Inverse Square Law

Purpose
The purpose of this experiment is to show that light intensity is inversely proportional to the square of the distance from a point light source.

Theory
The light from a point source spreads out uniformly in all directions. The intensity at a given distance, $r$, from the light will be equal to the power output of the light divided by the surface area of the sphere through which the light has spread. Since the area of the sphere goes as the square of its radius, $r$, the intensity will drop off as $\frac{1}{r^2}$. In general, the intensity of the point light source at any distance, $r$, is given by

$$I = \frac{\text{constant}}{r^2}$$

Thus, the ratio of the intensity ($I$) of the light at a position ($r$) as compared to some reference intensity ($I_o$) measured at a position ($r_o$) is given by

$$\frac{I}{I_o} = \frac{r_o^2}{r^2}$$

Set Up
1. Place the photometer at the 70 cm mark on the optics bench.

2. Place a point light source at 40 cm. Put a neutral density filter on the side of the photometer that is opposite the point source. See Figure 2. Place the other light source on the same side of the bench that has the neutral density filter.

3. Adjust the neutral density filter for 100% transmittance.
Procedure

NOTE: You may want to cover the crossed-arrow object on each light source to reduce the excess light in the room. The room lights must be off for this experiment.

1. Turn off the room lights. The only sources of light should be the two point sources.

2. Look into the photometer and move the light source on the filter side to a position that gives equal intensities. The light source on the filter side will remain at this position for the rest of the experiment. This light will act as the reference intensity $I_o$. Record the positions of the photometer and the light source that is opposite the filter side of the photometer in Table 1. The position of the reference light (on the filter side) is not needed.

3. Rotate the neutral density filter to 75% transmittance. Move the point light source (the one opposite the filter side) to the position where the intensities are once again the same when viewed in the photometer. Record this new position of the light source in Table 1.
Table 1: Photometer Experimental Results

<table>
<thead>
<tr>
<th>Photometer Position</th>
<th>Light Source Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>Position 1</td>
<td></td>
</tr>
<tr>
<td>Position 2</td>
<td></td>
</tr>
<tr>
<td>Position 3</td>
<td></td>
</tr>
<tr>
<td>Average Position of Point Source</td>
<td></td>
</tr>
<tr>
<td>Distance from Photometer</td>
<td></td>
</tr>
<tr>
<td>Calculated Intensity</td>
<td></td>
</tr>
<tr>
<td>% diff</td>
<td></td>
</tr>
</tbody>
</table>

4. Repeat the last step for 50% and 25% transmittance.

5. Repeat steps 2-4 twice more for positions other than the 40 cm specified in the Set Up section above.

Analysis

1. Using the measured positions in Table 1, calculate the distances of the point source from the photometer and record in Table 1.

2. For each of the different positions, calculate the intensity using

\[ I = \left( \frac{r_o}{r} \right)^2 I_o \]

where \( r_o \) is the initial distance of the point source (100%) and \( r \) is the distance at the given intensity. Note that the intensity is calculated in terms of the initial intensity \( I_o \). Record your answers in Table 1.

3. Calculate the percent difference between the calculated intensities and their corresponding expected values. Record in Table 1.