Lights on the International Space Station

Background

This problem is part of a series that applies mathematical principles in NASA's human spaceflight.

According to James C. Maida, author of *An Illumination Modeling System for Human Factors Analyses,* "Seeing is critical to human performance. Lighting is critical for seeing. Therefore, lighting is critical to human performance."

Here on Earth, the sense of sight and the benefits of illumination can easily be taken for granted. Yet, while on orbit, the sun rises and sets approximately every forty-five minutes, and humans must cope with dynamic lighting conditions. Since contrast conditions of harsh shadowing and glare are also severe, the optimization of lighting conditions is essential for critical operations.

The Lighting Environment Test Facility (LETF), located at NASA Johnson Space Center in Houston, Texas, investigates and evaluates proposed lighting systems for use on space vehicles to enhance the crews' direct and indirect viewing ability. This effort includes the investigation, measurement, and analysis of:

- artificial lighting systems, such as docking lights, portable lights, and navigation lights;
- reflective characteristics of various materials and the effects of solar lighting;
- transmission characteristics of transparent materials used for visors, displays and windows; and
- camera performance for minimum and maximum illumination.

Figure 1: Astronaut James S. Voss performs tasks in the Destiny Laboratory on the International Space Station.

LETF mission planners determine both the types of lighting (quality of light) and light quantities required for a crewmember to perform certain tasks. Light optimization is required for crew safety, electrical power, and equipment maintainability. Although mission planning is a significant role of LETF, the group is also actively involved in research and development of new and advanced lighting technologies.

Instructional Objectives

You will

- analyze data from a simulation;
- model data from a simulation using a graphical and algebraic approach; and
- apply the measure of illumination, $lux = \frac{candela}{m^2}$, to various situations.

Flashlight Reading Investigation

In this exercise, you will be investigating the relationship between the distance of a light source from a book and your ability to read that book. You will divide into groups of four, each with a specific role (outlined below). The materials required for this activity are: a flashlight, a measuring tape, and a text book.

- **Flashlight Holder** Name________________________

  The Flashlight Holder will hold the flashlight at different distances from the book, pointing the flashlight at the book.

- **Distance Manager** Name________________________

  The Distance Manager will measure each distance between the flashlight and the book. The distance between the flashlight and the book should begin at 0.5 meters, and increase in distance at least 0.5 meters each time.

- **Book Holder** Name________________________

  The Book Holder will stand at the designated distance from the flashlight with the book open, and will remain in the same position throughout the investigation.

- **Book Reader** Name________________________

  The Book Reader will stand at a distance from the book which is naturally comfortable to read, and will remain in the same position throughout the investigation. The Book Reader will determine the ability to read the book (as easy, moderate, or difficult).

As a group, you will provide observations, which will be documented in Table 1 (Flashlight Reading Data). A minimum of four readings should be taken. Answer the questions in the prediction section before starting the investigation.

Predictions

1. Will the flashlight's distance from the book affect your ability to read? Why?

2. Predict the flashlight's maximum distance from the book (in meters, or m) in which you will still be able to read the book comfortably.

3. Besides reducing your distance from the book, what other things could you do to improve your ability to read the book?

Table 1: Flashlight Reading Data

Flashlight Distance (m)	**Ability to Read the Book** (Easy, Moderate, Difficult)	**Observations**

Questions

1. How well did you predict the outcome?

2. Does the flashlight's distance from the book affect your ability to read? Explain.

3. What is the farthest distance the flashlight can be from the book for you to read comfortably?

4. Is it desirable to have the book close to the flashlight? Explain.

5. Based on your observations from this investigation, what factors would influence an astronaut's ability to perform a task on the International Space Station (ISS)?

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Embedded Question

On the TI-Nspire™ handheld, open the document, *Lights-ISS*. Turn to page 1.2 and record your answer to the following question.

1.2 Based on your observations from the Flashlight Reading Investigation, what factors would influence an astronaut's visibility and ability to perform a task on the ISS?

Problem

As you have discovered, the farther you are from a light source, the more difficult it is to see and perform a task like reading. This is primarily due to illumination. Illumination is the light that allows humans to see their environment in order to live and work.

Sunlight is a source of illumination. However, artificial illumination from lamps, overhead lights, and flashlights provides humans with light to see in school, our homes, and the workplace in both day and night.

The primary measure of illumination is lux.

$$lux = \frac{amount\ of\ light\ produced}{(distance\ from\ light\ source)^2}$$

The amount of light produced is measured in candelas (sometimes called candle power) and the distance from the light source is measured in meters (m).

Therefore, $lux = \frac{candela}{m^2}$.

On page 2.3, you will find a simulation of the Flashlight Reading Investigation that you performed. The measurements recorded for this demonstration are illumination (lux). On this page, turn on the flashlight by dragging the closed circle to the ON position. Then drag the open point to collect the measurements necessary to complete the table below.

Table 2: Distance vs. Illumination

Distance (m)	Illumination (lux)
0-1.0	
2.0-3.0	
4.0-5.0	
6.0-7.0	
8.0-9.0	
10.0-11.0	
12.0-13.0	
14.0- 15.0	

2.5 Does the table support your understanding on how illumination changes with the distance from the light source? Explain.

2.6 What mathematical relationship exists between the distance from the light source and the amount of light produced?

On page 2.8, you will see the information recorded in the previous table along with many of the data values that were collected as you dragged the open point. Investigate the scatter plot of the data collected, which is distance from flashlight versus illumination (shown on page 2.8).

2.10 Is the scatter plot consistent with the behavior of an inverse variation? Explain.

2.11 On page 2.11, the inverse variation function, $f(x)=\frac{k}{x}$ is graphed for *k* = 2, where *k* is the constant of inverse variation. Use the slider to change the value of *k* to get a better model for the collected data. What is the best *k* value? Is this a good model? Explain.

2.13 On page 2.12, return the value of *k* to 2. Edit the **f1** function to represent an inverse squared variation function by double clicking on the equation and editing the text within, i.e. $f1(x)=\frac{k}{x^2}$. Use the slider to change the value of *k* to get a better model for the collected data. What is the best *k* value? Is this a good model? Explain.

The relationship between illumination and distance from a light source is modeled by the formula, $lux=\frac{candela}{m^2}$. The constant of inverse variation in this formula is candela which is the amount of light produced from the source.

2.15 In the front seat of a car, there is a street address written on a piece of paper which requires reading. The size of the writing is small, and it is night time. The overhead map light is 0.5 meters from the paper. If 300 lux of illumination is needed to read the address, how many candelas of light would be required?

Directions: Complete the questions on pages 3.2–3.3 independently. Round all answers to the nearest thousandth, and label them with the appropriate units.

The Columbus Laboratory is an ISS module designed for scientific research. The module is cylindrical in shape with a diameter of 4.5 meters and a length of 6.9 meters. Each fluorescent light on the ISS produces 170 candelas.

Figure 2: Astronaut working in the ISS Columbus Laboratory Module

3.2 How many lights are needed to provide the astronauts with 300 lux if the lights are located 1.5 meters overhead?

3.3 The robotic arm on the ISS is being used to repair a loose wire. In order to repair the wire, the robotic arm's video camera must provide a good visual image to the astronauts. To record a good image, the video camera requires 5 lux of illumination. The astronauts prefer to use a powerful 2500-candela spotlight to illuminate the wire. What is the maximum distance the spotlight can be away from the wire, yet still provide enough light to obtain a good image? Explain.