Teaching about the angle of insolation, a.k.a.

The Giant Protractor Lab!


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We use the planetarium to teach students that the two key factors responsible for our Earthly seasons are the duration and the angle of insolation.

Our fulldome video system is capable of demonstrating the sun's daily path, including a history trail for each of the solstices and equinoxes. With those lines on the dome, the students can really see the obvious difference in the first factor: the duration. They have no trouble seeing that the summer line is longer than the equinox line(s) and much longer than the winter line. Furthermore, we can change location and show how the effect is exaggerated or diminished at polar or tropical latitudes.

However, they still didn't seem to get what the sun's altitude had to do with the intensity. The human eye is so good at adapting to different light environments that we don't perceive that sunlight is actually brighter on the ground in summer than in winter.

We explained and showed the students diagrams, talked about shadow lengths, but we never really felt like they understood how the sun's altitude affected the intensity. Teachers use illustrations like the one below to explain the concept, but test results demonstrated that understanding was still lacking.

We also can inadvertently reinforce a common misconception with such diagrams because students can think that the insignificantly longer distance the light travels to the polar region is responsible for the lower intensity.

A few years ago, we had an idea for a new lab activity. We dreamed up an exercise that would involve tactile interaction and physical measurements by the students to really drive home the effect of the angle of incoming light. The activity required two novel devices: a giant protractor and a light that projected a crisply-focused beam.

A very big protractor

Thanks to leftover pieces of a musical set, Williamsville North's stage crew was able to create giant 8-ft-wide protractors for our lab. We just had to find a light source that would project a tightly focused area. Every bulb, flashlight, or lamp we tried was insufficient because it did not provide illumination with a definite edge. We finally came across the ETC Source 4 Mini light fixture, which is a miniature version of stage lights called "ellipsoidals" or "leekos." It uses lenses to create the precise illumination control that we needed. We applied for and were awarded a grant to purchase two of the light fixtures.

While the difference in the light intensity is clearly apparent from higher or lower angles, we didn't have a way for the students to quan-

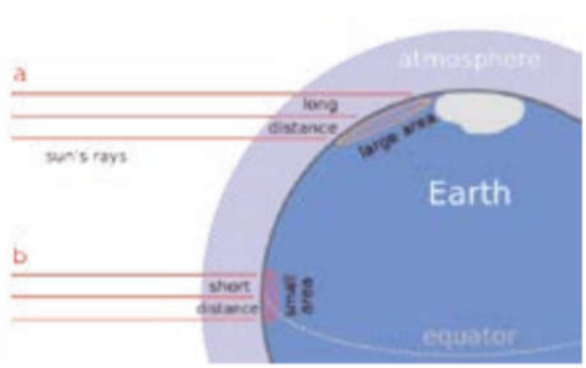
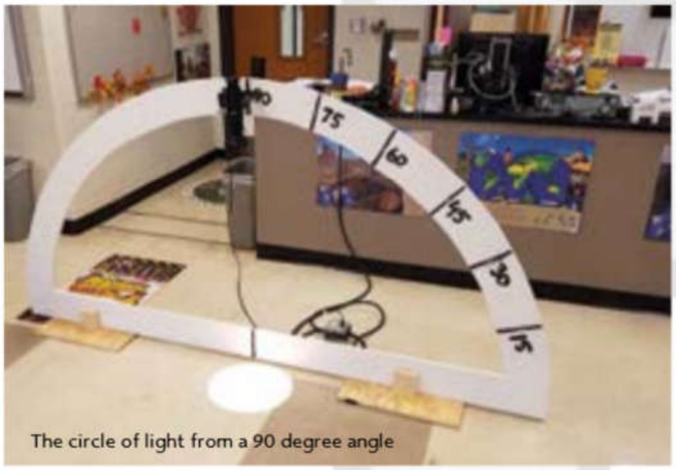


