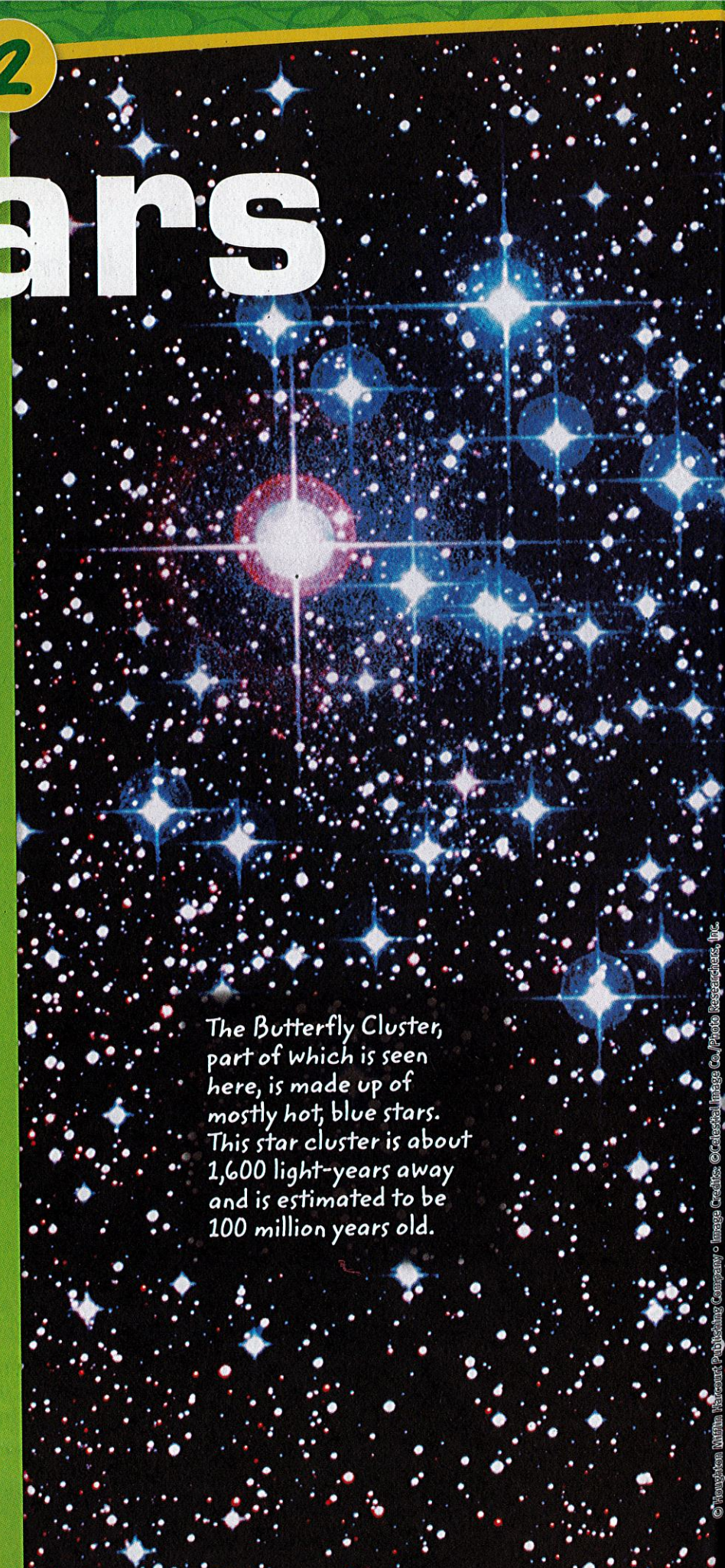


Stars

ESSENTIAL QUESTION

What are some properties of stars?

By the end of this lesson, you should be able to describe stars and their physical properties.



The Butterfly Cluster, part of which is seen here, is made up of mostly hot, blue stars. This star cluster is about 1,600 light-years away and is estimated to be 100 million years old.

