Investigating Stars Name:____Block:_____________

FYI: The Color of Stars & Filters **E2:R2**

1. Read FYI: *The Color of Stars* **and** FYI: *Filters in Astronomy*

   As you read use the spaces below to write down any information you find especially interesting. Also define the bold terms used in the text. If you run across any other words that you don't know the meaning of, write those down and ask your teacher to help you with them.

Word/Term	Definition
Blackbody Curve	The shape of the graph of a _______________ ________________ is often called a **blackbody curve**.
Wien's Law	__________ and _________________ are related by a simple mathematical formula known as **Wien's Law**.
Stefan-Boltzmann Law	The **Stefan-Boltzmann Law** states that the <u>energy a star emits</u> is equal to a constant number times the <u>temperature</u> of the star raised to the ___________ power.
Filters	An astronomical filter is a colored piece of glass or acrylic that ______________ only a ___________ portion of the electromagnetic spectrum and ___________ all other wavelengths.
Extra space for additional words or interesting information.	

1. What's the connection between the peak wavelength a star emits and its surface temperature?

2. If a star has a surface temperature of 11,600 K, how would its energy output compare to that of our Sun?

3. What does a filter do?

4. Give three (3) reasons astronomers use filters.

FYI The Color of Stars

As you learned in FYI: *Spectral Lines*, energy is released in the form of electromagnetic radiation when the atoms that make up an object collide with one another. Because the atoms can move at almost any speed, the energy released through collisions can be at any energy or wavelength, and a continuous spectrum of electromagnetic radiation is produced.

The amount of light a star produces at each wavelength is proportional to the star's surface temperature. Hotter stars have atoms that are moving at a faster average speed, so their collisions result in the production of higher-energy photons. This means these stars emit more blue photons than red photons and appear blue. Similarly, cooler stars have atoms that are moving at a slower average speed, so their collisions result in the production of more low-energy photons than high-energy photons. These stars appear red. Stars at middle temperatures, like our sun, emit mostly green or yellow photons. When the brightness of electromagnetic radiation from a star is plotted versus its wavelength, it produces a smooth curve like the one shown in Figure 4-20.

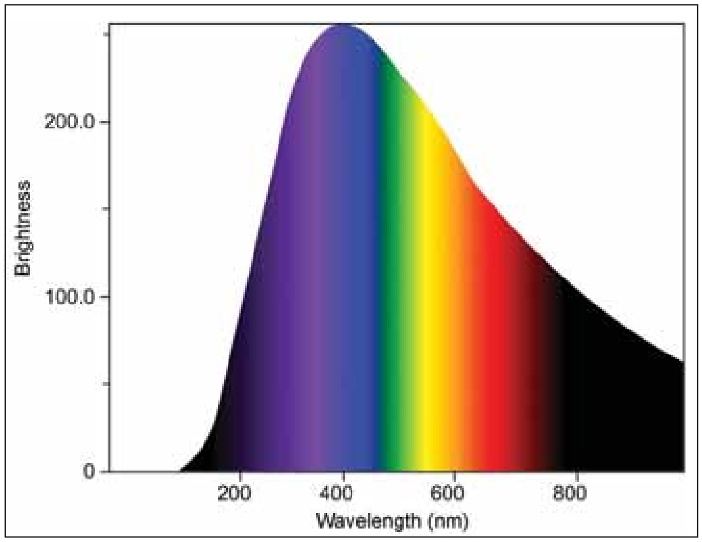

Figure 4-20: Graph of a star's brightness plotted versus its wavelength

All astronomical objects emit electromagnetic radiation, and most of them will have a continuous spectrum with or without additional spectral lines. The shape of the graph of the continuous spectrum, often called a **blackbody curve**, is roughly the same for all objects, but the peak of the curve for a hotter object is higher (brighter) than that of a cooler object, and it peaks at a shorter wavelength than that of a cooler object.

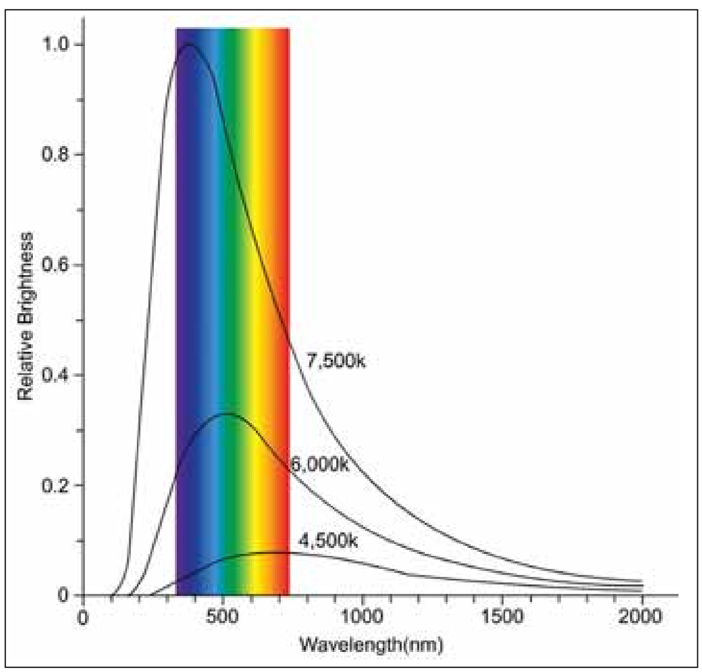

Figure 4-21: Graph of the blackbody curves for three different temperatures of objects

The peak wavelength of cool objects, such as human beings and very cool stars, lies in the infrared region, not in the visible portion of the electromagnetic spectrum—this is why you don't glow in the dark! Very hot stars peak in the ultraviolet region. Because the amount of radiation emitted by an object is greatest at the peak wavelength, this wavelength is dominant in determining the overall color of an object.

