



## Star in a Box Worksheet - Beginning with solutions

☆ Launch *Star in a Box* and open the lid. The main plot is a Hertzsprung-Russell diagram. On the right, the information panel allows comparisons between the radius, surface temperature, luminosity and mass of the star relative to the Sun. The starting parameters are for a star like the Sun.

**A.** Click the play button below the Hertzsprung-Russell diagram to show the Sun's evolution. Once it is complete, you can click on "Data Table" (upper right) to see a range of parameters.

1. Describe how the Sun changes over its lifetime. The Sun's brightness and size will increase (with some thermal pulsations as helium burning starts) until it is ~200 times the size it started. At the point it loses its outer layers, exposing the core of the star, and its size drops to about 1/100th of its original size as a hot and very bright White Dwarf star. This has no thermonuclear reactions supporting it, so it gradually fades away.
2. When will the Sun be at its brightest? During the Asymptotic Giant Branch, when it is about 10,205.16 billion years old.
3. When will the Sun be at its hottest? During the Thermally-pulsing Asymptotic Giant Branch at 10209.76 billion years old.
4. In which stage of its life does the Sun spend the longest time? The Sun spends the most time on the main sequence.
5. In which stage of life will the Sun undergo the most change? The Sun undergoes the most change in size, luminosity and temperature between the two asymptotic giant branches.
6. What kind of star will the Sun be at the end of its life? A Carbon/Oxygen white dwarf.
7. How long will the Sun live for? 11,907.96 billion years

**B.** By adjusting the mass of the star in the "Star Properties" you can explore the evolution of different stars.

1. Where do the different mass stars lie on the main sequence? Smaller stars towards the bottom right, more massive stars towards the upper left.
2. List the different final stages of a star's life. Helium white dwarf, carbon/oxygen white dwarf, neutron



star, black hole.

**C.** Follow the evolution for five stars with different masses. Complete the table below filling in a row for each mass.

Mass of star ( $M_{\text{Sun}}$ )	Time on main sequence (Myr)	Number of stages	Final state	Total lifespan (Myr)	Maximum radius ( $R_{\text{Sun}}$ )	Maximum luminosity ( $L_{\text{Sun}}$ )	Maximum temperature (K)
0.2	868,300.00	4	Helium White Dwarf	1,034,300	0.33	87.78	119,316
.65	57,610.00	4	Helium White Dwarf	62,450	1.45	422.47	191,117
1	8992.81	7	Carbon/Oxygen White Dwarf	10,210.26	200.26	3910.21	194,312
2	1163.03	7	Carbon/Oxygen White Dwarf	1491.92	204.31	4656.93	233,346
4	178.91	7	Carbon/Oxygen White Dwarf	214.64	353.02	14,154.68	322,701
6	65.96	7	Carbon/Oxygen White Dwarf	76.2	444.02	23,621.09	434,410
10	24.46	6	Neutron star	27.44	748.00	64,520.84	1,942,227
20	8.82	5	Neutron star	9.84	1507.39	191,029.31	2,123,244
30	5.95	6	Black hole	6.66	1142.88	266,317.68	129,062
40	4.87	6	Black hole	5.48	1433.51	425,402.46	132,008

**D.** Compare the data table for a range of stars.

- Are more massive stars the brightest and hottest types of star for their whole lives? **No**
- Which mass star gets the hottest? **The 20 Solar mass star appears to get the hottest, but I suspect it is really the 40 Solar mass one.**
- Which mass star gets the coolest? **The 0.2 solar mass star has a low temperature of 2995 K. Otherwise, the 30 and 40 solar mass stars end in black holes at 0 K.**



4. Which mass star becomes the most luminous? **The 40 solar mass star has the highest luminosity at 425,402.46 solar luminosities.**

**E.** *Deneb and Betelgeuse are both 20x the mass of the Sun, but look very different. Deneb has 100 times the radius of the Sun and its temperature is about 8000 K. Betelgeuse has 1000 times the radius of the Sun and its temperature is about 3500 K.*

1. What stages of their lives are the two stars in? **Deneb is between the main sequence and the Hertzsprung Gap. Betelgeuse is between the Hertzsprung Gap and core helium burning.**
2. How long does each star have to live? **Deneb has about 1 million years left to live and Betelgeuse has about 400 thousand years to live. Their lives end when they go supernova.**