Intensity of Light and Heat

When talking about a light source, most people are more comfortable with the word "brightness" than they are with the word "intensity." Scientists generally prefer the word "intensity" and there are a couple of reasons for that.

The first reason is that although brightness is a property of only light, the concept of intensity can be applied to light, heat, and other forms of radiation. We feel heat from the Sun. We see light from the Sun. Generally speaking, the heat is most intense when the light is most intense.

Important concept: it is the heat from the Sun, and not the light from the Sun, that is primarily responsible for our weather and climate. However, since we can see and measure light more easily, we will use what we learn about the intensity of light from the Sun to better understand the heat. The factors that influence the intensity of light will also influence the intensity of heat in the same way.

The second reason that scientists prefer the word "intensity" is… Well, see for yourself.

- **Imagine that you saw two green circles. How would you decide which was the "brighter" shade of green?**

- **On the following web page you will find two green circles. Open the web page (which may take a moment), look at the two pictures, and BEFORE YOU DO ANYTHING ELSE write down which *CIRCLE* is brighter: the upper one or the lower one?**

  Go to http://www.instruction.greenriver.edu/physics/intensity and click on "Introduction to Intensity"

- **Now follow the instructions on the web page. After you have done everything on this page, look back at your answers above. How reliable are your eyes for determining brightness? How were they fooled?**

Scroll down and go on to the next page. You should now be at

http://www.instruction.greenriver.edu/physics/intensity/intensity.html

You should see a dark brown screen illuminated by a faint circle of light.

- **Read the instructions on the page and then click on the "Concentrate the light beam" button a few times. Keeping in mind that the total amount of light hitting the screen is not changing, describe in your own words what is happening.**

- **Click on the "Spread out the light beam" button a few times. Again, keeping in mind that the total amount of light hitting the screen is not changing, describe in your own words what is happening.**

- **Imagine a book that is resting on the table. Another student could then take that same book and stand it on end, still on the table. Think of the total FORCE and the total PRESSURE that the book exerts on the table in both cases. Which changes? Which stays the same?**

- **Can you think of an analogy between the force and pressure exerted by the book and the light that you see in this animation? Explain your analogy here.**

Scroll to the bottom and go on to the next page IntensityQ1.html. You should see two circles of light. The questions ask you which circle has the most intense light, which circle has the most light, and which circle has the most area.

In this example and in those that follow, by “amount of light” we mean the amount of light energy that strikes the screen every second. That may sound complicated, but this is what is meant by “watts”. A high wattage light bulb produces more light energy per second than a low wattage light bulb.

On IntensityQ1.html , the second question has been answered for you. See if you can answer the first and third. Check your results by clicking on “show answers.” Talk to your classmates or your teacher if you are having trouble.

Go on to the next page: IntensityQ2.html. Again, try to answer the questions and check your results. Again, check with classmates or your teacher.

Go on to the next page: IntensityQ3.html. Try to answer the questions and check with classmates or your teacher.

- **Thinking back to your analogy about the book on the table, can you come up with a definition of the word “intensity” that we could use for the intensity of light or heat?**

- **Imagine that light flies out from the sun or from a light bulb in straight little rays (which we call “light rays”). If each ray carries the same amount of energy per second, what arrangement of rays will produce the most intense light? What arrangement would produce less intense light?**

By using a definition like the one you came up with, scientists can define the concept of intensity in a way that can be measured. Check your definition and your idea about the light rays with a teacher.

Scroll to the bottom of the screen and go back to the main menu.

Before starting the next animation, look at the paper in front of you. Light is hitting this paper (otherwise you would not be able to see it).

- **It you have a paper near a source of light, what are some things you can do to change the intensity of the light on that paper?**

- **Try out your ideas above. How do they work?**

- **The seasons on Earth are largely caused by changes in the intensity of heat (and light) that we receive from the Sun. What do you think causes these changes in the intensity of solar radiation on Earth? (Go ahead and guess!)**

You probably suggested changing the distance from the light source as one way of changing the intensity of the light. That will be the first method we investigate.

Click on “Solar intensity and distance” (under “Intensity and Distance).

