

HR Diagram – Student Guide

Background Information

Work through the background sections on Spectral Classification, Luminosity, and the Hertzsprung-Russell Diagram. Then complete the following questions related to the background information.

Question 1: The table below summarizes the relationship between spectral type, temperature, and color for stars. Note that the surface temperature of the stars in the table increases.

| Star | Surface Temperature K | Spectral Type | Color |
|---------------|-----------------------|---------------|--------------|
| Betelgeuse | | M2 | |
| Arcturus | 4,300 | | |
| | | G2 | Yellow |
| Procyon A | | F5 | Yellow-White |
| Sirius A | | A1 | White |
| Rigel A | 11,000 | | |
| Delta Orionis | | O9 | |

Question 2: Complete the following table related to stellar luminosities in solar units using the equation $L \propto R^2 T^4$.

| Radius (R_{\odot}) | Temperature (T_{\odot}) | Luminosity (L_{\odot}) |
|------------------------|-----------------------------|----------------------------|
| | 1 | 1 |
| 1 | 2 | |
| | 1 | 9 |
| 1 | 1/2 | |

Question 3: The mass luminosity relation $L \propto M^{3.5}$ describes the mathematical relationship between luminosity and mass for main sequence stars. It describes how a star with a mass of $2 M_{\odot}$ would have a luminosity of _____ L_{\odot} while a star with luminosity of $3,160 L_{\odot}$ would have an approximate mass of _____ M_{\odot} .

HR Diagram Explorer

Open the **HR Diagram Explorer**. Begin by familiarizing yourself with the capabilities of the Hertzsprung-Russell Diagram Explorer through experimentation.

- An actual **HR Diagram** is provided in the upper right panel with an active location indicated by a red x. This active location can be dragged around the diagram. The **options panel** allows you to control the variables plotted on the x-axis: (temperature, B-V, or spectral type) and those plotted on the y-axis (luminosity or absolute magnitude). One can also show the main sequence, luminosity classes, isoradius lines, or the instability strip. The **Plotted Stars** panel allows you to add various groups of stars to the diagram.
- The **Cursor Properties** panel has sliders for the temperature and luminosity of the active location on the HR Diagram. These can control the values of the active location or move in response to the active location being dragged. The temperature and luminosity (in solar units) are used to solve for the radius of a star at the active location.
- The **Size Comparison** panel in the upper left illustrates the star corresponding to the active location on the HR Diagram. Note that the size of the sun remains constant.

Exercises

- Drag the active location around on the HR Diagram. Note the resulting changes in the temperature and luminosity sliders. Now manipulate the temperature and luminosity sliders and note the corresponding change in the active location.

Question 4: Check the appropriate region of the HR diagram corresponding to each description below.

| Description | Top | Right | Bottom | Left |
|----------------------------------|-----|-------|--------|------|
| Hot stars are found at the: | | | | |
| Faint stars are found at the: | | | | |
| Luminous stars are found at the: | | | | |
| Cool stars are found at the: | | | | |

- Drag the active location around on the HR Diagram once again. This time focus on the Size Comparison panel.

Question 5: Check the appropriate region of the HR diagram corresponding to each description below.

| Description | Upper Left | Upper Right | Lower Right | Lower Left |
|--|---------------|----------------|----------------|---------------|
| Large Blue stars are found at the: | | | | |
| Small Red stars are found at the: | | | | |
| Small Blue stars would be found at the: | | | | |
| Really Large Red stars are found at the: | | | | |

- Check show isoradius lines. Note that at each point on a green line, stars have the same value of radius. Use these isoradius lines to check your answers in the table above.

Question 6: The equation below describes the luminosity of a star in terms of its radius and temperature. Use this equation to explain the results you found in the table of the previous question.

$$L = 4\pi R^2 \sigma T^4$$

- In addition to the isoradius lines, check **show luminosity classes**. This green region (dwarfs V) is known as the main sequence and contains all stars that are fusing hydrogen into helium as their primary energy source. Over 90% of all stars fall in this region on the HR diagram. Move the active cursor up and down the main sequence and explore the different values of stellar radius.

Question 7: Describe the sizes of stars along the main sequence. What are stars like near the top of the main sequence, the middle, and the bottom?

- The background pages of this module talked about the mass-luminosity relationship for stars on the main sequence:

$$L \propto M^{3.5}$$

Question 8: What can you conclude about the masses of stars along the main sequence?

Question 9: Use the results from the previous 5 questions to construct a “conceptual” HR Diagram. You simply want to draw arrows showing the direction in which variables are increasing.

- a) Draw in an arrow on the y axis showing the direction of increasing “intrinsic luminosity” of the stars. (This is complete for you.)
- b) Draw in an arrow on the x-axis showing the direction of increasing surface temperature of the stars.
- c) Draw in an arrow showing the direction of increasing radius on the diagram. (hint: this must be perpendicular to the isoradius lines.)
- d) Draw in an arrow showing the direction of increasing mass for main sequence stars on the diagram. (Note that his arrow only applies to main sequence stars, but that is over 90% of stars.)

