MEASURING AND GRAPHING LIGHT

ENGAGE

1. On a sticky note, write your answer to this question: What planet or moon in the Solar System (excluding Earth) should our country target for building a human colony?

2. As directed by your teacher, form pairs and compare answers. Explain to your partner why you think your location would be a good place. Then, form groups of four and repeat the process. Finally, post your suggestion where the entire class can see it. Fill out T-Chart below as you watch the video "Can We Colonize Mars?" (https://youtu.be/9yI3U_yCfj8)

   Record the benefits and challenges of targeting Mars for a colony:

Reasons to Target Mars	Challenges of Building on Mars

3. One challenge of colonizing Mars is collecting solar energy for warmth and energy. List strategies the video suggests for collecting this beneficial solar radiation.

4. Managing hazardous radiation is another challenge. What types of electromagnetic radiation from the Sun are hazardous? (See the figure below.)

Types of Electromagnetic Radiation Made by the Sun

5. Mars is farther from the Sun than the Earth. Does that make the intensity of incoming solar radiation relatively higher on Mars or on Earth? Explain.

6. In general, does the amount of radiation increase, decrease, or stay the same as the distance from a source is increased? Is there a mathematical equation for this relationship?

EXPLORE

Measurements:

1. Form groups as directed. Each group needs one flashlight and 1–2 metersticks.
2. In a dark room, hold the flashlight at a distance shown in Column 1 of the data table away from a flat surface (it can be a wall, the floor, or a table).
3. For each distance from the surface (Column 1), measure the RADIUS of the OUTERMOST circle of light in centimeters (cm). Record this radius in Column 2 of the data table on page 4. Measure all of the Column 2 radii before calculating Columns 3–5.

Calculations:

1. Calculate Column 3 by dividing the number in Column 2 by 100 (100 centimeters = 1 m).
2. Using ***COLUMN 3*** radii, calculate the light circle AREA using the area equation for a circle: AREA = πr^2. Report results in Column 4.
3. Brightness (or intensity) of light depends on the area the light occupies. So, you can calculate the brightness of light by dividing the number "1" by the area in Column 4. (A shortcut is to use the "1/x" button with the Column 4 result.) Write the result of this calculation in Column 5.
4. Have your teacher check your calculations before continuing. Numbers in Column 5 should decrease as you go down the table and near or greater than "1" in value.

Graphing: Use the graph paper on page 4 to make two scatter graphs.

GRAPH A. Plot CIRCLE RADIUS (Column 2; y-axis) vs. distance from surface (Column 1; x-axis)

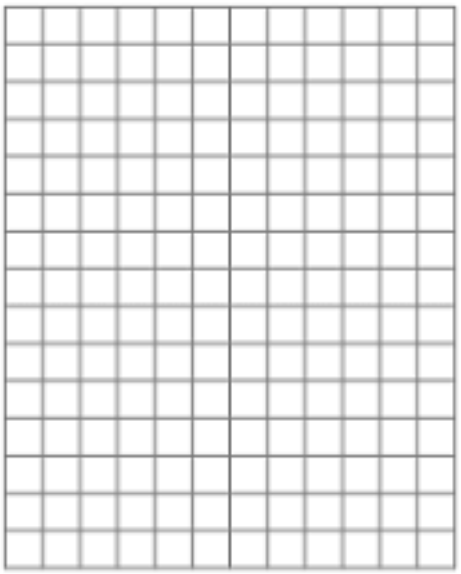
GRAPH B. Plot BRIGHTNESS (Column 5; y-axis) vs. distance from surface (Column 1; x-axis).

Label the axes of graphs. Numerically spread data along axes (do not evenly space numbers if they are not evenly spaced).

