Light Intensity – ID: 12336

By Irina Lyublinskaya

Time required
45 minutes

Topic: Light and Sound

- *Relate the brightness of a light source to the distance between the source and the observer.*

Activity Overview

In this activity, students investigate the relationship between light intensity and distance with a flashlight. They use the collected data to identify a mathematical model for the relationship. They then compare this model with the inverse-square law for an ideal point source.

Materials

To complete this activity, each student or student group will require the following:

- *TI-Nspire™ technology*
- *Vernier Light Sensor*
- *Vernier EasyLink™or Go!™Link interface*
- *flashlight*
- *meter stick*
- *copy of student worksheet*
- *pen or pencil*

TI-Nspire Applications

Graphs & Geometry, Lists & Spreadsheet, Notes, Data & Statistics

Teacher Preparation

Before carrying out this activity, you should review with students the definitions and units of power, intensity, and illuminance as a measure of light intensity.

- *If time permits, you may have students repeat the experiment using a different light source and have them compare their results to those obtained in the main activity.*
- *The screenshots on pages 2–5 demonstrate expected student results. Refer to the screenshots on page 6 for a preview of the student TI-Nspire document (.tns file). The student worksheet is included on pages 7–8.*
- ***To download the .tns file, go to education.ti.com/exchange and enter "12336" in the search box.***

Classroom Management

- *This activity is designed to be* ***student-centered****, with the teacher acting as a facilitator while students work cooperatively. The student worksheet guides students through the main steps of the activity and includes questions to guide their exploration. Students may record their answers to the questions on blank paper or answer in the .tns file using the Notes application.*
- *The ideas contained in the following pages are intended to provide a framework as to how the activity will progress. Suggestions are also provided to help ensure that the objectives for this activity are met.*
- *In some cases, these instructions are specific to those students using TI-Nspire handheld devices, but the activity can easily be done using TI-Nspire computer software.*
- *The .tns file for this activity is quite short and simple. If you wish, instead of distributing the .tns file for the activity, you may have students start with a blank .tns file.*

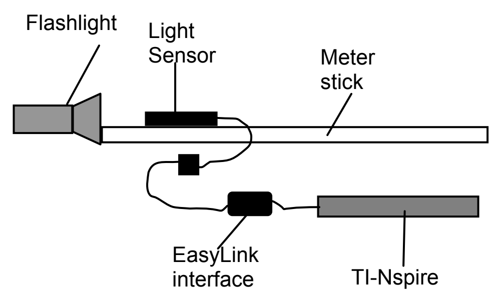
The following questions will guide student exploration during this activity:

- How does light intensity change with the distance away from a flashlight?
- What is the mathematical model for this relationship?
- How does the model for the flashlight compare with the theoretical results for a point light source?

The purpose of this activity is for students to explore how a flashlight propagates light and to compare the relationship between intensity and distance for a flashlight with the theoretical relationship predicted for a point source. Students collect data on light intensity as a function of distance, analyze these data, develop a mathematical model for light intensity, and compare this model to the theoretical formula for the ideal point source. If time allows, students may explore several different light sources.

Part 1 – Collecting data

Step 1: Students should set up the equipment according to the instructions provided in the student worksheet. A diagram of the setup is shown to the right.



Step 2: Students will use a Vernier EasyLink interface with a handheld or a Go!Link interface with a computer. Students should connect a Vernier Light Sensor to the EasyLink or Go!Link interface. Before students carry out the activity, you should test the flashlights they will be using with the Light Sensor to determine the maximum light intensity of the flashlight. You should then instruct the students which setting (0–150,000 lx, 0–6,000 lx, or 0–600 lx) they should use on the Light Sensor. Students should then answer questions 1 and 2.

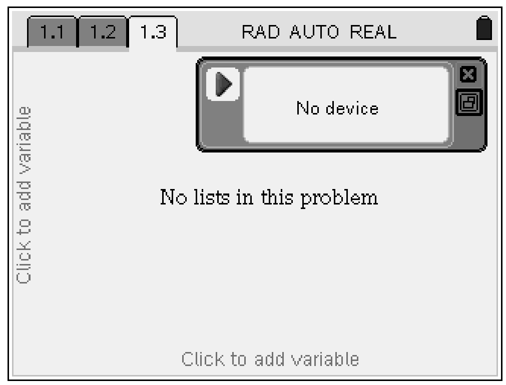
Q1. How does light intensity change with distance away from a point light source?