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Lesson Labs

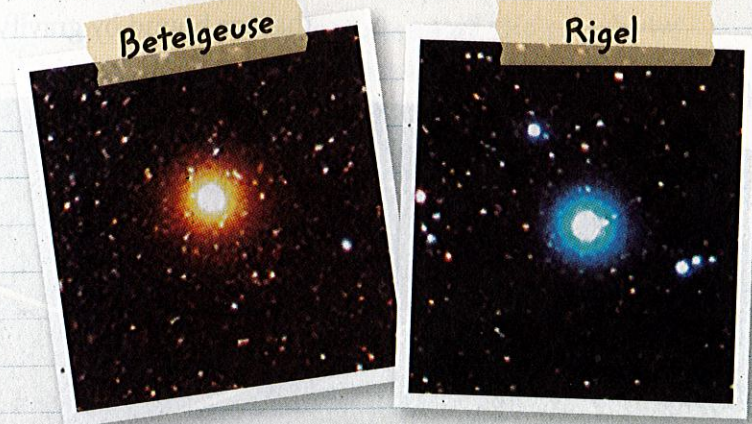
- Quick Labs**
- Modeling Star Magnitudes
 - Using a Sky Map
- Exploration Lab**
- Star Colors and Temperatures

Engage Your Brain

1 Predict Check T or F to show whether you think each statement is true or false.

- | | | |
|--------------------------|--------------------------|---|
| T | F | |
| <input type="checkbox"/> | <input type="checkbox"/> | The sun is a star. |
| <input type="checkbox"/> | <input type="checkbox"/> | Stars are made mostly of nitrogen and oxygen. |
| <input type="checkbox"/> | <input type="checkbox"/> | If two stars have the same apparent magnitude, they are the same distance from Earth. |
| <input type="checkbox"/> | <input type="checkbox"/> | Red stars have higher surface temperatures than blue stars. |
| <input type="checkbox"/> | <input type="checkbox"/> | Some stars are about as small as Earth. |

2 Describe In the images below, the stars Betelgeuse (left) and Rigel (right) are shown. Both stars are located in the constellation Orion. Describe any differences between these two stars that you see in this pair of images.



Active Reading

3 Synthesize Many English words have their roots in other languages. Use the Latin word below to make an educated guess about the meaning of the word *luminosity*.

Latin word	Meaning
<i>lumen</i>	light

Example sentence.
The luminosity of stars is measured relative to the luminosity of the sun.

luminosity:

Vocabulary Terms

- star
- apparent magnitude
- luminosity
- absolute magnitude

4 Apply As you read, place a question mark next to any words that you don't understand. When you finish reading the lesson, go back and review the text that you marked. If the information is still confusing, consult a classmate or a teacher.

Reach for the Stars!

What is a star?

Active Reading

5 Identify As you read the text, underline any physical properties of stars that are discussed.

A **star** is a large celestial body that is composed of gas and emits light. The sun is a star. Stars are made mostly of hydrogen and helium. But stars also contain other elements in small amounts. Stars emit light and vary in brightness. Although the sun may appear bright from Earth, the sun is not a bright star in comparison to many other stars. The temperatures of stars also vary. These differences in temperature result in differences in color. Stars may range in color from red, which indicates a cool star, to blue, which indicates a very hot star. The sun is a relatively cool yellow star. Stars have different sizes. Stars may be 1/100 as large as the sun or as much as 1,000 times as large as the sun. In addition, two or more stars may be bound together by gravity, which causes those stars to orbit each other. Three or more stars that are bound by gravity are called *multiple stars* or *multiple star systems*.

Visualize It!

6 Describe Write in the correct answer for each question.

Theta Orionis in the Orion Nebula is a multiple star.

A Describe What is the color of this star?

B Describe What is the color of this star?

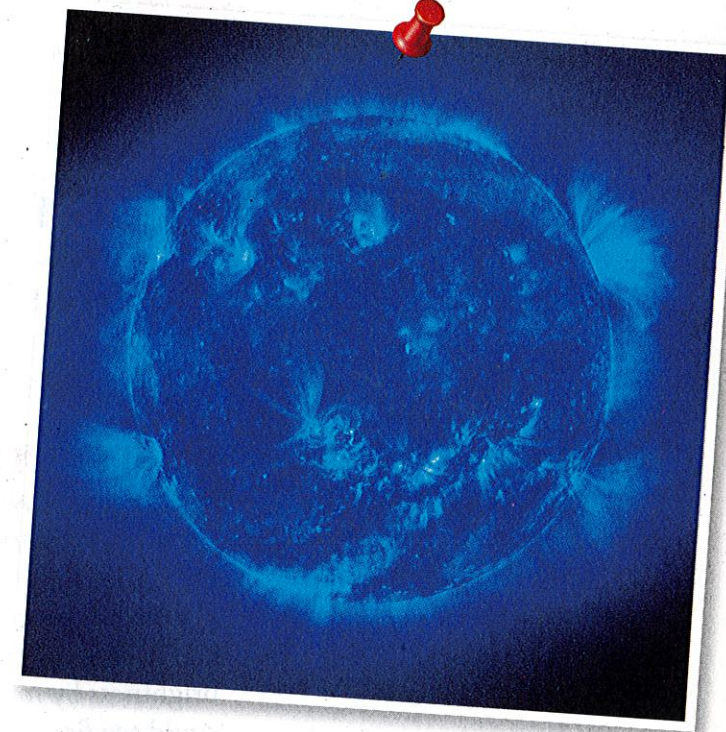
C Describe Is this bright area one star or more than one star?