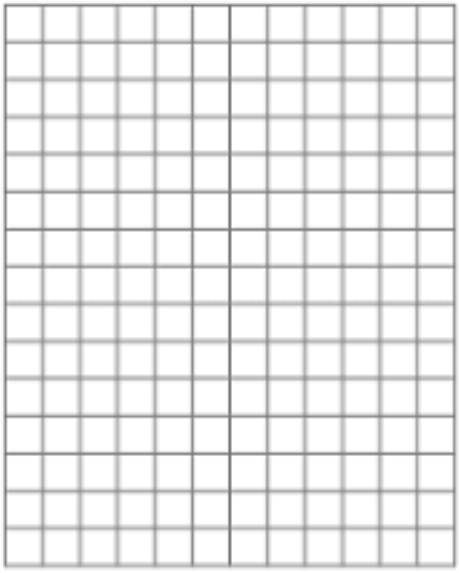
DATA TABLE

Column 1 Light distance from surface (cm)	Column 2 Light circle radius (cm)	Column 3 Light circle radius (m) = Column 2 / 100	Column 4 Light circle AREA = π(radius)(radius) = $\pi r^2 = \pi$ (column 3)^2	Column 5 Light circle BRIGHTNESS = 1/AREA = 1/Column 4
7				
14				
21				
28				

GRAPH A: Radius vs. Light Distance

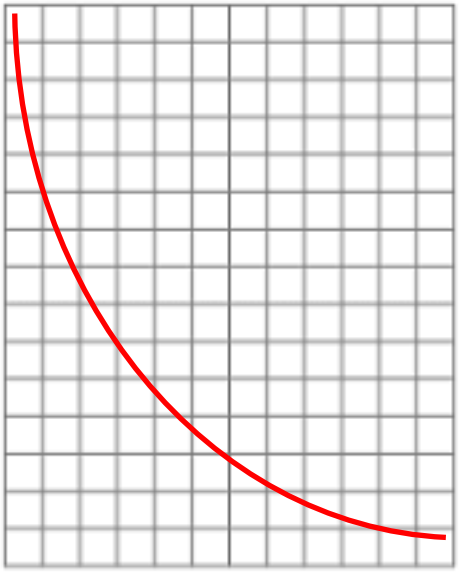


GRAPH B: Brightness vs. Light Distance



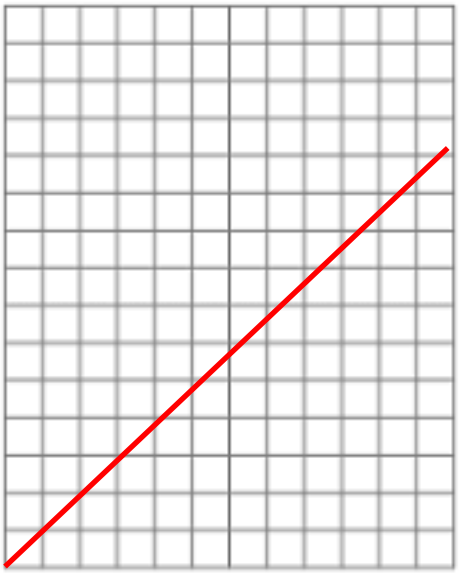
GRAPH C: An INVERSE Relationship

$y \sim 1/x$; y decreases as x increases



GRAPH D: A DIRECT Relationship

$y \sim x$; y increases as x increases



EXPLAIN

1. Look at Graph A. As the distance between a flashlight and a surface increases, does the light circle RADIUS increase or decrease?

2. Does Graph A look more like Graph C or Graph D?

3. Based on your previous answers, does Graph A show a DIRECT or INVERSE relationship?

4. As the distance between the flashlight and the surface increases, does the AREA of a light circle increase or decrease? Is that a DIRECT or an INVERSE relationship with light distance?

5. Now switch to Graph B. As the distance between the flashlight and the surface increases, does the BRIGHTNESS of the light circle increase or decrease?

6. Compare your BRIGHTNESS graph (Graph B) to Graphs C and D. Does the brightness of a light circle have a DIRECT or INVERSE relationship with the distance of a flashlight from the surface?