A. *Intensity,* I*, is measured by illuminance, which is defined as power,* P*, per unit area. Light from a point source travels in spherical wave fronts. The surface area of a sphere is* $4\pi r^2$*, so the equation for light intensity from a point-source light is* $I = \frac{P}{4\pi r^2}$*. Therefore, the intensity of light from a point source should decrease according to an inverse-square law.*

Q2. How do you think light intensity changes with distance away from a flashlight?

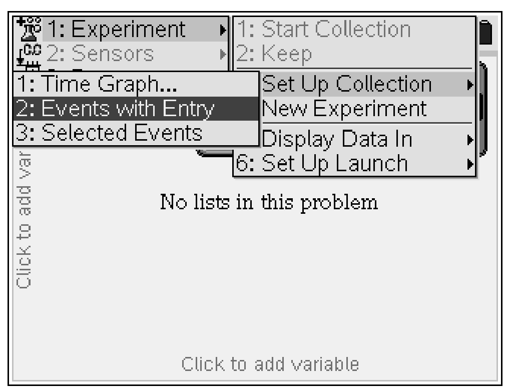
A. *Answers will vary, but students will probably state that the intensity should decrease with distance away from the flashlight. Encourage student discussion, and ask students to try to be more specific about the hypothesized relationship. Do they think it will follow an inverse-square law? Why or why not? You may wish to remind students that the light from a flashlight is not a point source, because a flashlight uses a reflector to direct the light. Or, you may allow students to discover this on their own.*

Step 3: Students should open the file **PhyAct_12336_LightIntensity.tns** and read the first two pages. When students finish reading page 1.2, they should connect the interface to their handhelds or computers. When prompted, they should choose to display their data in a new *Data & Statistics* application. A new page should be inserted, and a Light Sensor data display box should appear.



Step 4: Next, students should wait for the light intensity reading to stabilize, and then they should zero the Light Sensor.

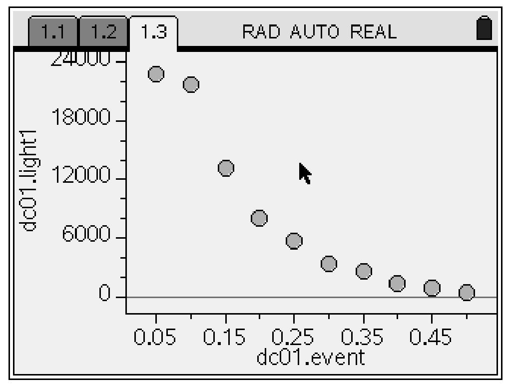
Step 5: Next, students should set up the data collection to **Events with Entry** mode.



Step 6: Next, students should turn on the flashlight and begin data collection. They should collect their first data point at a distance of 0.05 m (5 cm) from the flashlight.

Step 7: Students should move the Light Sensor to the 10 cm mark and collect another data point. Note: Make sure students wait until the intensity reading has stabilized before recording each data point. For accuracy, it is also important that students remain in the same position relative to the Light Sensor throughout the experiment. Taking this precaution will reduce the chances of error caused by a student casting a shadow on the Light Sensor.

Step 8: Students should repeat step 7 eight more times, collecting a total of 10 data points. A graph of the data points will form on page 1.3 as students collect the data.



Step 9: When students have finished collecting data, they should close the data collection box and disconnect and deactivate the Light Sensor. They should then answer questions 3 and 4.

Q3. Describe and explain the shape of the graph.

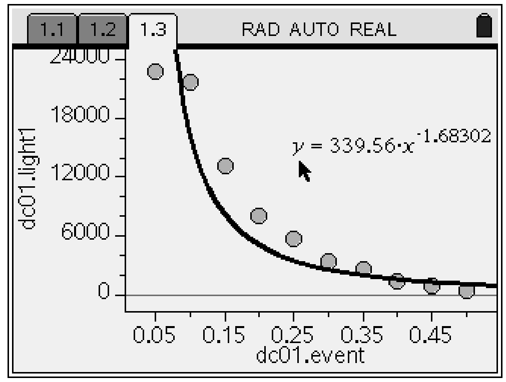
A. *The answers will vary depending on the quality of the flashlight. In general, light intensity decreases with distance. Student explanations for the data may refer to the increase of the surface area reached by the light as distance increases, or to diffusion of light.*

Q4. What mathematical model appears to best fit your data?

