Intensity of Light

Initial Observations (4 points)
Your instructor will turn out all the lights in the classroom. Then, he will turn on several lights, one at a time. For each light, write down your observations concerning brightness. Which appears brighter or fainter? Rank them in order from faintest (1) to brightest (4):

Light A:
Light B:
Light C:
Light D:

Discussion (2 points)
What factor(s) do you think affected the brightness of the light, as you perceived it?

Some Language:
When we talk about the light coming from an object, we use two different terms:
Luminosity: the actual amount of light emitted by the object. You can also think of it as the total power emitted by the light.

Brightness: the amount of light we receive, which determines how bright or faint an object appears.

Tool Introduction (4 points)
Each pair of students will receive a null-photometer. There are several pairs of light sources in the room – go to a pair of light sources. Move the null-photometer around between them, and write down your observations. For instance, when set exactly in the middle of a pair of lights, which side of the photometer looks brighter? What happens as you move the photometer closer to the fainter bulb in a pair?

Pair A:

Pair B:

Pair C:

Pair D:
Notice how, often, one side of the window on the side of the null-photometer will be brighter than the other. This tool measures when the brightnesses of two light sources are the same. You can use this tool to conduct an experiment that allows you to choose from among several conceivable equations that describe the relation between distance, luminosity (determined by the power rating of the bulb), and brightness.

**Model selection  (2 points)**

Scientists usually use existing theories and knowledge to select feasible equations to describe phenomena. They then develop experiments to test the accuracy of these mathematical models. However, it is also possible to use simple observations to think of feasible models, and use experiments to select from among them. Think of what caused the brightness to increase and decrease:

As the luminosity of the light source increases, the brightness ________________.

As the distance from the light source increases, the brightness ________________.

Some possible equations that would match this description are:

\[ B = \frac{L}{(4\pi D)} \]  
\[ B = \frac{L}{(4\pi D^2)} \]  
\[ B = L - (4\pi D) \]

_B_ is the measured brightness of the light  
_L_ is the luminosity of the light  
_D_ is the distance from the light

While there are some straightforward theoretical arguments that one could use to select a model (and would explain why you need the factor of \(4\pi\)), today you will explore this alternative approach of trying several models, and seeing if one closely matches experimental results.
**Experiment**

How do you choose between models? Well, you do an experiment, and see which model gives results that are close to what you see. The null-photometer tells you when the two light sources are of equal brightness. So, you will set up two light sources of known brightness and use the null-photometer to find a point at which both lights are equally bright. Then, you will measure the distance to each light source, plug that number into each of the potential equations, and determine if one of the equations gives calculated brightnesses that are equal.

Remember, careful experimental procedure requires that you repeat your measurements. It is also important to flip the null-photometer and measure the point of equal brightness using both possible orientations (Why is this important?). You should also switch the position of the bulbs (Why is this important?). Use the following step-by-step procedure:

1. Hold the null-photometer between the lights.
2. Move the null-photometer back and forth along the line between the lights until both halves of the photometer's window appear the same.
3. Your partner checks to ensure that the photometer is really on the line between the two lights.
4. Measure the distances $D_a$ and $D_b$. Ideally, these distances should be measured from the center of each light-bulb to the nearest side of the photometer.
5. Once both distances have been recorded, flip the photometer over so the left face is now the right face, and vice versa. Re-position the photometer between the lights, move it so both halves appear the same, and again measure the distances.
6. Swap the positions of the light bulbs, and again make two measurements. You should now have four separate measurements of the two distances.
7. Average each set of four measurements to get a more precise value; you can also look at the range of values for each measurement to get some idea of the accuracy of your work. (Why is this important?)

**Before moving on to the next pair of lights, be sure to record the luminous flux, in lumens. The accompanying chart relates the power and luminous flux of the bulbs used in this lab.**

<table>
<thead>
<tr>
<th>Power (watts)</th>
<th>Luminous Flux (lumens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>210</td>
</tr>
<tr>
<td>40</td>
<td>425</td>
</tr>
<tr>
<td>60</td>
<td>800</td>
</tr>
<tr>
<td>100</td>
<td>1600</td>
</tr>
<tr>
<td>200</td>
<td>3900</td>
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</tbody>
</table>
**Data Gathering (12 points)**

Record the data from your experiments in the chart below. Remember you should have FOUR measurements for each pair of lights, with the lights in different positions and the photometer in two orientations.

<table>
<thead>
<tr>
<th>Station</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>Average</th>
<th>Luminosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Da</td>
<td>Db</td>
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**Model Testing and Calculations (12 points)**

Now, determine which of the mathematical models most closely matches your observations. For each station, use the three different mathematical models to predict the brightness of the bulbs (at the location of the photometer). Using the measured values of L and D, calculate the different types of relations we want to test and fill in the chart below. Then calculate, for each model, the ratio of the two predictions.

<table>
<thead>
<tr>
<th>Stn.</th>
<th>L_a</th>
<th>D_a</th>
<th>L_b</th>
<th>D_b</th>
<th>L_a - 4πD_a</th>
<th>L_b - 4πD_b</th>
<th>ratio</th>
<th>L_a - 4πD_a</th>
<th>L_b - 4πD_b</th>
<th>ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
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**Results and Discussion (12 points total)**

(4 points) Which mathematical model describes the brightness of a light source? Present an argument, using the experimental results. Also, feel free to make a theoretical argument.
(2 points) Why is it important to flip the photometer over when making multiple measurements? How might this help improve your accuracy?

(2 points) Why is it important to switch the location of the light bulbs when making multiple measurements? How might this help improve your accuracy?

(2 points) If you can read comfortably by the light of a single 100 watt bulb which is 10 feet from your page, how many 100 watt bulbs would you need to provide the same brightness at a distance of 100 feet? Show your calculations.

(2 points) Consider a laser which fires a beam of parallel light rays. If the diameter of the beam is constant regardless of the distance from the laser, does the inverse-square law apply?

**Review**

Read the explanation of the inverse-square law on the lab website: [http://www.ifa.hawaii.edu/~barnes/ASTR110L_S03/inversesquare.html](http://www.ifa.hawaii.edu/~barnes/ASTR110L_S03/inversesquare.html)