Sunlight Spread

Use angles and area to explain changing solar intensity.

ESS.2.e "Use mathematics to explain how solar intensity and the tilt of the Earth's axis impact the distribution of sunlight on the Earth's surface, including zenith angle, solar angle, and surface area."

NAME _____ DATE _____

1 READ AND MARK

Read it twice

YOUR JOB Underline the two equations, circle the sentence that links Earth's tilt to the noon Sun's angle, and number the table rows from 1 for the highest intensity to 4 for the lowest.

Sunlight on the Courtyard

1. At noon, sunlight can strike a school courtyard almost straight down or reach it at a slant. The solar elevation angle measures the Sun's height above the horizon. The zenith angle measures how far the Sun is from directly overhead, so the two angles add to 90°. Solar intensity means incoming solar power per square meter, measured in W/m².

2. Imagine four equal beams, each carrying 1,000 W through a 1 m² cross section measured perpendicular to the rays. In this simplified model, ignore atmospheric losses. When a beam reaches level ground, its footprint is 1 ÷ sin(elevation angle) square meters. Its intensity is 1,000 × sin(elevation angle) W/m². The table shows rounded results.

EQUAL SUNLIGHT BEAMS ON LEVEL GROUND

Solar elevation (°)	Zenith angle (°)	Footprint (m^2)	Intensity (W/m^2)
60	30	1.15	866
30	60	2.00	500
90	0	1.00	1,000
45	45	1.41	707

3. Earth's axis is tilted about 23.5° relative to a line perpendicular to its orbital plane. As Earth travels around the Sun, that tilt changes the noon solar elevation angle at a given location. A higher Sun concentrates the same power onto less ground, increasing intensity per square meter. A lower Sun spreads that power across more ground, decreasing intensity.

2 ANSWER WITH EVIDENCE

Use the passage

1. At a solar elevation angle of 30°, what is the zenith angle? How many times larger is the beam's footprint than it is at 90°?

2. How many W/m^2 greater is the intensity at 60° than at 30°? Use the footprints to explain the difference.

3. At 45°, about what fraction of the 90° intensity reaches each square meter? How does the change in footprint help explain that fraction?

4. Suppose Earth's tilt changes a location's noon solar elevation from 30° in one season to 60° in another. Which season has greater intensity in this model, and by how much?

3 YOUR TURN

Your own words

Choose two different solar elevation angles from the table. For a beam carrying 800 W through a 1 m^2 cross section, calculate each approximate footprint and intensity, then explain how Earth's tilt could change the noon angle at one location.

Sunlight Spread

PART 1 · READ AND MARK

Underline the two equations, circle the sentence that links Earth's tilt to the noon Sun's angle, and number the table rows from 1 for the highest intensity to 4 for the lowest. Accept any marking that follows this job and points at the right text.

PART 2 · ANSWERS

#	QUESTION	ANSWER
1	At a solar elevation angle of 30°, what is the zenith angle? How many times larger is the beam's footprint than it is at 90°?	**The zenith angle is 60°. The 2.00 m^2 footprint is twice the 1.00 m^2 footprint at 90°.**
2	How many W/m^2 greater is the intensity at 60° than at 30°? Use the footprints to explain the difference.	**It is 366 W/m^2 greater. At 60°, the same power is spread over about 1.15 m^2, rather than 2.00 m^2.**
3	At 45°, about what fraction of the 90° intensity reaches each square meter? How does the change in footprint help explain that fraction?	**About 0.71 of the 90° intensity reaches each square meter (707 ÷ 1,000). The footprint is about 1.41 times as large, so the same power is less concentrated.**
4	Suppose Earth's tilt changes a location's noon solar elevation from 30° in one season to 60° in another. Which season has greater intensity in this model, and by how much?	**The season with a 60° noon elevation has greater intensity by 366 W/m^2 (866 minus 500).**

PART 3 · YOUR TURN (SAMPLE ANSWER)

I chose 30° and 60°. The 800 W beam covers about 2.00 m^2 at 30° and 1.15 m^2 at 60°. Scaling the table's intensities by 0.8 gives 400 W/m^2 and about 693 W/m^2. Earth's tilt can change the noon angle at a location during the year, concentrating the same power onto less ground when the Sun is higher.

The table ranks from highest to lowest intensity as 90°, 60°, 45°, 30°. Accept small differences in calculated intensity caused by rounding the table's footprints or intensities.