Hertzsprung-Russell Diagram Activity Sheet

This worksheet should be paired with the Hertzsprung-Russell Diagram Online Simulation found at: https://bit.ly/HRsimulation

The **Hertzsprung-Russell (HR) Diagram** is one of the most fundamental tools in stellar astronomy. It is a scatter plot that graphs stars according to two of their fundamental properties: **Luminosity** on the vertical axis (with low luminosity at the bottom and high luminosity at the top), and **Surface Temperature** on the horizontal axis (with high temperature on the **left** and low temperature on the **right**).

The H-R diagram is usually shown with **logarithmic scaling** (often called a "log-log" plot). This allows the plot to include a huge range in order to capture the wide spread of values stars can exhibit in luminosity and temperature. This means that **equal physical distances** on the plot represent **equal factors of change** in the star's property. For example, the distance between 1 L_{Sun} and 10 L_{Sun} is the same as the distance between 10 L_{Sun} and 100 L_{Sun} because both represent a **factor of 10 increase**. This can take getting used to, so make sure to take your time!

The simulation allows you to sample different points on the HR diagram by changing both luminosity and temperature and observing what kind of star that would produce, what its **radius** would be, and where it would be located on the diagram.

Learning Goals:

1. **Predict** and **explain** how a star's color changes as its surface temperature increases and decreases
2. **Investigate** and **determine** how a star's radius is affected by changes in temperature and luminosity.
3. **Explain** the underlying physical connection between radius, temperature, and luminosity
4. **Justify** why stars with the same luminosity can have vastly different temperatures, relating the difference to the star's radius.
5. **Compare** and **Rank** stars' radius based on their location on the HR diagram
6. **Classify** a star as a White Dwarf, Main Sequence Star, or Red Giant by its position on the H-R diagram, and **verify** the classification using its measured properties.
7. **Determine** whether all Main Sequence Stars have the same radius, and if not **Identify** which ones are the largest in relation to temperature and luminosity.

1. Open Play (https://bit.ly/HRsimulation)
   Play with the simulation for 5 minutes moving the temperature and luminosity sliders. Describe three things you notice:
   -
   -
   -

2. Set the Luminosity slider to a fixed value and move the Temperature slider from low to high. Describe how the **color** of the star changes with temperature.

3. Set the Luminosity slider to a fixed value and move the Temperature slider from low to high. Describe how the **radius** of the star changes with temperature for a set luminosity.

4. Set the **Temperature** slider to a fixed value and move the **Luminosity** slider from low to high. Describe how the **Radius** of the star changes with luminosity for a set temperature.

5. **Quantify:** use the sliders to fill in the **Radius** column in the table below.

Radius (R_{Sun})	Temperature (K)	Luminosity (L_{Sun})
	4,000	250
	4,000	1,000
	5,000	10,000
	20,000	10,000

6. **Analyze:** Use the data in your completed table above to investigate the relationships between the three variables.

a. **Effect of Luminosity:** Identify two rows in the table where the **Temperature** remains the same, but the **Luminosity** changes. Describe the resulting change in the star's **Radius**.

b. **Effect of Temperature:** Identify two rows in the table where the **Luminosity** remains the same, but the **Temperature** changes. Describe the resulting change in the star's **Radius**.

c. **Comparison:** Based on your results in (a) and (b), which variable (Temperature or Luminosity) has a much **stronger impact** on determining a star's radius?

7. The Stefan-Boltzmann law for the radius of a star is given by: $R = \sqrt{\frac{L}{4\pi\sigma T^4}}$

   Explain how this equation predicts the difference in impact you observed in Question 6(c).

8. *Conversation between two students about luminous stars:*

   Student 1: I want to make the **most luminous** star possible. I think it will also need to be **super hot**, since I know hot things are more luminous. Just think about heating up a piece of metal: the hotter it gets, the brighter it glows! This means the most luminous stars must be white or blue in color, just like white-hot metal.

   Student 2: Making it hot is definitely *one* way to boost luminosity, but look at the HR diagram. There are stars in the **upper-right** quadrant that are incredibly bright, even though they're at a much **cooler, red temperature**. Those stars have huge **radii**, too! I think you can still make a star extremely luminous just by making it **enormously big**, even if its temperature is low. The massive surface area makes up for it not being as hot.

   Which student do you agree with? Explain your reasoning.

