Homework #6

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Problem 1.

The Sun The energy production per unit time of the sun is equivalent to the luminosity of the sun; thus we can find

$$\frac{L_\odot}{M_\odot} = 1.92 \times 10^{-4}\,\mathrm{W\,kg^{-1}}. \tag{1}$$

The Human Body The "luminosity" of the human body is 2000 kilocalories per day; one calorie is 4.184 joules, and thus in SI units, $L_H = 96.8\,\mathrm{W}$. Assuming an 80 kg human, we have

$$\frac{L_H}{M_H} = 1.21\,\mathrm{W\,kg^{-1}}. \tag{2}$$

This means that the human body is roughly 6,289 times as luminous per kg as the sun is.

A Tesla Roadster The 2008-model Tesla Roadster has a maximum output power of 248 hp (or 185 kw), and weighs 1305 kg, giving us

$$\frac{L_T}{M_T} = 141.7\,\mathrm{W\,kg^{-1}}, \tag{3}$$

which is 117 times greater than the human body and 736,128 times greater than the sun.

Problem 2.

Alpha Particle The net reaction for the pp chain is

$$4\,\mathrm{H} \longrightarrow \mathrm{He} + \mathrm{E}, \tag{4}$$

where E is the energy from the loss in mass between 4H and He. The mass of H is $\Delta m_H = 7.28899\,\mathrm{MeV}$, and for He, $\Delta m_{He} = 2.42475\,\mathrm{MeV}$. Thus,

$$\Delta m = 4\Delta m_H - \Delta m_{He} = 26.73\,\mathrm{MeV}. \tag{5}$$

In order to account for the sun's luminosity, there would need to be 8.94×10^{37} reactions per second. Since each reaction yields one He, that would give us

$$m_{He} \times \left(8.94 \times 10^{37}\,\frac{\mathrm{reaction}}{\mathrm{s}}\right) = 5.94 \times 10^{11}\,\mathrm{kg\,s^{-1}}. \tag{6}$$

Carbon-12 Here we have $\Delta m_C = 0$, giving us

$$\Delta m = 3\Delta m_{H_e} - \Delta m_C = 7.27\,\mathrm{MeV}. \tag{7}$$