7 - Brightness As A Function of Distance

Purpose: To determine how the brightness of a light source changes as its distance from the viewer changes.

What do you think?

In the spaces provided, write your best estimate based on your personal experience.

In front of the classroom two 200-watt light bulbs are directed toward a block of wax (see Figure 1). The wax block is called a photometer. A photometer is a device that measures light by comparing how bright two sources of light are. When each light source is at the same distance from the photometer, both sides of the photometer appear equally bright.

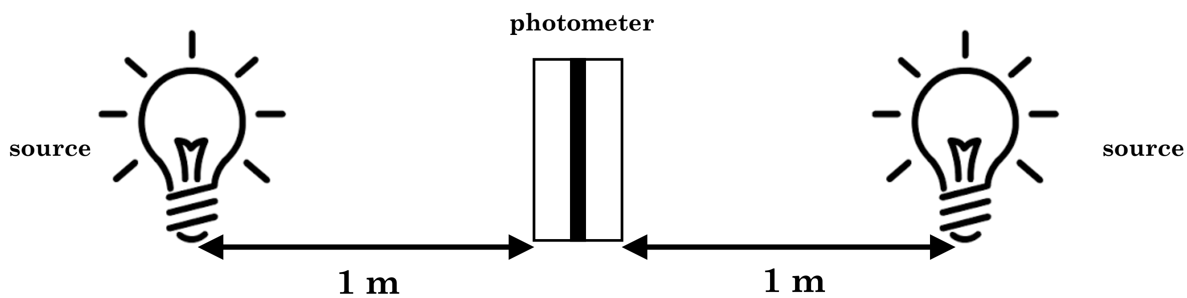

Figure 1: Two 200-watt light bulbs illuminating the photometer.

Your instructor will now move one of the sources from 1m to 2m from the photometer. Notice that one of the sides of the photometer looks dimmer. See Figure 2.

Q1. How many 200-watt bulbs do you think you would have to place at the 2m position so that both sides of the photometer look equally bright again? Explain:

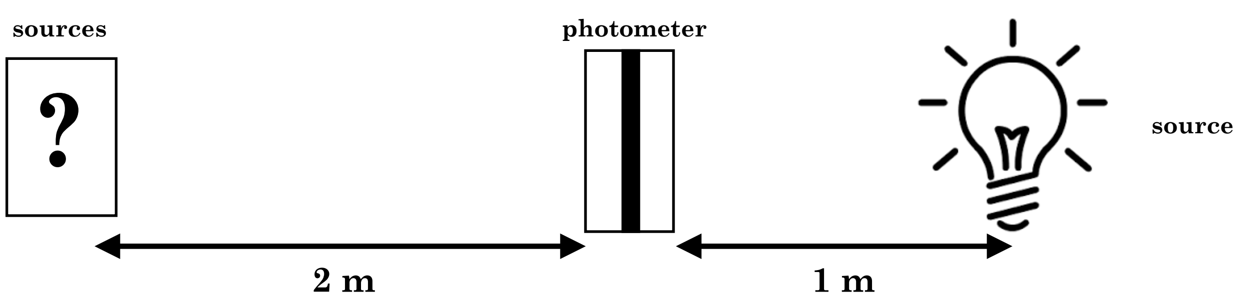

Figure 2: Photometer illuminated by one source at 1m and another at 2m.

Materials:

- 1 200-watt unfrosted bulb (source)
- 1 sheet of grid paper (screen)
- 1 sheet of black paper (aperture)
- 1 book end
- fishing line or measuring tape
- stand
- masking tape or scotch tape
- 2 pieces of cardboard
- scissors
- meter stick

Procedure:

1. Aperture: assemble four pieces of black paper on one of the cardboard pieces so that they create a small square of exactly the same size as **one** of the squares in the grid paper (screen). Using masking or scotch tape, make sure the aperture is structurally sound.
2. Screen: Tape the grid paper onto the second cardboard piece to assemble the screen. Make sure the screen is structurally sound. Secure the screen to the book end.
3. Set up: Position the aperture 10 cm from the source using a stand. The aperture should remain at this position for the rest of the experiment.
4. Measurements:
   A. Place the screen on the opposite side of the aperture in direct contact with the aperture. The light passing through the aperture is illuminating one square on the screen. See Figure 3. Count the number of squares illuminated by the source. Record your measurement in Table 1. Draw the area of illuminated squares in the spaces provided.
   B. Move the screen to 20m from the source. This will double the distance from your previous measurement. Make sure the screen is parallel to the aperture. Count the number of squares illuminated by the source and record it in Table 1.
   C. Repeat step B. for distances of 30cm, 40cm, and choose between 50, 60, 70, or 80cm.