The Sun Is a Star

To see a star, you need look no farther than the sun. The sun, like other stars, is composed mostly of hydrogen and helium. The sun also contains oxygen, carbon, neon, and iron.

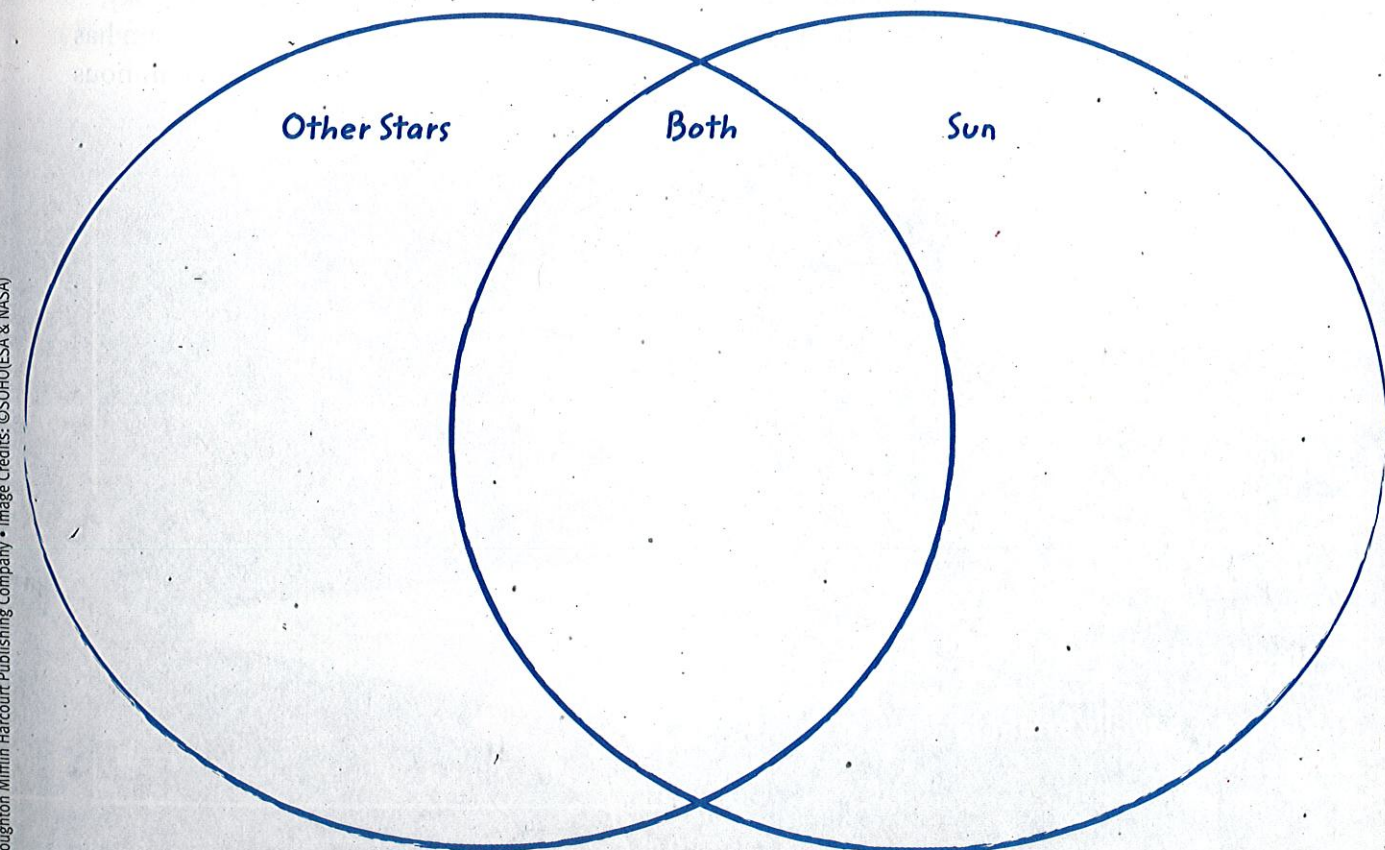
At the center of the sun lies the core. In the sun's core, gases are compressed and heated, and temperatures reach 15,000,000 °C. The core is where matter is converted into energy.