A. *Answers will vary. Encourage student discussion of their results. Most students should be able to infer that some sort of inverse relationship could fit their data. Guide students to realize that they can use a regression to determine the best-fit equation for their data. They will carry out this regression in the next part of the activity.*

Part 2 – Mathematical modeling

Step 1: Next, students use the **Power Regression** tool to calculate the best-fit equation for their data set. Encourage students to discuss their results, paying particular attention to the value of the exponent they find. Students should then answer question 5.



Q5. Compare your mathematical model with the theoretical formula for the relationship between light intensity and distance for a point-source light. Which light source produces the greatest decrease in intensity for a given distance from the source?

A. *For an ideal point-source light, intensity,* I*, and distance,* r*, are related by the expression* $I : \frac{1}{r^2}$*. Students' best-fit equations will vary, but the light produced by most commercial flashlights will decrease less quickly than that from an ideal point source. For example, the sample data set shown above yielded a best-fit relationship of* $I : \frac{1}{r^{1.68}}$*. This difference exists because most commercial flashlights use parabolic reflecting dishes to focus the light from the bulb in a specific direction. The reflector dish, in effect, increases the intensity of the light in the preferred direction while decreasing its intensity in other directions. It therefore changes the distance-intensity relationship. If you wish and time allows, you may have students plot an inverse-square function on page 1.3 (**Menu > Analyze > Plot Function**), along with the function for their data. Students should plot a function of the form* $y = \frac{a}{x^2}$ *that passes through their first data point (i.e., they should solve the equation for* a *using the coordinates of the first data point). Plotting the two functions together will illustrate more clearly the difference in functional forms between the flashlight and a point source. You may also wish to have students repeat the experiment using different types of flashlights—for example, they could compare the results from a flashlight that includes a large reflector dish to one that uses essentially a bare bulb as the light source. You may also wish to remind students that there is a systematic error in the distance measurements, as they are measured from the "cover" of the flashlight, rather than from the bulb.*

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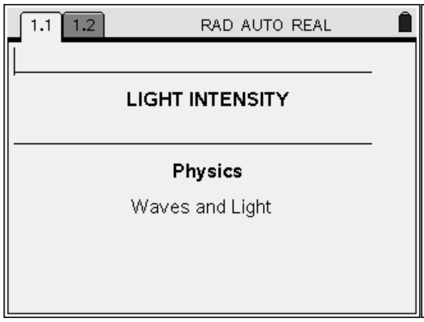
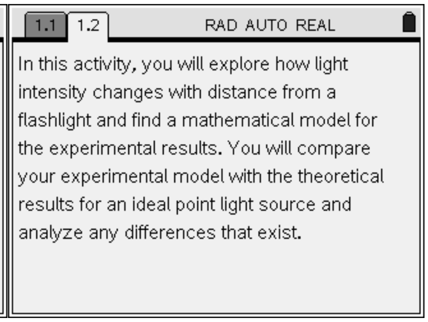
(Student)TI-Nspire File: *PhyAct_12336_LightIntensity.tns*





Light Intensity

ID: 12336

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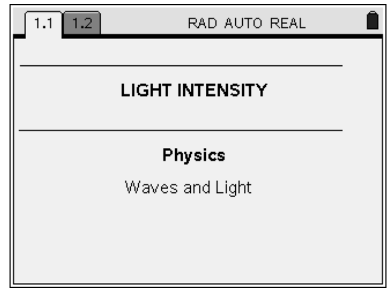
Class ______________________



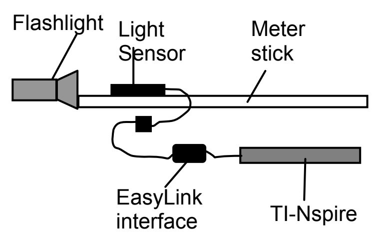
In this activity, you will investigate

- *how light intensity changes with distance away from a flashlight*
- *how to make mathematical models of physical phenomena*
- *the difference between the light produced by an ideal point source and that produced by a flashlight*

The light from a point light source spreads out uniformly in all directions. The light intensity at a given distance *r* from the light is measured by the illuminance, which is defined as the total luminous flux incident on a surface per unit area. Since the area of a sphere varies as the square of its radius, *r*, the intensity will vary as $\frac{1}{r^2}$. In SI, the units of illuminance are lux (lx), or lumens per square meter.