Color and temperature are related by a simple mathematical formula known as **Wien's Law**.

This law states that the wavelength of maximum brightness, λ max (measured in centimeters), is equal to a constant (C = 0.29 cm · K) divided by the temperature of the object (measured in degrees Kelvin).

Example: Calculate the wavelength of maximum brightness for two stars—one with a temperature of 3,000 K and one with a temperature
of 15,000 K. What color will each of these stars appear to be?

$$\lambda \max = \frac{C}{T(K)} = \frac{0.29}{3{,}000\ K} = 9.67 \times 10^{-5}\ cm = 967\ nm$$

$$\lambda \max = \frac{C}{T(K)} = \frac{0.29}{15{,}000\ K} = 1.93 \times 10^{-5}\ cm = 193\ nm$$

The 3,000 K star has a peak wavelength in the infrared region of the electromagnetic spectrum. Since our eyes can only detect visible light, this star will appear red. The 15,000 K star has a peak wavelength in the ultraviolet, and will therefore appear blue.

A second important radiation law that relates the temperature of any object to the total energy it emits is called the **Stefan-Boltzmann Law**, which states that the total energy emitted by an object is equal to a constant number (σ) times the temperature of the object raised to the fourth power:

$$E = \sigma T^4$$

This means that temperature is a dominating factor in the energy output of stars. The sun's surface temperature is about 5,800 K. The Stefan-Boltzmann Law says that if a star has twice the surface temperature of the sun, it will emit not twice, not four times, not eight times, but 16 times more energy ($2^4 = 16$).

An image of the McMath-Pierce solar telescope on Kitt Peak in Arizona

FYI Filters in Astronomy

You are probably familiar with light **filters** used in everyday life, such as UV-blocking sunglasses and red plastic automobile tail-light covers. In the case of the sunglasses, a special coating is applied to the lenses in order to absorb harmful ultraviolet rays before they enter and damage your eyes, while still allowing visible light through so that you can see. The tail-light covers transmit only the red wavelengths from the white light bulbs beneath the covers, providing you with a visible cue that the car in front of you is braking.

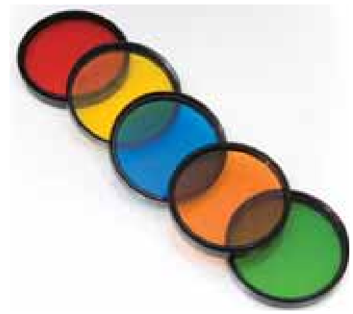

Figure 4-22: Photograph of filters

Similarly, an astronomical filter is a colored piece of glass or acrylic that transmits only a specific portion of the electromagnetic spectrum and absorbs all other wavelengths. By isolating a particular range of wavelengths, filters are able to enhance features of both solar system and deep-sky objects that may be otherwise imperceptible to the human eye. Filters are used for making detailed images, identifying the presence of specific chemical elements, and determining the relative temperatures of objects in space.

A filter is designated as either “broad-band” or “narrow-band,” depending on how wide a range of wavelengths it lets through. The choice of filter depends on the particular piece of information you wish to determine about an object.

The colors of hot, dense objects such as the interiors of stars are determined by their temperatures. However, most of the approximately 2,000 naked-eye stars observable in the northern hemisphere appear white. Broad-band filters such as R (red) and B (blue) filters can be used to identify cooler, redder stars and hotter, bluer stars respectively. When viewed through a red filter, cooler redder stars will appear bright and hotter bluer stars will appear dim. Similarly, hot stars will appear bright when viewed through a blue filter and cool stars will appear dim. Broad-band colored filters also have a variety of uses for studying features of solar system objects such as planets and comets.

A computer screen uses a mix of just three colors—red, green, and blue (R, G, B)—to create the multitude of colors displayed on your monitor. Astronomers use a similar process of additive color mixing to construct a composite color image by adding three separate images of the same object taken through R, G, and B filters. The resulting tri-color image appears as it would to our eyes if the human eye were sensitive enough (Figure 4-23).

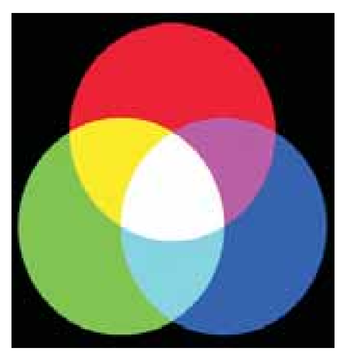

Figure 4-23: Diagram of color mixing

Narrow-band filters transmit only a very small span of wavelengths that correspond to particular atomic transitions. Such filters allow astronomers to identify the presence of specific chemical elements. The “H-alpha” filter is a commonly used filter that isolates a particular wavelength of red light corresponding to the natural transition of neutral hydrogen from the n = 3 energy state to the n = 2 energy state. This filter is useful for locating hot hydrogen gas in deep-sky objects such as nebulae.