9.7 Light intensity experiment

Anyone who has looked at a light source, such as a street light, from different distances will realise that
the intensity of light varies depending on how far you are from the source.

In synchrotron experiments this is an important factor, since the intensity of the light equates to the amount of
energy delivered to the experiment. It is for this reason that beamlines usually contain curved mirrors to focus the
light onto the experiment and so increase the intensity.

In the following experiment you will collect data and
investigate the relationship between light intensity
(measured in lux) of a normal light source and the distance
from the source (measured in centimetres).

After collecting the data, your first job will be to plot the
data so that you can judge what sort of relationship might
apply. Your second challenge will be to find a more precise
relationship through using a spreadsheet.

Stage 1 – collecting the data

Materials

- tube, roughly 8 to 10 cm in diameter, minimum length one meter
- light source
- a metre ruler
- equipment to collect data such as light detector

Aim

To investigate the relationship between light intensity and the distance from the light source.

Method

This sketch assumes that you are using a light detector probe attached to a graphical calculator. Your
teacher will supply the equipment you need and any additional instructions you require.
1. Attach the torch securely to the end of the metre ruler using the duct tape. It is important that the axis of the light beam is parallel to the ruler. Note: the focusing mirrors have been removed from around the bulb.

2. Insert the ruler and torch into the pipe, pushing it down as far as possible without losing control of the ruler. As shown in the picture to the right, the control end of the ruler protrudes through a slot cut in the end of the tube. This minimises light interference.

3. Mount the light detector in the mouth of the pipe, facing the torch. It is critical for success that the light detector is positioned in the centre of the axis of the beam of light.

4. Measure the initial separation between the detector and filament of the torch bulb.

5. Note the measurement on the ruler at the other end of the tube which corresponds to this. Use this measurement to move the ruler so that the separation between the detector and source is correct for the first measurement.

6. Start the experiment with a minimum distance of 20 cm between the light source and the light probe.

7. It is essential that outside light leakage is kept to a minimum while taking measurements. You can do this by poking the light detector through a slot in the tube. A black shroud over the whole apparatus can also increase accuracy.

8. Measure the light intensity at the initial position, recording the distance and light intensity.

9. Move the ruler carefully back through the pipe, pausing regularly to record the distance and light intensity. The most reliable data set will generally be found in the range of 20 cm to 60 cm.
Stage 2 – Entering and displaying the data

If you used the Light intensity explorer to collect your data, then your results have already been saved to the clipboard, ready to be pasted into a spreadsheet. Open Microsoft Excel and paste this information.

If you performed the experiment yourself, then you will need to enter the data into a spreadsheet as shown. Table headings should be the same as those in our example.

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Plot the data so that you can judge what sort of relationship might apply. One possible way to do this is to use Excel's charting ability as shown above. Your own data should be similar to this example.

If you are not sure how to produce a scatter graph using Excel then, in brief, the procedure is:

- Highlight both columns of data and click on the chart icon:

- In Chart type (which displays the different types of graphs), select XY (Scatter) and the sub-type shown.

- Click on the Finish button.
Stage 3 – identifying the relationship

The easiest way to identify the relationship is to reduce it to a few possibilities and then linearise the data for each one in turn. Whichever one produces a straight line (or is the closest to one) is the most likely candidate.

Working individually or with a partner:

1. Decide on two to four possible relationships that you think might fit the shape of the data.

2. For each one of these, decide how to linearise it.

   Note: If you decided to try an exponential decay rule, then you may need to consult your teacher on how to linearise it. The process requires logarithms.
Stage 4 – using spreadsheets to linearise

Begin by creating two additional columns showing the data after it has been transformed.

For example, suppose that we suspect that the relationship is $y = \frac{a}{x} + b$. In this case the transformations would be $p = y$ and $q = \frac{1}{x}$.

Create new columns as functions of the old in order to perform these.

The required calculations for this sheet and the $\frac{1}{x}$ relationship are displayed on the right; it is likely yours will be different.

You should now have two new columns of data. Graph the new data in a new chart.

It may seem obvious whether the transformed data is linear or not, but it is a better procedure to overlay a line of best fit. To do this, select the whole chart by clicking on the background. The result should be as shown in the image to the right.

From the Chart menu, choose the option Add Trendline.
A window will appear. At the top of this window, choose the **Type** tab. In the **Type** screen, select **Linear** as the type of **Trend/Regression type**.

Now click on the **Options** tab (at the top of the window). Tick the option **Display the equation on chart**.

You final result should be similar to the diagram below, although we have increased the equation’s font to allow for easier reading.

Comparing the ‘linearised’ data with the trend line shows that the choice of $y = \frac{a}{x} + b$ as a model was probably incorrect since the data does not scatter randomly about the line.

Use similar methods to those demonstrated to decide which, if any, of the relationships you chose earlier is the correct one.
Stage 5 – final results and follow up

1. Use the equation of your trendline to find the coefficients of your chosen rule. Write it in a form giving \( I \) (intensity) from \( d \) (distance).

Result: ..........................................................................................................

2. Why do you think the light intensity should follow this rule?

\[ \text{Image courtesy: DUIT Multimedia} \]

**Hints:**

Consider the shape that the energy forms as it spreads out into the environment. What would be the surface area of that shape?

Consider the area of the detection window of the light probe. How does the amount of light reaching it change, as you move further away?

3. If you had to come up with a formula for average light energy per second (ie power) per square metre, what might it look like?