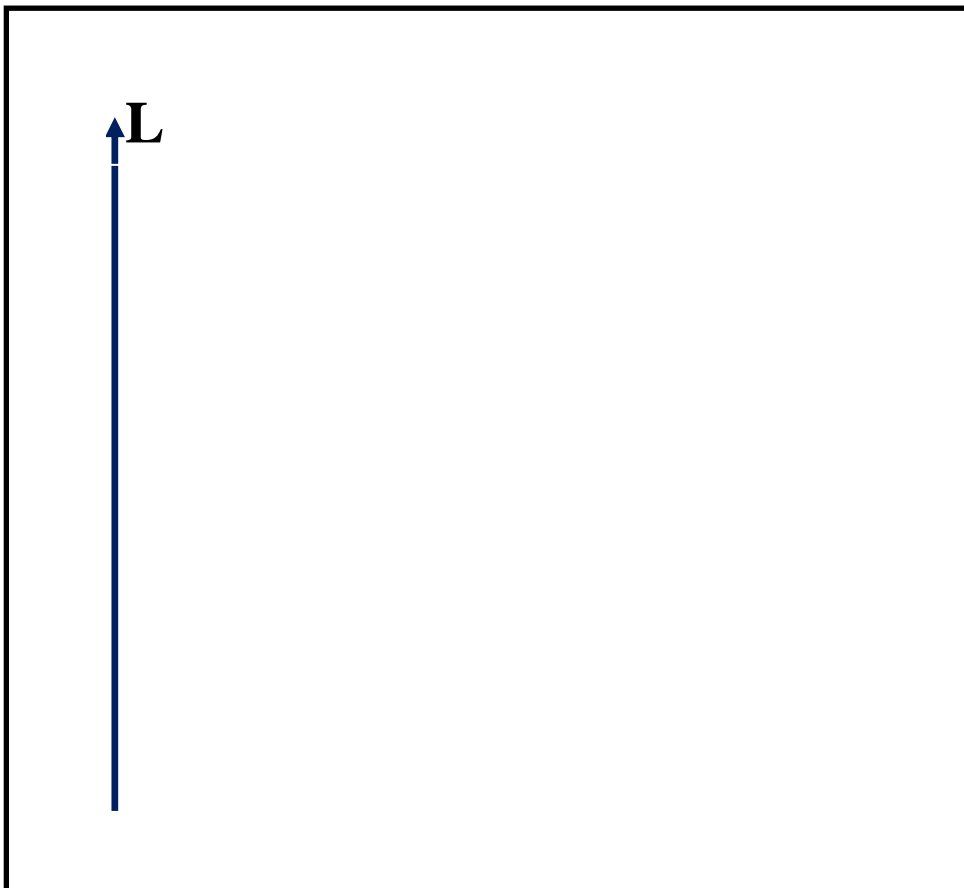


Figure 1: Conceptual HR Diagram

- Uncheck show luminosity classes and check **show instability strip**. Note that this region of the HR Diagram indicates where pulsating stars are found such as RR Lyrae stars and Cepheid variable stars. These stars vary in brightness because they are pulsating – alternately growing bigger and smaller – which changes their radii and surface temperatures and resulting their luminosities.

Question 10: Describe the characteristics of stars that are found in the instability strip. You should cover their range of temperatures, colors, luminosities, and sizes. (Hint: Comparing them to the sun is useful.) Are variable stars necessarily on the main sequence?

- Check the plotted stars option **the nearest stars**. You should cover their range of temperatures, colors, luminosities, and sizes.

Question 11: Describe the characteristics of the nearest stars.

Question 12: Do you think these stars are rare or very common among all of the stars of our galaxy? Explain your reasoning. Are any assumptions involved in your reasoning?

- Uncheck the plotted stars option **the nearest stars** and check **the brightest stars**. Why are these stars the brightest in the sky? Three students debate this issue:

Student A: “I think it’s because these stars must be very close to us. That would make them appear brighter to us in the sky.”

Student B: “I think it’s because these stars are very luminous. They are putting out a tremendous amount of energy.”

Student C: “I think it’s because these stars are very close and very luminous.”

Question 13: Use the tools of the HR Diagram to support the views of one of the three students. Why are the stars we perceive as bright in the night sky really bright?” (hint: You may find the options labeled **both the nearest and brightest stars** and **the overlap** useful.)

Question 14: Do you think that these bright stars are very common (make up a large percentage of all stars in general)? Explain your reasoning.

Deriving the Isoradius Lines (optional, mathematical section)

$$L = R^2 T^4$$

$$\log L = \log(R^2 T^4)$$

$$\log L = \log R^2 + \log T^4$$

$$\log L = 2\log R + 4\log T$$

Question 15: The HR Diagram is a log-log plot of the solar units equation $L=R^2T^4$. Use the boxed equations to argue that isoradius lines on the HR Diagram must be parallel lines.

Question 16: Complete the table below. Then add the points to the following HR Diagram and use them to draw in the isoradius lines for 1, 10, and 100 solar radii.

| Symbol | L (L_{\odot}) | R (R_{\odot}) | T (T_{\odot}) |
|----------|-------------------|-------------------|-------------------|
| x | 1 | 1 | 1 |
| A | | 1 | $\sqrt[4]{10}$ |
| B | | 1 | $\sqrt{10}$ |
| C | | 10 | 1 |
| D | 1,000 | 10 | |
| E | | 10 | $\sqrt{10}$ |
| F | | 100 | 1 |
| G | | 100 | 2 |
| H | | 100 | 0.5 |

HR Diagram

