Star in a Box

The Lifecycle of Stars Answer Sheet

* Open the following link in a web browser <https://starinabox.lco.global>
* Open the lid of your ‘Star in a Box’.
* The graph is a Hertzsprung-Russell diagram, where a star’s luminosity is plotted against its temperature.
* The information panels allow comparison between the radius, surface temperature, brightness (luminosity) and mass of the star relative to the Sun.

# A. 1 Solar Mass Star

* Press play to watch the evolution of your star on the Hertzsprung-Russell diagram.
* Click on the data table tab and download the CSV file for your 1 Solar mass star and save it in a spreadsheet.
* Using Excel, plot graphs of Mass, Luminosity, Surface Temperature and Radius against time.

1. Describe how the Luminosity of this star changes with time.

Luminosity remains constant at about 1 Lsun until about 10,000 Myr when it suddenly (and briefly) increases to over 4500 Lsun.

1. Describe how the radius of this star changes with time.

Radius remains constant at about 1 Rsun until about 10,000 Myr when it suddenly (and briefly) increases to over 200 Rsun.

1. Describe how the mass of this star changes with time.

Mass remains constant at about 1 Msun until about 10,000 Myr when it decreases to approximately 0.5 Msun and remains mostly constant at this value.

1. Describe how the surface temperature of this star changes with time.

Surface temperature is constant at about 6000K until 10,000 Myr when it suddenly and briefly increases to almost 200,000K before returning to around 6000K and decreasing more gradually.

1. At around 10,000 Myr this stars life changes stage. What are the names of the stages it changes from and to?

Star changes from Main Sequence to Red Giant

NB: Students may have zoomed in and noticed that on the luminosity and radius graphs, there are in fact 2 peaks, this is considered in Part B below . It is not directly examined.

# B. Stretch and Challenge

* You may need to refer to textbooks or the internet to answer these questions.

1. If you zoom in on the peaks of the luminosity and radius graphs, you will see that there are in fact two peaks. Suggest why you think this happens.

The 1st peak occurs when hydrogen fusion stops. The trough between the peaks is when Helium fusion is occurring. The 2nd peak occurs when helium fusion stops.

1. Using your knowledge of processes involved during this stars lifecycle, explain what is happening within the core of the star to cause the sudden changes in luminosity and temperature?

The dominant type of fusion has changed. The core of the star has collapsed under gravity as there is no longer an outward pressure from the radiation to create balanced forces. This collapse causes the temperature to suddenly increase. The outer layer of the star expands to a Red Giant and the increase in radius and temperature causes an increase in luminosity (Stefan’s Law).

1. What happens to the mass that is lost from the star after the red giant stage?

The mass is ripped of the star and forms a planetary nebula. This enriches the interstellar medium with the heavier elements such as carbon.

# C. 30 Solar Mass Star

* Using the ‘Star Properties’ banner, select a star with a starting mass of 30 Msun.
* Press play to watch the evolution of your new star on the Hertzsprung-Russell diagram.
* Click on the data table tab and download the CSV file for your 30 Solar Mass star and plot the same graphs as in part A.

1. How does the luminosity graph for the 30 solar mass star compare with the luminosity graph from the 1 solar mass star? State the differences in timescale and the changes in luminosity.

Time scale for the 30 solar mass star is much less (1 solar mass = 10,000 Myr 🡪 30 solar mass = 10 Myr). The 30 solar mass star increases its luminosity much more gradually over its lifetime than the 1 solar mass does. The 30 solar mass star reaches a much greater luminosity (300, 000 Lsun rather than 4500 Lsun).

1. Compare how the mass of these two stars changes,
   1. During their time spent on the main sequence?

On the main sequence, a 30 solar mass star loses a larger proportion of its mass (30 to 28 Msun) than a 1 solar mass star (1 to 0.9 Msun) does.

* 1. Over their whole lifetime?

The total change in mass for 30 Msun star is 30Msun to 6Msun, for the 1 Msun star it changes 1Msun to 0.5Msun.