The sun's surface, the photosphere, is the layer of the sun's atmosphere that we see from Earth. The photosphere has an average temperature of 5,527 °C. From the core, energy is continuously transferred to the photosphere. There, energy escapes into space as visible light, other forms of radiation, heat, and wind. The sun's atmosphere extends millions of kilometers into space. Temperatures in the sun's middle atmosphere, the chromosphere, are 4,225 °C to 6,000 °C. In the sun's outer atmosphere, or corona, temperatures may reach 2,000,000 °C.



This extreme ultraviolet image of the sun shows areas of different temperature that are found in the sun's atmosphere.

7 Compare Fill in the Venn diagram to compare and contrast the physical properties of the sun with the physical properties of other stars.



You're a Shining Star

How is star brightness measured?

When you look at stars in the night sky, you see that stars vary in brightness. Some stars are bright, and other stars are dim. In reality, one star can appear brighter than another star simply because it is located closer to Earth.

Active Reading

8 Define As you read the text, underline the definition of *apparent magnitude*.

By Apparent Magnitude

Apparent magnitude is the measure of a star's brightness as seen from Earth. Some stars are actually more luminous, or brighter, than the sun is. If these stars are located far from Earth, they may not appear bright to us.

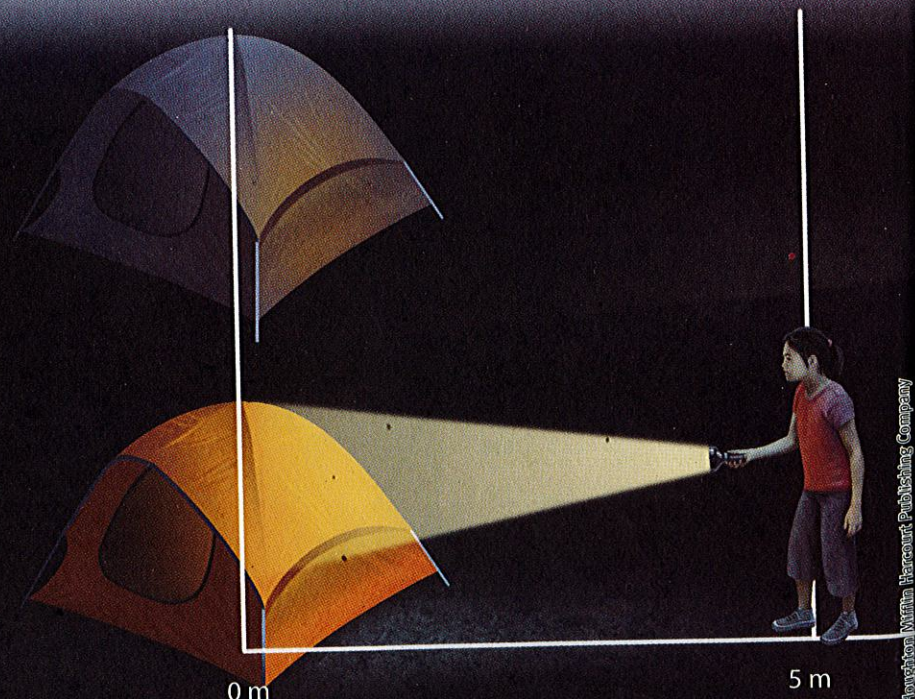
Using only their eyes, ancient astronomers described star brightness by magnitude. They called the brightest stars they could see *first magnitude* and the faintest stars they could see *sixth magnitude*. Astronomers using telescopes see many stars that are too dim to see with the naked eye. Rather than replacing the magnitude system, astronomers added to it. Today, the brightest stars have a magnitude of about -2 . The faintest stars that we can see with a telescope have a magnitude of $+30$.