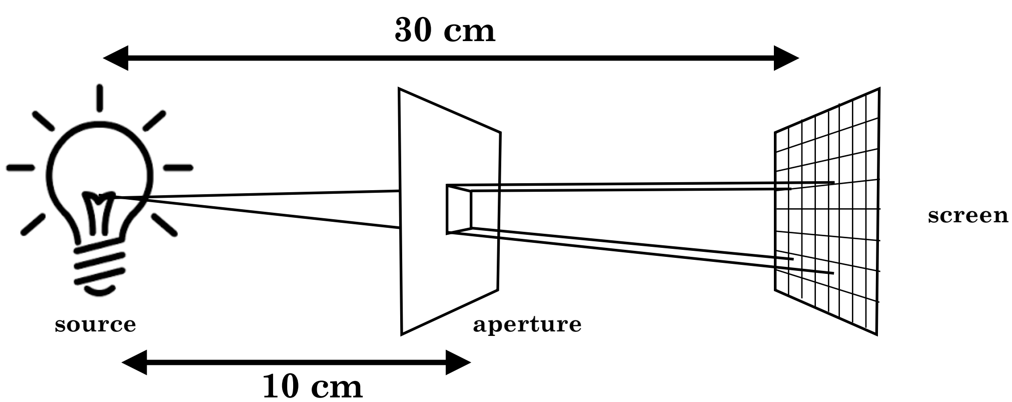

Figure 3: Experimental setup for screen at 30cm and aperture at 10cm from the source.

Table 1: Distance and Illuminated Squares

Distance of Screen from Source (cm)	Number of Grid Squares Illuminated	Drawing
10		

To answer the following questions refer to your measurements in Table 1.

Q2. What fraction of the light passing through the aperture falls on ONE of the squares on the screen at **10cm**?

Q3. What fraction of the light passing through the aperture falls on ONE of the squares on the screen at **20cm**?

Q4. What fraction of the light passing through the aperture falls on ONE of the squares on the screen at **30cm**?

Q5. Using the answers from Q2-Q4, complete Table 2. In each row, enter the fraction of light passing through the aperture that falls on ONE of the squares when the screen is up to a distance of 100 cm.

Table 2 - Fraction of Light on ONE Square

Distance of Screen from Source (cm)	Fraction of Illuminated Squares on Screen
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

To correctly answer Q6-Q9, refer to your measurements in Table 1 and your inferences in Table 2. Think carefully before answering.

Q6. When the screen was 40 cm from the source, a fraction of ___________ of the light passing through the aperture hit one square on the screen. How many identical 200-watt light sources would you have to place at the position of the source for this ONE square at 40cm to be as bright as it was at 10cm?

Q7. If the screen were placed 9 times farther from the aperture, a fraction of _______ of the light passing through the aperture would hit one square on the screen. How many identical 200-watt light sources would you have to place at the source position so that ONE square at the screen is as bright as when the screen was at 10cm?

Q8. If the screen were 3.1 times farther from the aperture, a fraction of _______ of the light passing through the aperture would hit one square on the screen. How many identical 200-watt light sources would you have to place at the source position so that ONE square at the screen is as bright as when the screen was at 10cm?

Q9. If the screen were at a distance 0.7 times that of the aperture, a fraction of _______ of the light passing through the aperture would hit one square on the screen. How many identical 200-watt light sources would you have to place at the source position so that ONE square at the screen is as bright as when the screen was at 10cm?

Q10. The planet Mars is 1.5 times farther from the Sun than Earth. How would the brightness of the Sun as seen from Mars compare to the brightness of the Sun as seen from Earth?

Q11. Neptune is 30 times farther from the Sun than Earth. How would the brightness of the Sun as seen from Neptune compare to that as seen from Earth?

Q12. Mercury is 0.4 the distance between Earth and Sun. How would the brightness of the Sun at Mercury compare to that as seen from Earth?

Q13. After consultation with your instructor or TA, use graph paper to plot the brightness against distance. On the horizontal axis, mark the distance from 0 cm to 100 cm at even intervals of 10 cm. On the vertical axis, mark numbers from 0 to 1 at even intervals of 0.1. Using your data from Table 2, plot for each distance the corresponding fraction. These fractions are directly related to the brightness of a source. We will use these fractions as proxy for brightness. To obtain full credit, your graph must contain:

- ☐ Horizontal and vertical axes labels and units
- ☐ Horizontal and vertical axes appropriate tick marks
- ☐ Correct data point placement based on your Table 2
- ☐ Title

Q14. Reading your plot in Q13, at what distance will the brightness of the source be 50%?

Q15. Using the results from your work so far, fill in Table 3. This table is different from Table 2 in that it reports the number of identical sources at various distances that would produce a brightness equal to that of one source at 10cm. We will call the 10 cm distance with one square illuminated as the reference position.

Table 3 - Number of Sources

Distance of Screen from Source (cm)	Number of Sources that result in equal brightness at reference position.
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Using your measurements in Table 1 and your inferences from Table 3, answer the following questions. At all times, assume that all the sources (light bulbs) are identical. Show your work clearly.

Q16. How many sources at 30 cm will produce the same brightness as 1 source at 10 cm (the reference position)?

Q17. How many sources are needed to produce the same brightness as one source when placed 5 times farther from the reference position?

Q18. How many sources will produce the same brightness at a distance 10 times farther than the reference position?

Q19. Assume you have a source 25 cm from you. How many sources would you have to place at a distance of 100 meters to match the brightness when a single sources was at 25 cm?

Q20. How many sources would you have to place at 1 kilometer to produce the same brightness as one source at 50 cm?

Q21. If the Sun were to become 100 times more luminous, how far would we have to move away from the Sun so that it would appear as bright as it normally does?

Q22. Saturn is about 10 times farther from the Sun than the Earth. How will the brightness of the Sun as seen from Saturn compare to its brightness as seen from Earth?