  Graphical Analysis 29

Light, Brightness, and Distance

You may have noticed that a light source appears to be brighter when you are close to it and dimmer when you are farther away. This is because the amount of the light that enters your eye increases as you move closer to the light source.

There are several ways to measure the brightness of light. In this experiment, you will use a light sensor to measure the illuminance detected by the sensor in lux. You will observe how illuminance varies with distance and compare the results to a mathematical model.

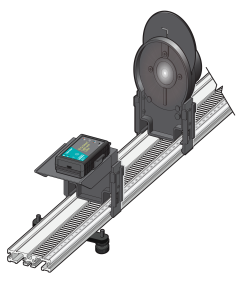


Figure 1

objective

Determine the mathematical relationship between illuminance and distance from a light source.

Materials

Chromebook, computer, or mobile device

Graphical Analysis 4 app

Go Direct Light and Color

Vernier Dynamics Track

Optics Expansion Kit (OEK): Light Source Assembly, Screen, and Light Sensor Holder

pencil

flashlight

Initial setup

1. Launch Graphical Analysis. Connect Go Direct Light and Color to your Chromebook, computer, or mobile device.
2. Set up the data-collection mode.
   1. Click or tap Mode to open Data Collection Settings. Change Mode to Event Based.
   2. Enter Distance as the Event Name and cm as the Units. Click or tap Done.
3. Position the light source assembly so that the LED is exposed and is facing along the length of the Dynamics Track. Align the back edge of the foot of the light source assembly with the 10 cm mark on the track.
4. Turn on the light source. The brightness of the LED light source varies when it is first turned on. Make a note of the current time so that you can ensure 15 minutes have passed before you begin making the measurements during the Procedure.
5. Position the cradle that holds the light sensor on the base of the OEK Light Sensor Holder using the pins on the right side as you look towards the light source. The arrows on the cradle should point towards the light source. Place the light sensor in the cradle and snap it in place. This will align the light sensor with the light source in the center of the track.
6. Position the light sensor near the 100 cm mark, so it is out of the way. The position of the sensor can be read using the notch near the base of the holder. Later, you will move the sensor closer to the light source for data collection.
7. Turn down the lights to darken the room. A very dark room is critical to obtaining good results. There should be no reflective surfaces behind, beside, or below the bulb.

Procedure

1. In this experiment, you will vary the distance between the light source and the light sensor and measure the illuminance. Predict the relationship between illuminance and the distance from a light source. Sketch a graph of how you think illuminance will vary with distance.
2. To explore the relationship between illuminance and distance, stand the screen along the track between the light source and the light sensor, far from the light source. Hold up a pencil between the screen and the light source so that a shadow is produced on the screen. Slowly change the position of the pencil and observe how the shadow changes. Where does the pencil produce the largest shadow? Where does it produce the smallest shadow?
3. If you were to think of the pencil as “catching” light, where does the pencil catch the most light? The least? Where would a measurement of the illuminance on the pencil be greatest? Do your observations change how you would sketch the graph of illuminance vs. distance?
4. Check that the light source has been on continuously for at least 15 minutes. Move the light sensor so the notched arrow is at the 20 cm mark.
5. Rotate the disk of the light source assembly until no light from the LED is visible. Click or tap the Illuminance meter and choose Zero to define the light level as zero. The illuminance reading should now be near zero.
6. Click or tap Collect to start data collection.
7. Click or tap Keep. Enter the distance between the light sensor and the light source and click or tap Keep Point.
8. Move the light sensor 1 cm farther away from the light source and repeat Step 7. Briefly turn on the flashlight if it is too dark to see the markings on the track.
9. Repeat Step 8, moving the sensor in 1 cm increments, until the light sensor is 20 cm from the light source.
10. Repeat Step 8, this time moving the sensor in 10 cm increments, until the light sensor is 60 cm from the light source.
11. Click or tap Stop to stop data collection. In your data table, record the illuminance for each distance.

data table

|  |  |
| --- | --- |
| Distance (cm) | Illuminance (lux) |
| 10 |  |
| 11 |  |
| 12 |  |
| 13 |  |
| 14 |  |
| 15 |  |
| 16 |  |
| 17 |  |
| 18 |  |
| 19 |  |
| 20 |  |
| 30 |  |
| 40 |  |
| 50 |  |
| 60 |  |

Analysis

1. Examine the graph of illuminance vs. distance.
2. Compare your data to your model. To model an inverse square, first calculate the inverse square of the distance data, and then compare it to the illuminance data.
   1. Click or tap View, , and choose Table.
   2. Click or tap More Options, , in the Distance column header in the table. Then, choose Add Calculated Column.
   3. Enter 1/d^2 as the Name.
   4. Click or tap Insert Expression and select the equation A/X^B. Choose Distance for the Column for X. For the A value, enter 1. For the B value, enter 2.
   5. Click or tap Apply.
   6. Click or tap View, , and choose Graph and Table. If necessary, change the x-axis to 1/d^2 and the y-axis to Illuminance.
   7. Click or tap Graph Tools, , and choose Apply Curve Fit. Select Proportional as the Fit Equation. Click or tap Apply.
3. How well does the model fit your experimental data? Do your data approximately follow an inverse square function?

Extensions

1. If you have a window facing the sun, it can be interesting to try an experiment to measure the illuminance from the sun. Place the light sensor 10 cm from a 150 W clear light bulb and measure the illuminance. Point the Light Sensor at the sun and measure the illuminance from the sun relative to the light bulb. How many light bulbs would you have to place 10 cm from the light sensor to be equal to the illuminance from the sun? Use the mathematical relationship found in this experiment to calculate the illuminance from the sun if it was placed 10 cm from the light sensor. Determine how many of these light bulbs would be equivalent to this value.
2. Use the light sensor to measure the illuminance from the sun over the period of a school day.
3. Use the light sensor to examine sunglasses. By what percentage is the sun’s illuminance reduced when sunlight passes through the lens of sunglasses?
4. Use the light sensor to compare other light sources to the light source that you used in the lab. For instance, how does illuminance vary as you move away from a long fluorescent bulb or a circular fluorescent bulb?
5. Suppose a small light source is placed at the center of two transparent spheres, as shown in Figure 2. One sphere has a radius R, and the other a radius 2R. Energy in the form of light leaves the source at a rate P. That same power P passes through the surface of the inner sphere and reaches the outer sphere. Intensity is the power per unit area. What is the intensity at each sphere? Solve this problem by considering the following:
   * How does the power passing through the inner sphere compare to the power reaching the outer sphere?
   * How do the surface areas of the two spheres compare?
   * In general, then, how will the intensity vary with distance from the source?

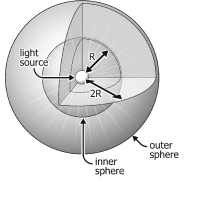


Figure 2

1. Compare the concentric spheres model described in Extension 5 to your experimental data.
   * Is your illumination vs. distance data consistent with the concentric spheres model? How can you tell?
   * Is the best-fit curve that you fit to your experimental data consistent with the concentric spheres model?
2. Since most light bulbs that you use are not true point sources of light, how do you think your answers to Extension 5 would change if an incandescent light bulb were used?