9.1 Light intensity

In this activity, students will explore the relationship between light intensity and the distance from the source with the aim of discovering the inverse square proportion relationship. Following their data collection, students will explore the possibility of different rules using a spreadsheet.

The most appropriate rule is selected through the process of data linearisation, in which a non-linear relationship is converted to a linear one by applying a transformation. For example, a relationship such as $y = \frac{k}{x^2} + c$ is converted to a linear one by graphing y against $\frac{1}{x^2}$ rather than y against x. To assist students unfamiliar with this method, we have provided a worksheet that guides students through the process. Students can analyse the data collected by hypothesising on the type of relationship and then experimenting with different transformations to see which one produces a set of data which is closest to linear.

During this activity, light intensity will be measured in lux, the amount of energy (light) per unit area per second. Lux can sometimes be confused with lumens (the total light output of the light source). In this activity we will be using a light meter as the measuring instrument. To work within the capabilities of the meter, which is the amount of light falling on a set unit of area, we will work in lux.

Note 1: The *Light intensity explorer* was produced using the results from an actual experiment. The reason for Lux being the unit of measurement is because this is the measurement used by most light probes available in schools.

Note 2: It is better to plot using Excel than to try and plot the results manually. If you choose to plot manually, we suggest rounding to two decimal places**.**

Notes to assist with the experiment

This activity will be most useful if students are able to perform the experiment in class and gather the data themselves.

Section 9.5 and section 9.7 are similar. Although section 9.7 takes students a little further by getting them to analyse the data they have collected. In 9.7 students use technology to find the equation of the relationship in the form of $I = \frac{c}{d^2}$.

It is strongly suggested that you conduct this experiment yourself, prior to the class activity to ensure you get good results.

There are a several ways to proceed:

- Perform a demonstration of the experiment at the front of the room (greater control, less equipment required) and then share one data set between all the students.
- Use the **9.4 Light intensity explorer**. This animated experiment will supply data in a format that can be analysed in a spreadsheet.
- Use the **9.6 Light intensity data set**. This contains four data sets produced by students who performed the experiment.
- Work in conjunction with the Science Department. For example, by asking a science teacher to help with the experiment, or by asking that they perform the experiment in a science period, telling the students to bring the data to their mathematics lesson for analysis.

Data can be gathered in a variety of ways. Some possibilities are:

- Using a graphical calculator/computer plus a light probe to gather the data.
- Using a photo-electric cell to gather the data.
- Enclosing the light source in a tube.
- Conducting the experiment in a darkened room.

An example experiment is briefly outlined in the following notes. **This example experiment is NOT intended to be given to the students – it is provided purely as a guide to assist teachers.**

The example provided uses a light detector, a graphical calculator and a light source (a torch) enclosed in a large tube. It was adapted from an activity supplied courtesy of Alan Cadby and Gary Young from Hale School (Western Australia).

The teaching/learning order prescribed in this document is to:

a. Take the student through the mathematical process of linearisation.

b. Perform the experiment and obtain data.

c. Apply the linearisation technique to the collected data.

Alternatively, you can perform the experiment first and then pose the question of how to analyse the results applying the technique of linearisation.

Some practical considerations

Any external light source, in addition to the one being measured, will interfere with the results in two ways:

1. By possibly adding a $+c$ to the rule which would normally be $I = \frac{k}{d^2}$ where I is intensity and d is the distance between light source and detector.
2. By drowning out low intensity values at longer distances from the source.

There are several solutions to this:

1. Enclose the light source in a large diameter postal tube (~10 cm) and cover both ends when taking measurements.
2. Use 10 cm diameter PVC pipe and line the interior with non-reflective black paper to minimise reflection of light.
3. Use a completely darkened room. This may not be practical in a school environment, although some Science Departments have these rooms.

If possible, remove the focusing mirrors from the surrounds of the torch bulb (see the photograph in the example experiment). The artificial focusing of the light into a 'beam' can interfere with the inverse square rule which assumes a spherical spread.

Measurements close to or far away from the light source are likely to be erroneous. Using the torch we found that the best data sets were obtained using a range of 20 cm to 60 cm. To ensure quality data, teachers should experiment with the light source they are using before the class activity.

Assumed Skills

This activity assumes that students:

- Have already worked with problems in both direct and indirect proportion, and have examined relationships such as $y \propto \frac{1}{x^2}$.
- Have a good knowledge of scatter graphs and lines of best fit. They should be able to plot data, draw an approximate line of best fit and, given technology, find the true line of best fit. It is advantageous (but not essential) that students are familiar with the significance of the correlation coefficient. Judgment of the best fit by eye should be sufficient though.
- Have a moderate familiarity with spreadsheets. The method used to determine the most appropriate relationship is to linearise the data. This is completed for each possible relationship, judging by eye on a scatter graph which is the best one.