9. Use the sliders in the simulation to place the star in the **upper-right** part of the HR diagram. Circle the correct word in each pair of <u>underlined</u> words to best match what you find:

   Stars in the **upper-right** part of the HR diagram are very **<u>Luminous/Dim</u>** and have relatively **<u>Large/Small</u>** radii. They are also very **<u>Hot/Cool</u>**, and therefore **<u>Blue/Red</u>** in color. A good name for these stars would be:

   A. White Dwarfs
   B. Red Dwarfs
   C. Red Giants

10. Use the sliders in the simulation to place the star in the **lower-left** part of the HR diagram. Circle the correct word in each pair of <u>underlined</u> words to best match what you find:

    Stars in the **lower-left** part of the HR diagram are very **<u>Luminous/Dim</u>** and have relatively **<u>Large/Small</u>** radii. They are also very **<u>Hot/Cool</u>**, and therefore **<u>Blue/Red</u>** in color. A good name for these stars would be:

    A. White Dwarfs
    B. Red Dwarfs
    C. Red Giants

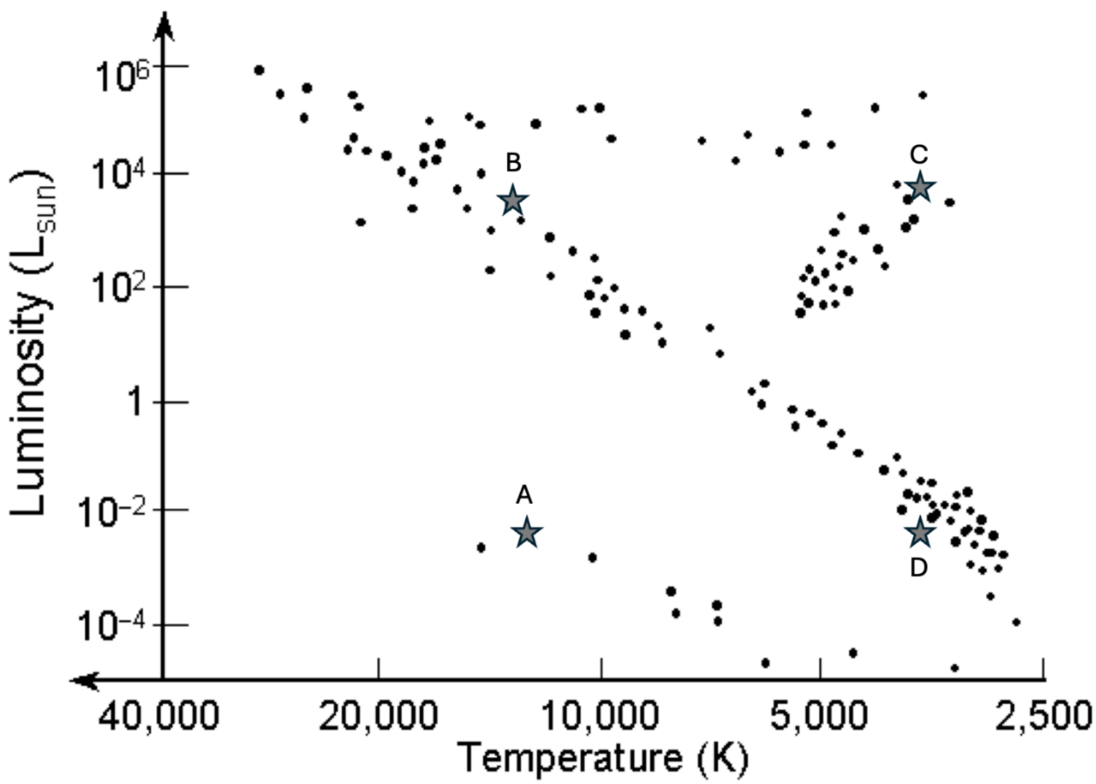
11. The band of stars that run along the diagonal from the top-left to bottom-right of the HR diagram are called Main Sequence stars.

    a. Manipulate the sliders to investigate stars all along the Main Sequence band. Do all Main Sequence stars appear to have the same radius?

    b. Identify the trend: based on the radius readout in the simulation, which end of the Main Sequence contains the largest stars: The **hot, luminous** end (Upper-Left)? Or the **cool, dim** end (Lower-Right)?

12. **Ranking**: On the diagram below, rank stars A, B, C, and D in order of largest to smallest **Radius.** Make your predictions before verifying using the simulation.

Largest radius _____ > _____ > _____ > _____ Smallest radius



13. **Real Stars**: below is a table of radii/temperatures/luminosities of real stars in our galaxy. Use the sliders to determine the missing values in the table and where each star would be located on the HR diagram and use this to determine whether each star is a white dwarf (WD), red giant (RG), or main sequence (MS) star. Complete the table and plot the location of each star on the HR diagram below.

Star	Radius (R_{Sun})	Temperature (K)	Luminosity (L_{Sun})	Type (WD, RG, MS)
Sirius A	1.7		25	
Sirius B		25,000	0.025	
Betelgeuse	640	3,600		
Vega	2.7		47	
Arcturus	25	4,300