In this activity, you will collect light intensity data from a flashlight, analyze these data, and develop a mathematical model for the light intensity as a function of distance from the light source. You will then compare this model with the theoretical model for an ideal point light source and analyze the differences.

Part 1 – Collecting data

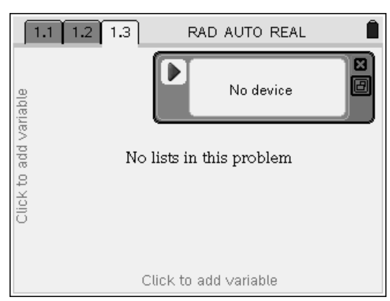


Step 1: Align the zero end of the meter stick with the front of the flashlight, as shown to the right. Align the Light Sensor with the 5 cm mark on the meter stick. You will measure light intensity starting at the 5 cm mark and ending at the 50 cm mark in 5 cm increments.

Step 2: Connect the Light Sensor to the EasyLink interface (if you are using a TI-Nspire handheld to collect data) or a Go!Link interface (if you are using a computer to collect data). Your teacher will tell you the correct position (0–150,000 lx, 0–6,000 lx, or 0–600 lx) for the switch on the Light Sensor.

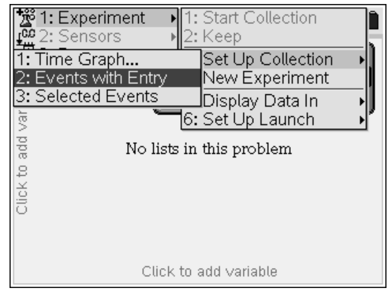
Q1. How does light intensity change with distance away from a point light source?

Q2. How do you think light intensity changes with distance away from a flashlight?



Step 3: Open the file **PhyAct_12336_LightIntensity.tns** and read the first two pages. Connect the EasyLink or Go!Link interface to your handheld or computer. A dialog box should pop up asking you where you would like to display your collected data. Select *Data & Statistics*, and then select OK. A new *Data & Statistics* page (page 1.3) should be inserted, and a data collection display should appear.

Step 4: Wait for the light level reading to stabilize, and then zero the Light Sensor (**Menu > Sensors > Zero**). (Note: Make sure you are not casting a shadow on the Light Sensor when you zero it.)



Step 5: You will be collecting light intensity readings at specific distances from the flashlight. To do this, you will use the **Events with Entry** experimental setup. Select **Events with Entry** from the **Experiment** menu (**Menu > Experiment > Set Up Collection > Events with Entry**).

Step 6: Turn on the flashlight. Make sure the end of the Light Sensor is 5 cm (0.05 m) from the flashlight. Press the Play button (►) on the data collection box. When the reading has stabilized, click on the box in the lower left side of the data collection box. This is the Keep button; it tells the TI-Nspire that you want to record a data point. A dialog box will pop up. In the dialog box, enter the distance (in meters) between the flashlight and the Light Sensor, and then click OK. (For the first reading, enter 0.05, corresponding to the distance of 0.05 m.)

Step 7: Move the Light Sensor 5 cm farther from the flashlight (so the Light Sensor is aligned with the 10 cm mark). Wait for the reading to stabilize, and then "Keep" the data point. (Enter 0.10 for the distance in meters)

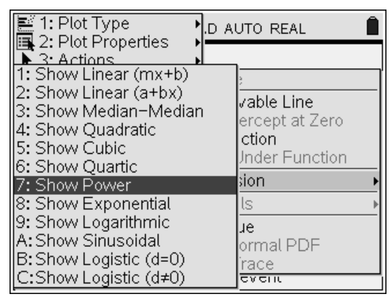
Step 8: Repeat step 7 eight more times, moving the Light Sensor 5 cm each time. Make sure you enter in the dialog box the correct distance in meters for each data point. (You should have a total of 10 data points.)

Step 9: After data are collected, close the data collection box and disconnect the sensor.

Q3. Describe and explain the shape of the graph.

Q4. What mathematical model appears to best fit your data?

Part 2 – Mathematical modeling



Step 1: An idealized point-source light produces an inverse-square relationship between intensity and distance. To determine whether your data have this relationship, carry out a **Power Regression** on your data (**Menu > Analyze > Regression > Show Power**). Once you have found the best-fit curve for your data, answer question 5.

Q5. Compare your mathematical model with the theoretical formula for the relationship between light intensity and distance for a point-source light. Which light source produces the greatest decrease in intensity for a given distance from the source?