Why is it warmer at the equator?

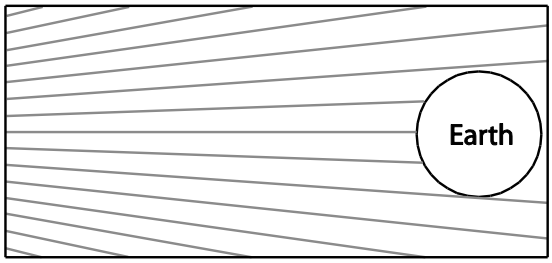
Objective: When you have completed this lab you should be able to clearly and fully explain why it is warmer at the equator than it is at the poles.

When we scale various solar system distances such that Earth has a diameter of 1 cm,

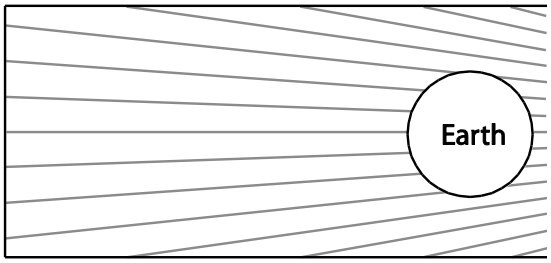
- The sun would have a diameter of a bit more than 1 meter.
- If the sun were at "Broken Shields",…
- then Earth would be orbiting in a circle with a radius of 120 m (12,000 cm) from the sun… just past the railroad tracks on one side, and just past Main street on the other side.

1. For each diagram below, imagine the sun is to the left, but 12,000 times the diameter of Earth away. Which diagram most accurately portrays the pattern of sun rays hitting Earth? Why?

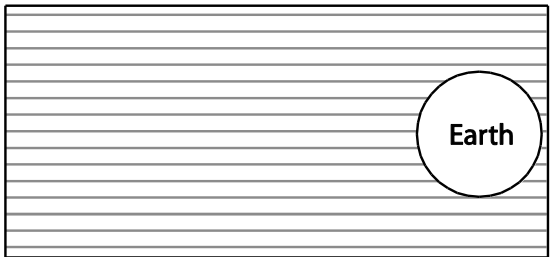
a.



b.



c.



Now go visit this interactive Desmos graph at <desmos.com/calculator/zmqm2pz1yu>. On this graph, you can see "rays" coming out of the sun, and you can adjust the distance between Earth and sun. Earth's diameter is 1 on this graph. So the realistic distance for the sun would be about 12,000. See what happens to the rays as the sun gets about that far away. If necessary, go back and revise your guess and explanation (above).

There should be a grid pattern on a transparency on the overhead projector at the front of the lab. Turn on the projector and project the image of the grid onto the sheet of white poster board. The overhead projector represents the sun. The flat sheet of poster board represents an **imaginary flat earth** with the flat side directly facing the sun. Note the sizes and the brightness of the squares projected onto the various parts of the piece of poster board.

2. Are all of the squares projected onto the piece of poster board the same size? Draw a diagram to illustrate your answer.

"Latitude" is a measure of how far north (or south) you are from the equator. The equator has a latitude of 0 (degrees) and latitude increases to 90 at the north pole, and -90 at the south pole.

3. If Earth were flat like the poster board is, would the intensity of sunlight be the same at all latitudes on Earth? Explain. (Keep in mind your answer about the angle of the sun's rays from question 1.)

4. Imagine a tiny person standing on various places on your model of a flat earth--the piece of poster board (your person would be standing sideways). If the Earth were flat like the poster board is, would the **noonday** sun be directly overhead at all latitudes on Earth, or would there be some variation? Explain. Sketch a diagram to illustrate your answer. (Keep in mind your answer to question 1.)

With the overhead transparency on the overhead projector; turn on the projector and **project the image of the grid onto a large globe**. The overhead projector represents the sun. The globe represents the Earth (now realistically represented as a sphere). Note the sizes and the brightness of the squares projected onto the various parts of the globe.

5. Now look at the projections of the squares on the globe…Are all of the squares projected onto the globe the same size and brightness or are there variations (and if so, *how* are size and brightness varying)? Draw a diagram to illustrate your answer.