Image from Wikimedia commons



The circle of light from a 90 degree angle

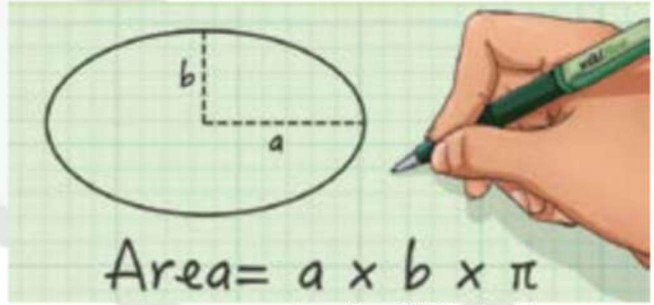
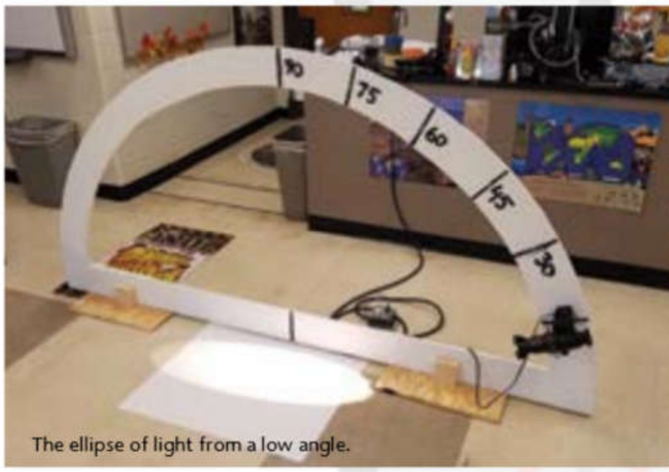
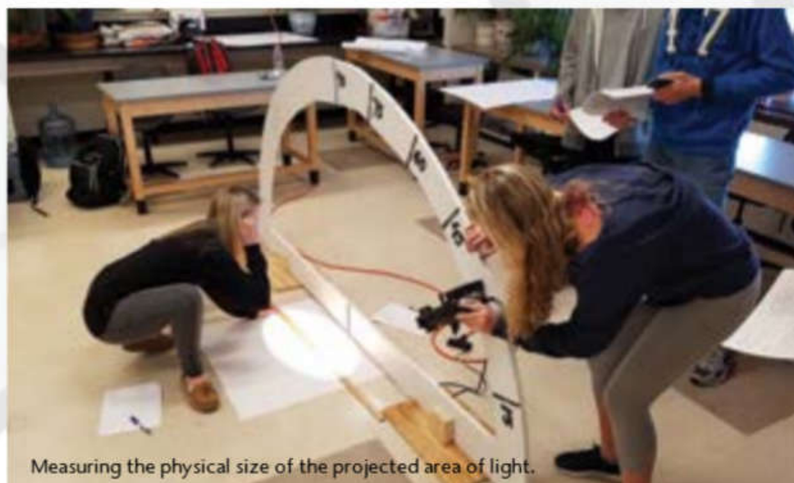


Image from WikiHow/creative commons

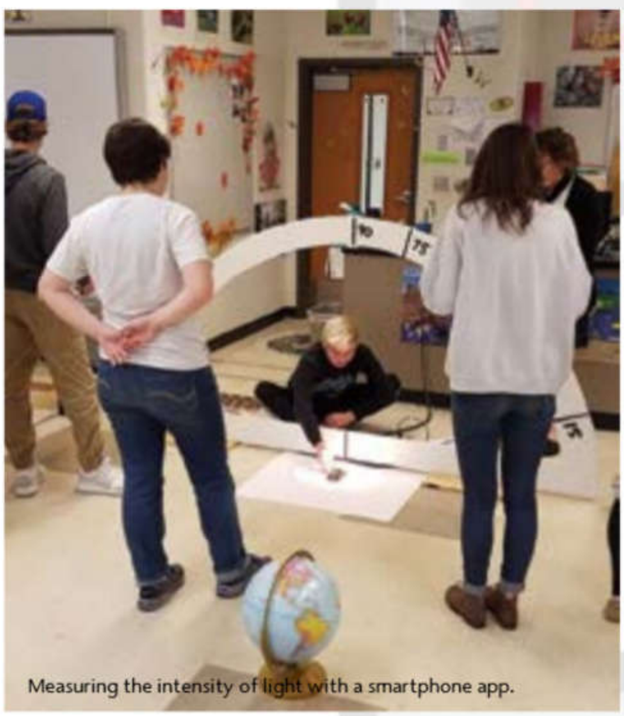
Photo courtesy of ETC (Electronic Theatre Controls, Inc.)



The ellipse of light from a low angle.



Measuring the physical size of the projected area of light.



Measuring the intensity of light with a smartphone app.

Here are some pictures by the authors of the setup and the students working with the giant protractor. (Note: The room lights are on for these pictures, but they were turned off during the data collection for better light meter results.) All photos by the authors.

tify the brightness. We thought about using solar cells and measuring the voltage, but that approach would get complicated.

A Dome-L posting mentioned use of a smart phone app to measure light intensity as part of a different lab about the seasons. With this, we had a way for the students to collect numbers for graphing. The Lux Meter app by Crunchy ByteBox was our choice, but many others are out there.

We attached the light to the giant protractor over a series of angles (90, 75, 60, 45, 30 and 15 degrees) and aimed at the floor adjacent to the middle of the protractor. We had the students measure the circle or ellipse width and length, which conveniently fit within a meter stick. They calculated the area of the lighted area using the formula here:

Next, they measured the light intensity with someone's smartphone. Not only could they see the difference in the illuminated area and brightness, but they had data for both that they could graph.

The giant protractor method also helps dispel the distance misconception. The light fixture is the same distance from the projection area at each of the angles.

We hoped for better understanding, but were surprised at how very effective the lab was. Students enjoyed the experience and demonstrated deep understanding of the concept on their lab reports and subsequent tests. Students of all ability levels made graphs that showed the relationships clearly, and their written answers demonstrated mastery of the concept.

Now we have a great way to really show the effect of the angle of insolation. We're just trying to think of what else we can measure with our giant protractors! ☆