7. Explain (or guess) why the below equations are described as "inverse" and "square" laws.

Graph B and Graph C can be fit to the following algebra equation:

$$Brightness = \frac{1}{Distance^2} \quad \text{OR} \quad y = \frac{1}{x^2}$$

These equations are "inverse square laws," and other science equations are too.

8. From a geometry point of view, why does the radius of the circle increase proportionally with the flashlight distance? A drawing may help.

9. From a geometry point of view, why does area and brightness change with the "square" of the distance from the surface? (HINT: Review the steps used to calculate the data in the table.)

EXTEND

A flashlight is a model for the Sun and radiation projected by the Sun onto planets.

1. Which planet encounters the brightest, most intense sunlight: Venus, Earth, or Mars? Why?

2. Average surface temperatures of Venus, Earth, and Mars are 471°C, 16°C, and -28°C respectively. Do the temperature differences correlate with incoming sunlight? Explain.

3. Though distance from the Sun correlates, it is not the most important factor affecting solar system temperatures (e.g., the Earth is warmer than the Moon). What other factors affect the temperatures of Venus, Earth, and Mars? (Do research or brainstorm for discussion.)

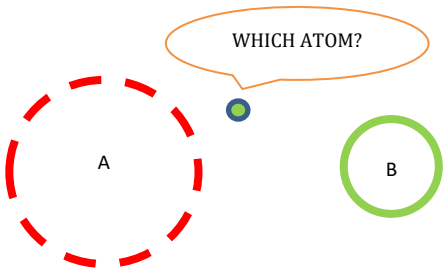
4. The Earth's orbit is elliptical, but northern hemisphere seasons are inversely correlated with distance from the Sun (we are closest in December). Get a flashlight and compare the light when you direct it straight down and at an angle. How does angling the light change the area and brightness of the light? How does this relate to seasons on Earth?

5. The “Goldilocks theory” says that a distant star is more likely to have a habitable planet within a range of distances that are neither too close nor too far from the star. Do you think the location of the “habitable zone” around a star depends on the brightness of a star? Explain using the inverse square law.

6. Two observations about incoming radiation at Mars and Earth: (a) A larger amount of dangerous solar radiation (such as UV light and solar wind) hits the Earth than Mars, but (b) a smaller amount of dangerous radiation reaches the Earth’s surface than Martian surface. Which observation (a or b) is consistent with the “inverse square law”? What causes the other observation to deviate from the inverse square law (research or guess before discussing)?

7. Jupiter is five times farther than the Earth from the Sun. Use the inverse square law to estimate the quantitative difference in the brightness of solar radiation hitting the Earth and Jupiter.

10. Attractive forces between negatively charged electrons and positively charged nuclei also follow the inverse square law and "flashlight logic." In the diagram shown, assume nucleus A and nucleus B have the same charge. Is the attraction stronger when the electron is on the dotted circle next to nucleus A or when the electron is located on the solid circle next to nucleus B? Explain.



11. Many students find it harder to pay attention and hear when they sit farther away from a teacher in class. Do you think the inverse square law plays any role in this? Why or why not?

12. Apply lesson experience do quick research to improve this MOSTLY TRUE sentence:

> *Mathematical rules for (a) light brightness, (b) gravitational forces between two objects, (c) electrostatic forces between two charges, and (d) magnetic forces between two magnets involve the inverse square law.*

EVALUATE

1. Fill-out T-Chart notes as you watch the video "Should We Colonize Venus Instead of Mars?" (https://youtu.be/gJ5KV3rzuag).

Reasons to Target Venus	Challenges of Building on Venus

2. The President of the USA asks you, "Should we colonize Mars or Venus first?"
   - Write a letter to the President to recommend a colony location.
     - You may recommend Mars, Venus, or another location in the solar system.
     - Use evidence to support your recommendation, such as T-Chart notes made while watching the videos. If necessary, rewatch the Mars video.
     - If time allows, do and use additional research.
     - The letter should be at least one page in length.