Answer on question #58698, Physics / Astronomy | Astrophysics

How long will a $5M_\Theta$ star burn hydrogen as fuel, given that the Sun will do so for about 10^10 years?

Solution:

Star`s lifetime equals to $t = \frac{E_{released}}{L}$, where $E_{released}$ - energy released after all hydrogen fusion into helium, L - star luminosity.

Solar luminosity equals to $3.828 \cdot 10^{33}\ erg/s$. For the star with $M=5M_\Theta$ the released amount of energy will be proportional to the mass, i.e.

$$5 \cdot E_{released} = 5 \cdot 10^{10} y \cdot 31556926 \frac{s}{y} \cdot 3.828 \cdot 10^{33} \frac{erg}{s} = 5 \cdot 1.21\ \cdot 10^{51}\ erg\ .$$

The increasing of mass leads to the increase of luminosity which is roughly proportional to $\frac{L}{L_\Theta} = \left(\frac{M}{M_\Theta}\right)^{\alpha}$, where $a \approx 3.9$

$\frac{L}{L_\Theta} = 5^{3.9} \approx 532.$

Then $L = 532 * L_\Theta = 532 \cdot\ 3.828 \cdot 10^{33}\ erg/s$

The final expression as follows

$$t = \frac{5 \cdot 1.21\ \cdot 10^{51}\ erg}{532 \cdot\ 3.828 \cdot 10^{33}\ erg/s} = 9.4 \cdot 10^{7}\ y$$

Answer: the star will burn its fuel in $9.4 \cdot 10^{7}\ y$