The magnitude scale may seem backward. Faint stars have positive (larger) numbers; bright stars have negative (smaller) numbers. Sirius (SIR•ee•uhz), the brightest star in the night sky, has an apparent magnitude of -1.46 . To the naked eye, the sun has an apparent magnitude of -26.8 , even though it is not as luminous a star as Sirius is. The sun is simply located closer to Earth.

Visualize It! Inquiry

9 Analyze How does the light from a flashlight that is shone from two different distances model the apparent magnitude of two stars with the same absolute magnitude?

This girl is approaching her tent in the dark. The tent is dimly lit by the flashlight beam when she is 20 m away. The tent is well lit by the flashlight beam when she is 5 m away. The beam appears dimmer at 20 m than at 5 m, but the flashlight is equally bright in both cases.



How is star luminosity measured?

When astronomers use the word **luminosity**, they mean the *actual* brightness of a star. To measure a star's luminosity, astronomers use an absolute brightness scale called *absolute magnitude*.

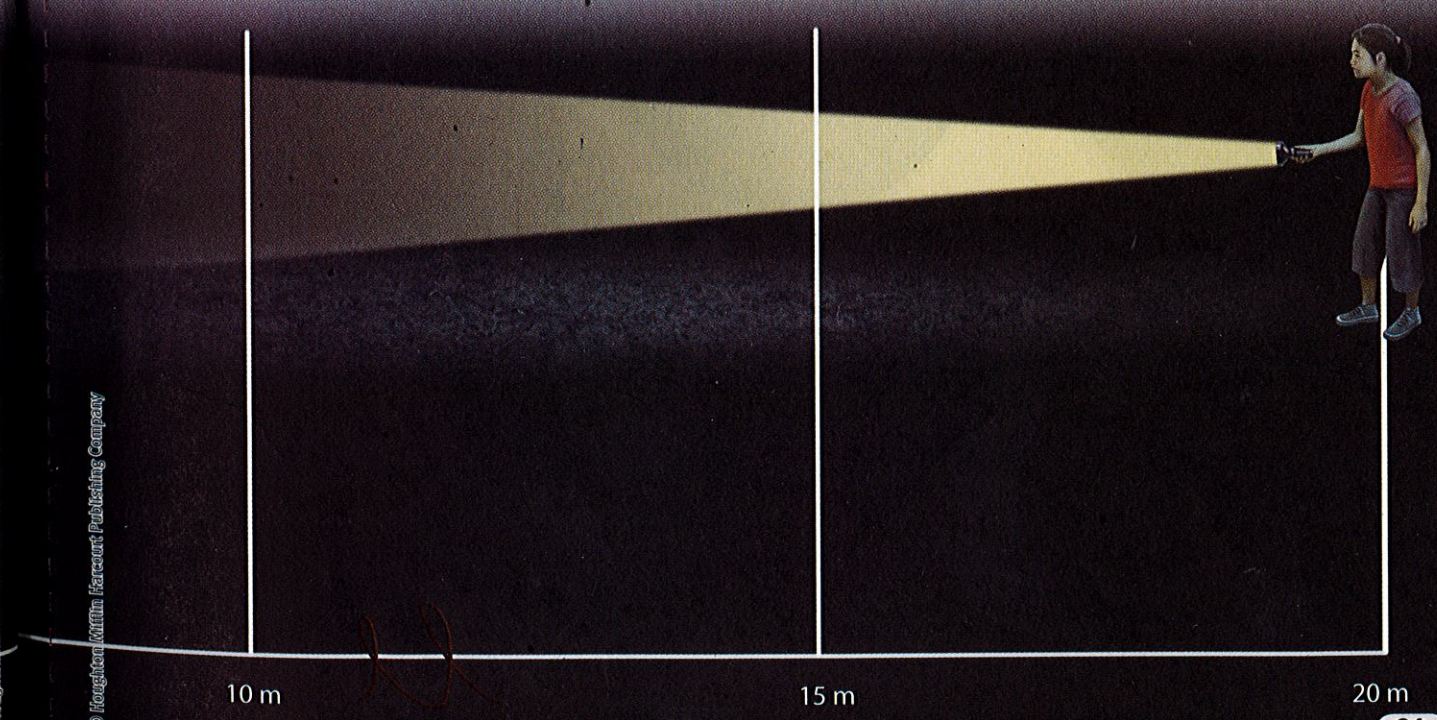
By Absolute Magnitude

Absolute magnitude is a measure of how bright a star would be if the star were located at a standard distance. In other words, absolute magnitude is a measure of the brightness of a star whose distance from Earth is known. Just like apparent magnitude, absolute magnitude uses the magnitude scale.

