Name: ASTR110L
Partner(s):

8 - Brightness as a Function of Distance

Purpose: To determine how the brightness of a light source changes as its distance from the viewer changes. Complete all questions (Q1–Q22) in the spaces provided, which include Tables 1–3. One graph (Q14) will be submitted per group.
Due: end of class time.

Pre-lab Questions—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. Move to be perpendicular to the photometer to see this.

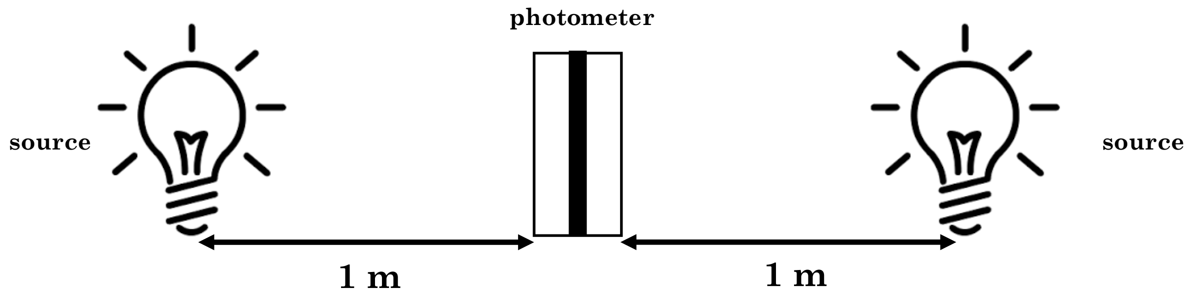

Figure 1: Two 200-watt light bulbs illuminating the photometer.

Your instructor will now move one of the sources from 1 m to 2 m 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 2 m position so that both sides of the photometer look equally bright again? Explain:

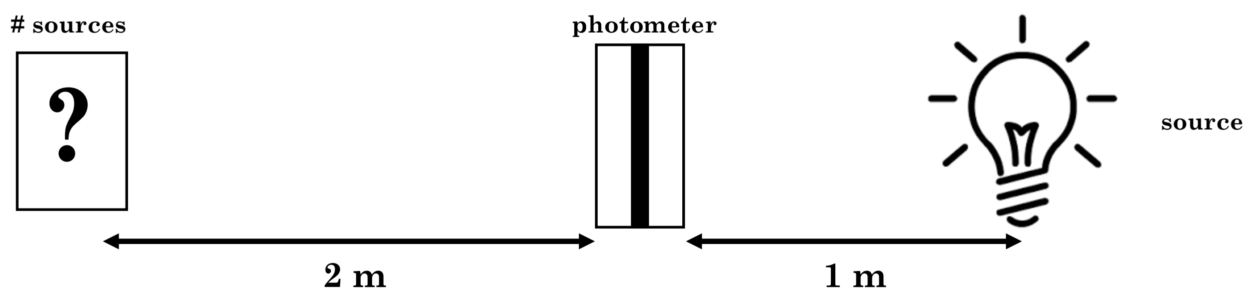

Figure 2: Photometer illuminated by one source at 1 m and another at 2 m.

Materials:

1 200-watt unfrosted bulb (source)
stand for source
1 sheet of grid paper (screen)
masking tape or scotch tape
1 sheet of black paper (aperture)
2 pieces of cardboard
2 bookends and binder clips
scissors
measuring tape
meter stick
graph paper

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 bookend with binder clips.
3. Set up: Position the aperture 10 cm from the source using another bookend. 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. In Table 1, for the 10 cm row, record the number of squares that the light passing through the aperture is illuminating on the screen. Also sketch the screen clearly showing the number of squares illuminated.
   B. Move the screen to 20 cm from the source; see Figure 3. This will *double* the distance from your previous measurement (at 10 cm because that's the fixed source-screen distance). Make sure the screen is parallel to the aperture. Count the number of squares illuminated by the source and record it in the next row of Table 1. Also sketch the illumination pattern on the screen.