6. Consider the points on the globe, all at the same *longitude*, that are experiencing solar noon. Is the intensity of sunlight the same at different *latitudes* on Earth along that line? Or different? Explain. Draw diagrams to illustrate your answer.

7. Imagine tiny people at noon standing at various latitudes on your globe. Would all of these people see the noonday sun directly overhead, or would there be some variation? Explain. Sketch a diagram to illustrate your answer.

In order to better understand why the intensity of the light hitting various parts of Earth varies, we will explore the relationship between the angle of incident light and the intensity of the light. **Intensity** means light energy divided by the area it's shining on.

1. Draw an 'X' on your paper and shine the flashlight straight down on your grid paper, holding the flashlight 2–3 inches above the paper. On the paper, outline the middle (bright) spot.
2. Keeping your flashlight at the same distance to your 'X', move your flashlight to an angle much closer to horizontal to your grid paper. Again, outline the middle (bright) spot.

(Paste a snapshot of your gridlines with labelled outlines in an empty page after this one.)

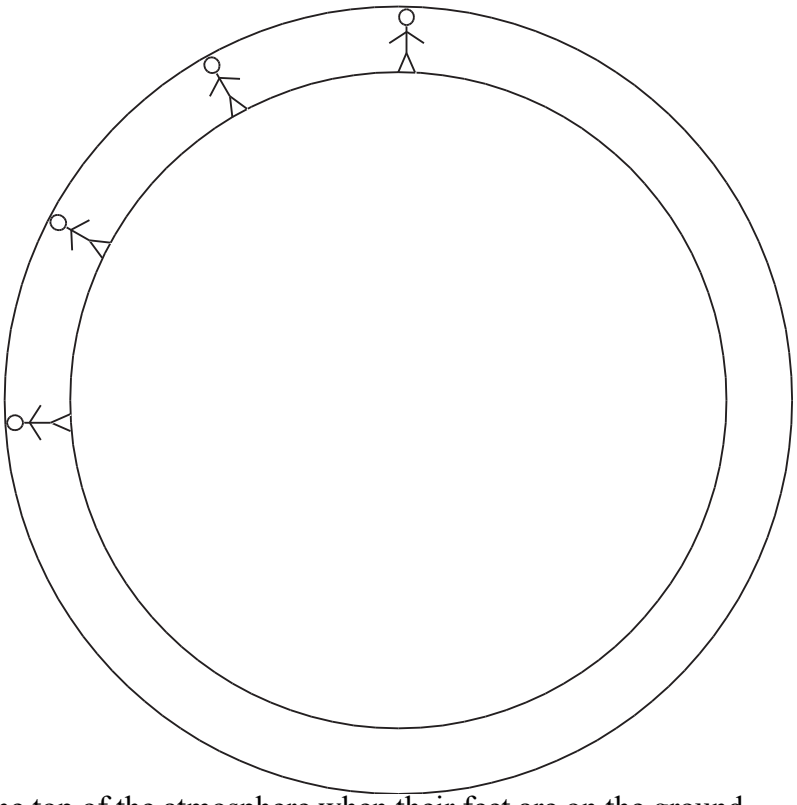
8. When light strikes a surface straight on (elevation angle near 90°, means coming from nearly straight overhead), the intensity of the light is

   stronger / weaker (circle the correct answer)

   than it is when the same light strikes a surface at a small angle of incidence (elevation angle near 0°, means coming from close to the horizon).

9. Clearly and fully explain why the angle at which light strikes a surface affects the intensity of the light energy felt by that surface.

10. There's one more piece to the puzzle of why the equator is warmer than the poles. This piece of the puzzle involves the atmosphere. The atmosphere absorbs, reflects and scatters sunlight; the more atmosphere a ray of sunlight must go through to get to the ground, the less energy will make it all the way to the ground. Imagine an atmosphere of uniform thickness covering your model Earth. The top of each "head" is the top of the atmosphere. Would sunlight have to go through the same thickness of atmosphere to reach the ground at the equator as it would to reach the ground near the poles? Explain. Imagine the sunlight coming (as parallel rays) from the left in this picture. Draw the paths of a couple of those rays to complete the diagram below to illustrate your answer.



NOT to scale (No one's head is at the top of the atmosphere when their feet are on the ground :->)

11. Use all the concepts you have learned so far to fully explain why the equator is warmer than the poles.