To understand the difference between apparent magnitude and absolute magnitude, let's use the sun as an example. The apparent magnitude of the sun is -26.8 . However, the absolute magnitude of the sun is $+4.8$, which is typical of many stars. Now compare the sun, which is located 8.3 light-minutes from Earth, to Sirius, which is located 8.6 light-years from Earth. Sirius has an apparent magnitude of -1.46 and an absolute magnitude of $+1.4$. Therefore, Sirius is much more luminous than the sun is.

10 Explain Why does a star such as Betelgeuse, which is located far from Earth, have a much greater absolute magnitude than apparent magnitude?

Magnitudes of Selected Stars			
Star	Distance from Earth	Apparent Magnitude	Absolute Magnitude
sun	8.3 light-minutes	-26.8	$+4.8$
Sirius	8.6 light-years	-1.46	$+1.4$
Betelgeuse	640 light-years	$+0.45$	-5.6



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Too Hot to Handle

How are the surface temperatures of stars measured?

If you look into the night sky, you may be able to see that stars have different colors. Why do the colors of stars vary? The answer is that differences in the colors of stars are due to differences in their surface temperatures. The same is true of all objects that glow.

By Color

You can see how temperature affects color in heated metal. As shown in the illustrations below, a steel bar glows different colors as it is heated to higher and higher temperatures. If an object's color depends only on temperature, the object is called a *blackbody*. As the temperature of a blackbody rises, it glows brighter and brighter red. As it gets hotter, its color changes to orange, yellow, white, and blue-white. It also glows more brightly.

The table shows the way in which the surface temperatures of stars are related to color. Stars that have the lowest surface temperatures (below 3,500 °C) are red. Stars that have the highest surface temperatures (above 25,000 °C) are blue.

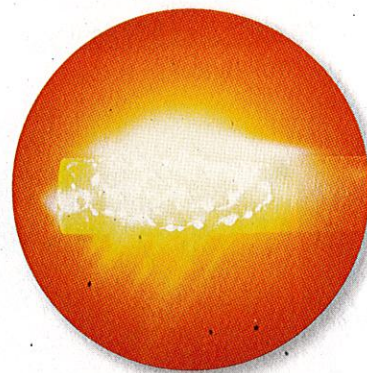
Color and Surface Temperatures of Stars	
Color	Surface Temperature (°C)
blue	Above 25,000
blue-white	10,000–25,000
white	7,500–10,000
yellow-white	6,000–7,500
yellow	5,000–6,000
orange	3,500–5,000
red	Below 3,500



A steel bar glows red when heated to about 600 °C.



At about 1,200 °C, the metal glows yellow.

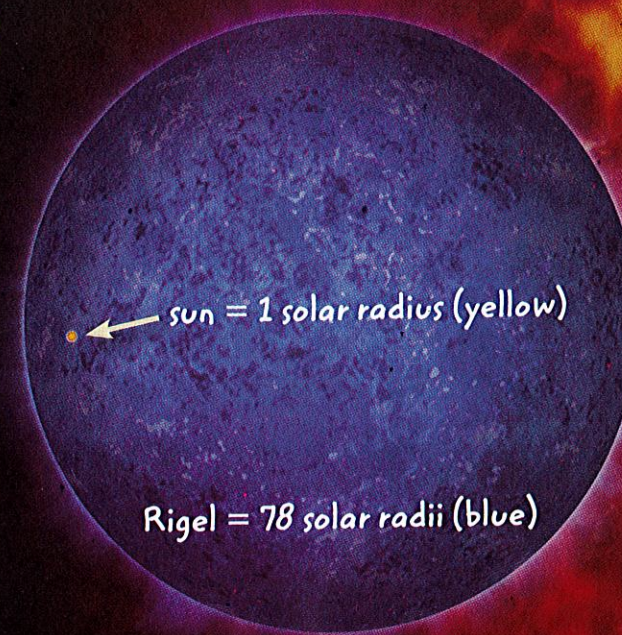


When heated to about 1,500 °C, a steel bar gives off a brilliant white light.

11 Explain Explain how the colors of stars that have different surface temperatures are similar to the colors of a steel bar that is heated to different temperatures.