Q2) Repeat step B. for distances of 30 cm, 40 cm, and one of 50, 60, 70, or 80 cm.

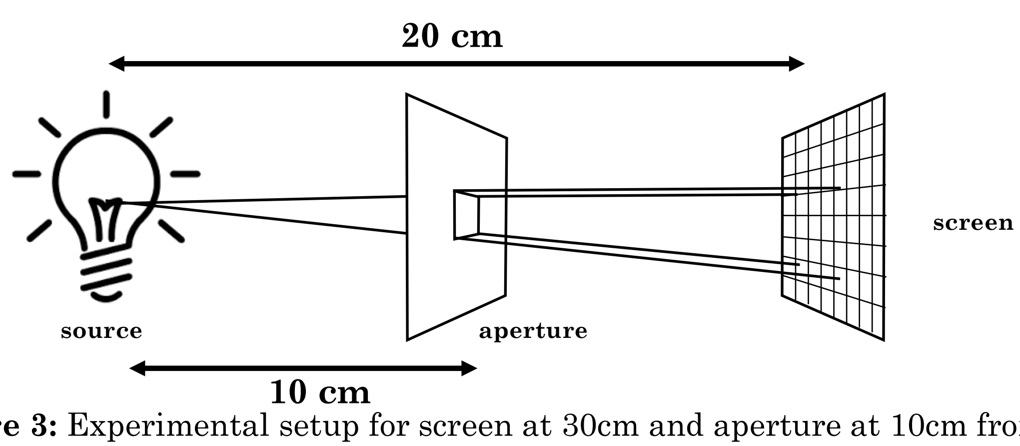

Figure 3: Experimental setup for screen at 30cm and aperture at 10cm from the source.

Table 1: Distance and Illuminated Squares

Distance of Screen from Source (cm)	Number of Grid Squares Illuminated	Drawing of Screen (illuminated squares and not)
10		

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

Q3) What fraction of the light passing through the aperture falls on ONE of the squares on the screen at **10 cm**?

Q4) What fraction of the light passing through the aperture falls on ONE of the squares on the screen at **20 cm**?

Q5) What fraction of the light passing through the aperture falls on ONE of the squares on the screen at **30 cm**?

Q6) Using the answers from Q3–Q5, 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. You did not measure everything up to 100 cm; you will be *inferring* the results or *extrapolating* your measurements.

Table 2: Fraction of Light on One Square

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

To correctly answer Q7–Q10, refer to your measurements in Table 1 and your inferences in Table 2. Think carefully before answering.

Q7) When the screen was 40 cm from the source (four-times farther from the aperture), 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 40 cm to be as bright as it was at 10 cm?

Q8) If the screen were nine-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 would be as bright as when the screen was at 10 cm?

Q9) 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 would be as bright as when the screen was at 10 cm?

Q10) If the screen were 0.7-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 would be as bright as when the screen was at 10 cm?

Q11) 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?

Q12) 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?

Q13) 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?

Q14) After consultation with your instructor or TA, use graph paper to plot the fractional brightness per square 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 the fractional brighness from 0 to 1 at even intervals of 0.15 or 0.2. Spread it out. 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, including group-member names

Q15) Reading your plot in Q14, at what distance will the brightness of the source be 50%?

Q16) 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 10 cm. We will consider the 10-cm distance with one square illuminated to be the reference position.

Table 3 - Number of Sources

Distance of Screen from Source (cm)	Number of Sources (that result in equal brightness compared to 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 for Q17–Q20. Show your work clearly.

Q17) How many sources at 30 cm will produce the same brightness as one 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, 10-times farther away, will produce the same brightness as at the reference position?

Q19) Assume you have a source 25 cm from you. How many sources would you have to place 100-m away to match the brightness when a single source was at 25 cm?

Q20) How many sources would you have to place 1 km away 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 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 is. How does the brightness of the Sun as seen from Saturn compare to the Sun's brightness as seen from Earth?