You should see a cartoon of the sun with light rays shooting out in every direction. This cartoon makes it appear that we are looking at the light rays from the side and yet we can still see them. We can’t really see light rays from the side unless there is fog or smoke in the air. Still, the “cartoon” gives us an idea about how intensity changes with distance.

The green line in the picture is intended to be something like the brown screens in the previous animations, except now we are thinking about the effect on a planet like our Earth. For the time being, we imagine that our planet is flat. Look next to “move the flat Earth” and click on “move closer to the sun” a couple of times. Click on “move away from the sun” a couple of times.

- **Look at the spots where rays of light hit the flat Earth. What happens to the distance between these spots as the flat Earth moves closer to the Sun?**

- ***Based on what you see in this animation,* does the intensity of light on our flat Earth change with the distance from the Sun? How do you know?**

Now try to “move the Sun.” This will allow the Earth to move back and forth in the same spot, but with the Sun positioned farther away. Click on “Not so near” and then repeat the “move the flat Earth” experiment.

- **Does the change in the position of the Earth still change the intensity of light from the Sun? How do you know?**

- **Do you think that a change in the position of the Earth changes the intensity of light from the Sun by as much as it did when the Sun was closer? Explain your reasoning.**

“Move the Sun” again. Click on “Farther away” and repeat the “move the flat Earth” experiment. Then click on “Very far away” and repeat the “move the flat Earth” experiment.

- **Does the change in the position of the Earth still change the intensity of light from the Sun? How do you know?**

- **Do you think that a change in the position of the Earth changes the intensity of light from the Sun by as much as it did when the Sun was closer? Explain your reasoning.**

- **July in Seattle is a lot warmer than January in Seattle. Based on what you have seen, do you think we can explain these differences based on changes in the distance between the Earth and the Sun? What else would you like to know before you make a decision?**

It might be useful to know something about how the distance between the Earth and the Sun really varies over the course of a year. For that we need real data, which we find…

Scroll down and go on to the next animation. (It uses a program we haven’t used yet, so it may take a moment to load.)

We’re in luck. This is an almost-to-scale animation of the Earth (green dot) going around the Sun (yellow disk). This still isn’t quite to scale since you wouldn’t be able to see the Earth if it appeared as small as it would in real life.

First of all, notice that in the animation there is a pale blue circle around the Sun. This is the path that the Earth would follow if it had a perfectly circular orbit. The orbits of the planets are actually elliptical, so they aren't quite perfect circles.

Second, notice the graph on the right. This will actually tell us the distance between the Earth and the Sun at different times of year.

Go ahead and run the animation. For this animation, one year is 366 days.

- **Look carefully at the difference between the path that the green dot (Earth) follows and the blue circle. Does the difference between the two paths appear to be great enough to cause the seasons here on Earth? Explain.**

- **Now look carefully at the graph of the actual distance between the Earth and the Sun. Do the changes in the distance appear to be great enough to cause the seasons here on Earth? Explain.**

- **Oh we almost forgot. It turns out that January starts at about the "day zero" in this animation. July comes around about "day 183." When is the Earth closer to the Sun? When should the intensity of Solar radiation (both heat and light) on Earth be the greatest?**

- **Can this explain the seasons in Seattle? Explain.**

Scroll to the bottom and go on to the next animation.

This animation is the same as the last except that there is an additional graph which shows the intensity of solar radiation on Earth. Run the animation.

- **Does the maximum intensity occur at the time of year that you predicted on the last page (two questions ago)?**

- **Imagine that the cause of our seasons *really was* an annual change in our distance from the sun. Keep imagining and imagine that we were closer to the Sun during our summer and farther from the Sun during our winter. Would this explain the seasons all over the world? Explain.**

- **In the film “Personal Universe” many Harvard graduates and even some Harvard faculty were interviewed about the cause of the seasons. Almost all of them said that it was summer when the Earth was closest to the sun and winter when the Earth was farthest from the Sun. Do you agree? If not, what might you say to them to try to get them to change their minds?**

Scroll to the bottom and go back to the main menu. We need to look for another explanation.

If you have not done so already (or even if you have) hold a piece of paper near a light source. Hold the surface of the paper so that it is perpendicular to the "light rays" coming from the light source.