# D. Wien’s Law

* Using the data table on the Star in a Box website and your knowledge of Wien’s Law, complete the following table.

*HINT: Wien’s Law: λmax T = 2.898 x10-3  m.K*

|  |  |  |  |
| --- | --- | --- | --- |
| Mass of Star (Msun) | Main Sequence Temperature (K) | Main Sequence λmax (μm) | Region of EM spectrum |
| 1 | 5,788 | 0.501 | Visible (green) |
| 2 | 7,332 | 0.395 | Visible (violet) |
| 6 | 14,655 | 0.198 | Ultraviolet |
| 10 | 21,622 | 0.134 | Ultraviolet |
| 20 | 26,872 | 0.107 | Ultraviolet |
| 30 | 27,765 | 0.104 | Ultraviolet |
| 40 | 27,492 | 0.105 | Ultraviolet |

# E. Stefan-Boltzmann Law

* Using the data table on the Star in a Box, complete the following table.

*HINTS: Assume all the stars are spherical.*

*You will need to convert some of the values into SI units.*

*Lsun = 3.8 x 1026 W Rsun = 3 x 108 m Stefan’s Law:*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Mass of Star (Msun) | Main Sequence Temperature (K) | Main Sequence Radius (Rsun) | Main Sequence Radius (m) | Surface Area of Main Sequence Star (m2) | Main Sequence Luminosity (Lsun) | Main Sequence Luminosity (W) |
| 1 | 5,788 | 1.69 | 0.507x109 | 32.23 x1018 | 2.82 | 1.07 x1027 |
| 2 | 7,332 | 3.71 | 1.11 x109 | 1.54 x1019 | 1,163.03 | 4.42 x1029 |
| 6 | 14,655 | 7.48 | 2.24 x109 | 6.31 x1019 | 2,286.13 | 8.69 x1029 |
| 10 | 21,622 | 9.34 | 2.80 x109 | 9.85 x1019 | 16,873.30 | 6.41 x1030 |
| 20 | 26,872 | 15.56 | 4.67 x109 | 2.74 x1020 | 111,686.32 | 4.24 x1031 |
| 30 | 27,765 | 22.18 | 6.65 x109 | 5.58 x1020 | 258,702.13 | 9.83 x1031 |
| 40 | 27,492 | 29.01 | 8.70 x109 | 9.51x1020 | 425,402.46 | 1.62 x1032 |

* Calculate the Stefan-Boltzmann constant.

1. What quantities will you need to plot on the x and y axis in order to produce a straight line graph, with a gradient equal to the Stefan-Boltzmann constant?

Plot y = Luminosity, x = AT4

1. Using the data in your table above and the quantities you suggested in question 1, draw a graph in Excel to calculate an approximate value for the Stefan-Boltzmann constant σ.

Gradient of straight line graph = Stefan-Boltzmann constant, σ = 5.51 x 10-8 W m-2 K-4

(Actual value is 5.67x10-8 Wm-2K-4).

# F. Multiple Choice Questions

* Circle the correct answer.

1. On a Hertzsprung-Russell diagram, white dwarfs are found in the

Top Left Corner Top Right Corner Bottom Left Corner Bottom Right Corner

1. Compared to white dwarf stars, Red Giant stars are

Hotter and Brighter Hotter and Dimmer Cooler and Brighter Cooler and Dimmer

1. For two stars with the same radius, the star with the greater surface temperature will have a greater luminosity.

True False It depends on the mass of the star

1. At the end of its life, a star with an initial mass of 40 Solar Masses will become

A white dwarf A Red Giant A Supernova A Black Hole

1. Which of the following statements is true for a star on the Main sequence?
2. The inward gravitational force is greater than the outward radiation pressure.
3. Hydrogen fusion is occurring within the stars core to create Helium.
4. Hydrogen fusion is occurring within the star’s core to create heavy elements e.g. Carbon.
5. The star is at its maximum radius.