

## Activity: Exploring Blackbody Radiation using the PhET Simulation

### Purpose

- To understand the blackbody radiation graph and its applications.

### Materials

- A computer with access to the internet.

### Background

Everything emits Electromagnetic (EM) radiation. The sun does, operating incandescent lights do. We do. (Stand near an athlete who has been working out for an hour. You can feel the EM radiation (heat) being given off by the athlete) Buildings do. (Stand near a brick building's west wall just after sunset. You can feel the EM radiation being given off). Anything at a higher temperature than its surroundings, gives off EM radiation.

As you will find out, the wavelength of the EM radiation is related to temperature. Astronomers (and this simulation) measure temperature in Kelvins (K). The coldest possible temperature is "Absolute zero" = 0 K =  $-273.15^{\circ}\text{C}$ . The freezing point of water is at  $0^{\circ}\text{C}$  or 273.15 K. To convert any temperature from Kelvins to Celsius, simply subtract 273.15.

The amount of power liberated in the form of EM radiation depends on the object's temperature in Kelvin, and its size in  $\text{m}^2$ . It has been found that the total power of the EM radiation being emitted by an object is proportional to  $T^4$  (the fourth power of the object's temperature in Kelvin)!

The EM radiation under investigation in this simulation should not be confused with an object's color due to reflection. An apple at room temperature appears red because it absorbs all the spectral colors of the white light illuminating it except for red. The heating coils in an operating toaster are red because they are hot. At room temperature they are grey.

The temperature of stars in the universe varies with the type of star and the age of the star among other things. By looking at the shape of the spectrum of light emitted by a star, we can tell something about its average surface temperature.

### Accessing and using the Simulation

1. Access the **PhET** web site (<http://phet.colorado.edu/>)
2. Click on **Play with Sims...** button
3. From the left hand menu pick **Light and Radiation**.
4. Choose **Blackbody Spectrum** from the choices.
5. Choose **Run Now!**
6. The curve in the simulator represents the amount of light emitted at each wavelength for an object of a given temperature. The horizontal axis gives the wavelength of light.
  - a. Use the + and - buttons to "zoom in" or "zoom out" on each axis.
  - b. Use the Temperature Slider to increase or decrease the temperature.

## Questions

Temperature = 4800K:

1. What would you say is the color of the EM “blackbody” source shown at the top as a star burst?
2. Are all three spectral colors - blue, green, red – needed to produce this color?
3. What is the temperature shown for this EM blackbody source?
4. What would this temperature be in Celsius?
5. Would a sensor that responds only to infrared be able to detect this EM source?
6. Would a sensor that responds only to ultraviolet be able to detect this EM source?
7. The energy output of the EM source is spread over a wide band of wavelengths and varies in strength. At what wavelength is the source’s output intensity the greatest?

Lower the temperature of the source:

8. Describe the change in color of the source.
9. Describe the change in shape of the graph.
10. How does the wavelength of the maximum intensity change?

Raise the temperature of the source:

11. Describe the change in color of the source.
12. Describe the change in shape of the graph.
13. How does the wavelength of the maximum intensity change?

Applications:

14. Everyday objects:

- a. At what temperature would an oven heating element just begin to glow red?
- b. According to this simulation, what is the color of an operating incandescent light bulb?
- c. What is the wavelength at which the most power is emitted for a light bulb?
- d. Is an incandescent light bulb primarily a light source or a heat source?
- e. Explain why regular incandescent bulbs waste a lot of energy. Be sure to include your reasoning.

15. Earth:

- a. What does this simulation assume is the average temperature of the earth's surface?
- b. What would this be in Celsius?
- c. We see the earth by reflected light, but why don't we see the earth glowing except at a few spots where there is an active volcano?

16. Other Solar System Objects:

- a. What part of the EM spectrum would be useful to determine the surface temperature of objects such as asteroids? Explain your answer.
- b. The surface of Mars appears reddish. Is Mars 'red-hot'? If so, what is its surface temperature? If not, where is the red light coming from?

17. Stars:

- a. If we observe a star's spectrum and find that the peak power occurs at the border between red and infrared light, what is the approximate surface temperature of the star?
- b. If we observe a star's spectrum and find that the peak power occurs at the border between blue and ultraviolet light, what is the surface temperature of the star?
- c. Which star is hotter, a red star, or a blue star?