

**Fall 2005 ASTR 1120-001 General Astronomy: Stars & Galaxies.
Problem Set 2. Due Th 15 Sep**

Your name:

Your ID:

Except for the tutorial, for which you should submit answers on line, please show your working on this sheet, and write your answers on this sheet. Attach extra sheets if you need them. If you mess up, you can get another copy of the problem set at http://casa.colorado.edu/~ajsh/astr1120_05/prob.html. Express your answers in scientific notation.

1. Tutorial on the Sun

Go to <http://www.astronomyplace.com>, press on the Cosmic Perspective 3rd Edition icon, log in. Join our class 'cm651430', so that you can record your work and submit it for grade on line. Click on Tutorials, and do the tutorial on the Sun. You can redo the tutorial as often as you like, to improve your grade. Unfortunately you cannot save a session, so you have to complete a session all in one go.

Your score should be recorded automatically, but as a double check against your score disappearing into a black hole:

My score was _____.

Your feedback on the experience:

What I liked about the tutorial was:

What I did not like about the tutorial was:

2. Proton-proton chain

Back in 1920, Eddington knew that mass and energy were equivalent ($E = mc^2$), and he knew that if the Sun could convert hydrogen into helium then it could be the mysterious source of the Sun's energy. However, there were two things he did not understand. First, how did 4 hydrogen nuclei (4 protons) manage to get together into 1 helium nucleus? Second, how did 2 of the protons convert into neutrons? It was not until 1938 that Hans Bethe solved these problems with the p-p chain. As regards Eddington's first problem, Bethe showed that hydrogen fusion in the Sun occurs through three steps, in each of which two nuclei collide and convert into something else.

Draw schematic diagrams that illustrate each of these three reactions. Each diagram should show two nuclei coming together to form other things.

As regards Eddington's second problem, in which of the three reactions is a proton converted to a neutron? As one of its by-products, the conversion produces a neutrino. What happens to this neutrino?

3. Sun Power

(a) Use the Stefan-Boltzmann law, $L = A\sigma T^4$, to determine the Sun's luminosity L in watts (W). Check that your answer agrees with the one in the book. [The Sun's area is $A = 4\pi R^2$ where the Sun's radius is $R = 696,000$ km. The Sun's surface temperature is $T = 5780$ K. The Stefan-Boltzmann constant is $\sigma = 5.67 \times 10^{-8}$ W/(m² K⁴). Make sure your units are consistent!]

The Sun's luminosity is _____ W.

(b) The Sun's luminosity L is equivalent to a certain mass loss rate, according to the equivalence of energy and mass, $E = mc^2$, where $c = 3 \times 10^8$ m/s is the speed of light. How much mass is the Sun radiating away per second? Express your answer in kilograms per second. [Basically all you have to do is divide the luminosity by c^2 .]

The Sun is radiating _____ kg/s.

(c) The Sun's mass is $M = 2 \times 10^{30}$ kg. How many years (1 year = 3×10^7 seconds) could the Sun last if it continued to radiate at its present rate, and could convert all its mass into energy with perfect efficiency? [You are given here the Sun's mass, and you have a mass loss per unit time from part (b), so to get a time you need to divide one by the other.]

The Sun could radiate for _____ yr.

(d) In practice, mass is generally not converted into energy with perfect efficiency. Instead, only some fraction of the mass is converted to energy. The following table shows the approximate efficiency (the fraction of mass which is converted to energy) for various different processes:

Energy	Efficiency
Chemical (e.g. coal)	10^{-8}
Gravitational contraction	10^{-6}
Fission (e.g. Uranium)	10^{-4}
Fusion (Hydrogen)	0.007
Matter-antimatter	1

From radioactive dating of carbonaceous chondrites, the Solar System and the Sun are thought to be about 4.6×10^9 years old. Which of the above processes could fuel the Sun for that time?

The Sun could be fueled by _____.