Think Outside the Book

12 Formulate Come up with a creative way to remember the colors of stars, from coolest to hottest.



sun = 1 solar radius (yellow)

Rigel = 78 solar radii (blue)

Antares = 776 solar radii (red)

The size of the sun is compared to the blue supergiant star Rigel and the red supergiant star Antares.

Visualize It!

13 Apply From Earth, the sun appears to be a very large star. In reality, the sun is quite small when compared to stars such as Rigel and Antares. At the scale shown on this page, why would it be impossible to illustrate stars that are smaller than the sun?

How are the sizes of stars measured?

Like the colors of stars, the sizes of stars differ greatly. Stars may be about the same size as Earth or larger than the size of Earth's orbit around the sun. So what do astronomers use to measure star size? It is always easiest to start with an object that is familiar. That is why astronomers use the size of the sun to describe the size of other stars.

Using Solar Radii

Astronomers have indirectly measured the dimensions of the sun. The sun's radius is approximately 695,000 km, or about 109 times the radius of Earth. Astronomers use this measure, the radius of the sun, to measure the size of other stars. Very small stars, which are called *white dwarfs*, are about the same size as Earth. The size of a white dwarf can be expressed as approximately 0.01 solar radius. Very large stars, which are called *giant stars*, typically have sizes of between 10 and 100 times the radius of the sun. There are also rare, extremely large stars that have sizes of up to 1,000 solar radii. These stars are called *supergiants*. Supergiants are often red or blue stars.

Visual Summary

To complete this summary, fill in the blanks with the correct word or phrase. Then use the key below to check your answers. You can use this page to review the main concepts of the lesson.

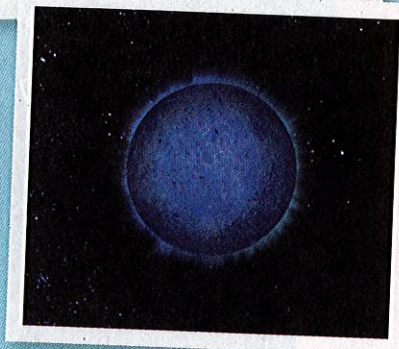
The brightness and luminosity of stars can be measured.

14 _____ is the measure of a star's brightness as seen from Earth.

15 _____ is the measure of how bright a star would be if it were located at a standard distance from Earth.

The color of stars is related to their surface temperature.

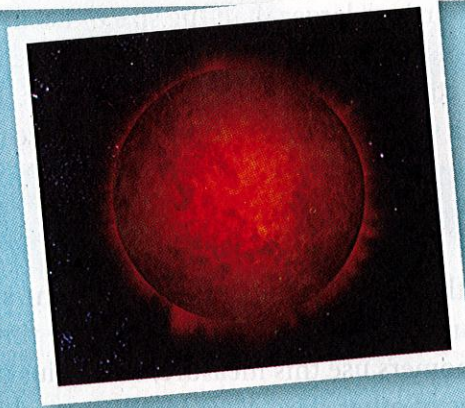
17 What is the color and surface temperature of the star in the illustration below?



Properties of Stars

Stars have different sizes.

16 What is the standard unit that astronomers use to measure the size of stars?



18 What is the color and surface temperature of the star in the illustration below?



Answers: 14 Apparent magnitude; 15 Absolute magnitude; 16 solar radius; 17 blue; 18 yellow; 19 Contrast How does the sun compare to other stars in terms of surface temperature, apparent magnitude, absolute magnitude, and size?

Lesson Review

Vocabulary

In your own words, define the following terms.

1 star

2 luminosity

3 apparent magnitude

Key Concepts

4 List What are some of the physical properties of stars?

5 Analyze Why is the absolute magnitude of some stars greater than their apparent magnitude?

6 Compare How does the size of the sun compare to the sizes of other stars?

7 Apply Mizar is a star system that is composed of two pairs of stars, Mizar A and Mizar B, or four stars in total. What do astronomers call a system that is composed of more than two stars?

Critical Thinking

Use the table to answer the following questions.

Color and Surface Temperature of Stars	
Color	Surface Temperature (°C)
blue	Above 25,000
blue-white	10,000–25,000
white	7,500–10,000
yellow-white	6,000–7,500
yellow	5,000–6,000
orange	3,500–5,000
red	Below 3,500

8 Apply Which stars have the highest surface temperatures, red stars or blue stars?

9 Apply The sun has a surface temperature of 5,527 °C. What is the color of the sun?

10 Calculate A star has a size of 0.1 solar radius. How many times larger is the sun than this star?