give you only 1/4 of the full points even if you get the correct answer.**

A. How many wavelengths of blue light would fit across the **thickness** of a sheet of paper? The easiest way to find the thickness of a sheet of paper is to take a stack of xerox pages that is (for example) 1 cm thick (use a ruler to measure it), count the number of pages in the stack, and then divide 1 cm by this number. (5 points)

B. How long does it take for red photons from the Sun to reach the Earth? (5 points) How about blue photons? (5 points)

C. The energy of one photon is equal to Planck's constant times the speed of light divided by the wavelength of the photon. Planck's constant is 6.63×10^{-34} Joule sec. The speed of light is 3.0×10^8 m/s. How many photons are emitted per second by a 100 Watt lightbulb? Notes: 1 Watt = 1 Joule per second. You can get the wavelength by assuming that the color is yellow. Do you see why you can't see individual photons? (10 points)

D. Here is a simple calculation that should give you an idea of how inadequate chemical reactions are for powering the Sun. According to the 76$^{\text{th}}$ Edition of the *Handook of Chemistry and Physics*, burning one gram of benzene (a simple and pure form of gasoline) produces 4.18×10^4 Joule of energy. The Sun's mass is 2×10^{30} kg and its luminosity is 3.8×10^{26} Joule/s. If the Sun were completely made of benzene and you burned it fast enough to produce the solar luminosity, how many years would it last? Other chemical reactions would be similar. Note that the Earth's age is about 5 billion years. (15 points)

E. In class, we found out that matter and energy are equivalent and that the energy "frozen" inside a given mass is the mass times the square of the speed of light ($E = mc^2$). This question should give you a feeling for how much energy there is in even a small amount of mass. If you could totally annihilate a 1 kg potato (that is, if you could completely convert it to energy), how many joules of energy would you get? The total electric power consumption of greater Austin averages about 1.1×10^9 watt (1 Watt = 1 joule/s; 1 joule = 1 kg m^2/s^2). How long could you satisfy Austin's electricity needs if you could harness all the energy from your potato? (10 marks)

F. Plot a Hertzsprung-Russell diagram on the graph paper provided. First plot absolute magnitude M_V against spectral type for the stars nearest to the Sun; they are listed on page A-4 (Edition 6) or 444 (Edition 7) of the text. Plot white dwarf stars at spectral type A0. Then use a different color pen to plot the brightest stars in the sky (page A-5 in Edition 6 or 445 in Edition 7). Finally, in a still different color, add the main-sequence stars (same page of the text). Plot points clearly and accurately. (15 points)

Label the following key regions on your diagram:

The main sequence (3 points)

The giant branch (3 points)

The supergiants (3 points)

The white dwarfs (1 point)

Here are some interesting things you can note from the plot and the tables:

(a) Compare your plot with Fig. 8-23 (Edition 6) or page 151 (Edition 7) in the textbook. They show the brightest and nearest stars in two separate Hertzsprung-Russell diagrams. Note that the nearest and the apparently brightest stars are very different: the nearest stars are mostly very faint, low-mass dwarfs, while the apparently brightest stars really are intrinsically bright and mostly far away. That is, no extreme dwarf star is so near the Sun that it looks very bright.

(b) The plot should convince you that the Sun in a very average star.

(c) Rigel and Betelgeuse are two of the brightest stars in Orion – Rigel is the right foot and Beteguese is the left shoulder, as we look at the constellation (see Figure 2-1 in the text). They are really very different: Betelgeuse is a very cool star with a temperature of 2900 K; when you look at it in the sky, you should be able to see that it looks reddish. Rigel, on the other hand, is extremely blue and bright; it's surface temperature is 36,000 K. That's why Betelguese is an M2 star and Rigel is B8. You can see the different colors of these two stars in Figure 2-4b of the text.

(d) Sirius and Canopus are the brightest stars in the sky (after the Sun, of course). They are only a factor of two different in apparent brightness, but in reality, Canopus is 4.5 magnitudes or 63 times more luminous than Sirius. Why do they look almost equally bright? Because Canopus is 11 times farther away. (The distances are given in the table.)

(e) In fact, Deneb, at apparent magnitude 1.26, is still one of the brightest stars in the sky, but is much farther away (1600 ly, compared to 98 ly for Canopus and only 8.7 ly for Sirius). It is a supergiant star, 60,000 times more luminous than the Sun. You really can't tell a star's distance or true luminosity just by looking at it.

(f) Alpha Centauri A, α Centauri B, and Proxima Centauri form a triple system and are the closest stars to the Sun. Proxima Centauri is the closest of the three. It's name comes from the Latin word for "close". Note where Proxima is on your Hertzsprung-Russell diagram. You will see that it is one of the least luminous dwarfs known.

(g) Sirius A and B and Procyon A and B are both binary stars, i. e., a pair of stars in orbit around each other. Note how different they are. The A stars are normal main-sequence stars; the companions are already white dwarfs. We will see that white dwarfs are essentially dead stars – they have virtually finished their evolution. We will also see that more massive stars die more quickly. The fact that the fainter member of each pair has already evolved to a white dwarf means that it started out more massive than it's brighter companion. When both stars were young, the star that is now the white dwarf would have been much the brighter of the two.

(h) Arcturus is an orange giant 27 times the size of the Sun and the fourth brightest star in the sky. Our Sun is expected to become very much like Arcturus in its old age (about 5000 million years from now).

(i) If you enjoyed the Star Trek TV series and movies, you may be interested to note that the fictional planet Vulcan which is the homeworld of Mr. Spock is said to revolve around the star ϵ Eridani (about half way down the table of nearest stars). It is a K2 star rather cooler and therefore redder than the Sun. That's why the "sunlight" on the planet is always shown as red. *Live long and prosper.*

G. Multiple-choice questions: for each question, circle the correct answer. (5 points each)

1. If the core of a main sequence star gets too hot,

   (A) the star explodes.

   (B) the star expands, engulfing its planets.

   (C) the core expands, cools, and thereby reduces its energy output.

   (D) the star contracts.

   (E) nuclear reactions produce Helium more quickly.

2. Which event marks the end of a star's life on the main sequence?

   (A) Core collapse

   (B) Helium ignition

   (C) Carbon deflagration

   (D) Hydrogen in the core is used up

   (E) Supernova explosion

3. Energy produced in the core of the Sun escapes

   (A) by conduction

   (B) by convection

   (C) by diffusion

   (D) first by convection, then, near the surface, by radiative diffusion

   (E) first by radiative diffusion, then, near the surface, by convection

4. Which of the following are affected by the Sun's 11-year cycle?

   (A) Sunspots

   (B) Prominences

   (C) Flares

   (D) The Earth's climate

   (E) All of the above

5. Globular clusters are 14 to 16 billion years old. What type of stars do they **not** contain?

   (A) red giant stars

   (B) 10 $M_\odot$ main sequence stars

   (C) 3 $M_\odot$ neutron stars

   (D) 1 $M_\odot$ stars like the Sun

   (E) 0.5 $M_\odot$ white dwarfs