- **Now tilt the paper so that it makes a 45° angle with these rays. Tilt it so that it makes an even larger angle with these rays. Is the light still as intense?**

Click on "Solar intensity and angle" to go on to the next animation.

As soon as the animation appears, you should again see our "flat Earth" but this time it is rotating. The Sun is not on the screen. It is off the screen to the left and so far away that as far as we can tell, the rays from the sun appear to be completely parallel. (That is a pretty good approximation of the way things are here on Earth!)

A word about angles: When the flat Earth stops rotating, the surface is perpendicular to the light rays that are hitting it. For historical reasons, scientists refer to this as an angle of "zero" (you might have called this angle 90° but convention calls it zero). This is not very important, but it will make later animations easier to understand.

Now click on "tilt surface clockwise" and "tilt surface counterclockwise." Look at the points where the light rays hit the flat Earth. If you are having trouble seeing them, try clicking on "show/hide" (clicking again will make them go away).

- **When are the light rays hitting the Earth in places that are closest together? When are the light rays hitting the Earth in places that are farthest apart?**

- **Sketch and label an angular arrangement of a light bulb and a flat piece of paper that would produce high intensity light on the paper. Make and label another sketch of an angular arrangement that would produce low intensity.**

Whenever you think you are ready, go on to the next animation.

This animation is the same as the last except that in comes with a graph that actually displays the intensity of light on the surface of our flat Earth. Notice that the units of intensity are not given, but that the intensity is reported as a fraction of the maximum possible intensity in this situation.

Click on “tilt surface clockwise” and “tilt surface counterclockwise” a few times. Watch the red dot that indicates intensity. Look at situations that produce low intensity and situations that produce high intensity.

- **Were your predictions of high intensity and low intensity arrangements (on the last page) correct?**

- **Explain in your own words the relationship between incoming light rays and a surface that produces the maximum possible intensity.**

Whenever you think you are ready, go on to the *next* animation: intensityangleQ1

There are three flat planets here: one red, one yellow, and one blue.

- **On which planet is the solar intensity the greatest? On which planet is the solar intensity the least? (Check your work.) Do your answers agree with the answers you would get if you were basing your judgment on distance from the Sun? Explain.**

Whenever you think you are ready, go on to the *next* animation: intensityangleQ2

There are again three flat planets here: one red, one yellow, and one blue, but this time they all have different sizes. See if you can decide which planet will have the greatest solar intensity and check your work.

Whenever you think you are ready, go on to the *next* animation: intensityangleQ3

This animation looks much like the last, but there is an important difference. You may repeat this one as many times as you like and it will rearrange the planets for you. Clicking on "Try another?" will give you another practice problem like this one. Clicking on "go on to the next animation" will give you another kind of practice problem.

Whenever you think you are ready, go on to the *next* animation: intensityangleQ4

This animation involves a more complicated shape. We no longer have a flat planet, but rather one that has a curved bowl-shaped surface facing the Sun.

- **Sketch the object below and make your prediction about where solar radiation will be most intense, where it will be a little less intense, and where it will be very small (but not zero). Explain your reasoning.**

- **Click on "answers" to check your work. If the answers are different from what you expected, look back at the three previous practice problems and see if you can figure out why.**

Whenever you think you are ready, go on to the *next* animation: intensityangleQ5

Finally we are faced with something that looks like a real planet. At least it is round.

- **Where on this real planet do you expect the solar radiation to be most intense *and why?* (Draw a sketch if that will help.)**

- **Another student says he knows that the sunlight will be most intense on the farthest left spot on this planet *because that is the part of this planet that is closest to the sun.* Do you agree? Have we seen any other shapes that suggest that this is an oversimplification?**

- **Think about (roughly) where the Equator is on the Earth. Think about (roughly) where the poles are. Can you explain the difference in the climates of these locations based on our current understanding of intensity and angles? If so, how?**

- **Harder question: Think about (roughly) where Seattle winds up in July and (roughly) where Seattle winds up in January. Can you explain the difference in temperatures during these two times of year based on our current understanding of intensity and angles? If so, how?**

- **Which explanation works better for you:**
  1. **"The seasons are caused by annual changes in the distance between the Earth the Sun."**
  2. **"The seasons are caused by changes in angle of incidence of radiation (heat and light) from the Sun."**

  Explain your reasoning.