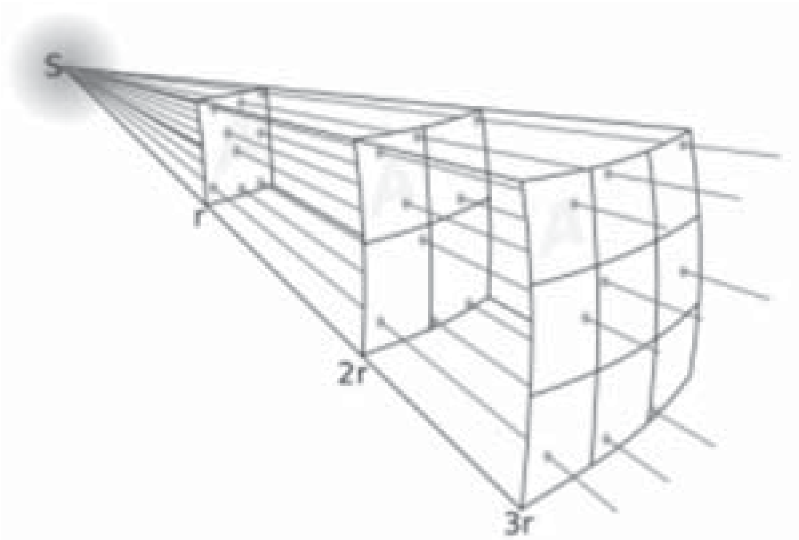
Light Law
Teacher Notes

Introduction

When radiation streams out from a point source, the energy is shared over ever-larger areas. This means that the energy that passes through unit area at a distance of one unit will pass through 4 square units at double the distance.



This idea applies equally to gravitation although no such gravitational radiation has been discovered. Light (from a point source), gravitation and electric field (again due to a point charge) all obey the inverse square law. This means that illumination of an object falls off rapidly with distance and putting a little distance between a gamma emitter and yourself quickly renders the radiation much less harmful.

In this activity students study the relationship between light intensity and distance from a light source. Using a light sensor connected to a TI-Nspire handheld, data can be collected in a spreadsheet. The data is plotted and a power regression carried out.

Having decided that there may be an inverse square law operating, light intensity can be plotted against 1/(distance)^2. Plotted points lie approximately on a straight line and a straight line of best fit can be fitted by eye.

Resources

There is an exemplar TI-Nspire document that includes some typical data and analysis.

You will need

A Vernier light probe, a TI-Nspire handheld and a 5m tape measure. You will also need a 60W tungsten filament lamp to serve as the light source and a room that can be darkened: it does not have to be totally dark, just shaded enough to reduce the effect of background light.

In this example data are collected as Events with Entry in the Experiment Set Up Collection menu. Instead of collecting data with time you need to set up the experiment to collect data with entries, the entries being, in this instance, the distances from the source. Data are automatically entered into a spreadsheet.

The science

The Light Law is just one accessible example of an "inverse square law". Students are required quite early on to understand that gravity falls off with distance much more rapidly than being proportional to distance would suggest.
By reference to inverse square laws, students may begin to appreciate:

- how little of the Sun's energy we receive;
- how little radiation from a sound source falls on the ear;
- why the effect of gravity falls off so rapidly with distance ;
- why a reading lamp needs to be so close for good illumination.

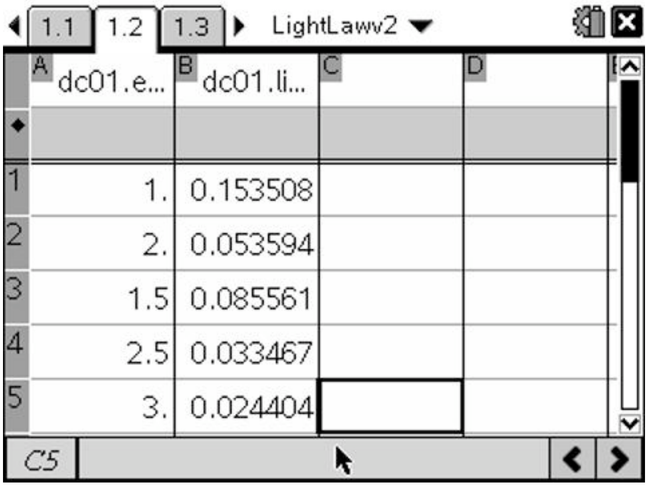
The mathematics

The activity provides opportunities for fitting functions to real data and using a straight line as a test of goodness of fit rather than just relying on regression.

The activity

Step 1: Collecting the data

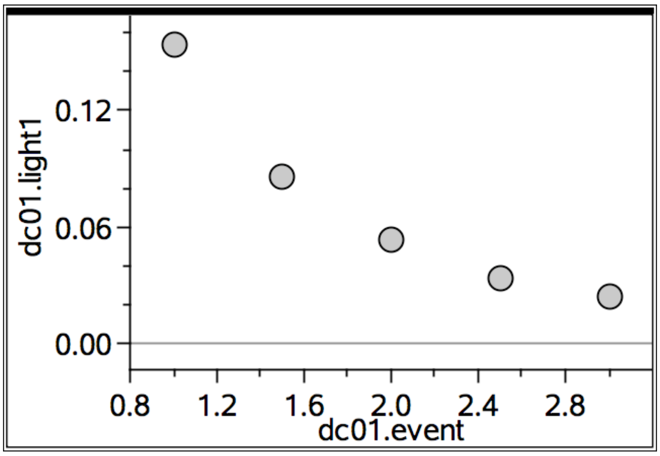
- Open a new TI-Nspire document and Plug the Vernier light probe into the USB port of the TI-Nspire handheld, using the EasyLink adaptor. A control panel opens at the bottom of the screen.
- Select Lists & Spreadsheet.
- Press (menu) and select *1:Experiment, 3:Set Up Collection, 2:Events with Entry*.
- Place the light probe one metre from the lamp and press (enter) when the highest reading is displayed.
- Another icon will be shown, press (enter) again and a new window will be displayed asking for the value of the entry. Enter 1.
- Repeat for different distances from the lamp.
- A spreadsheet similar to this will be produced.



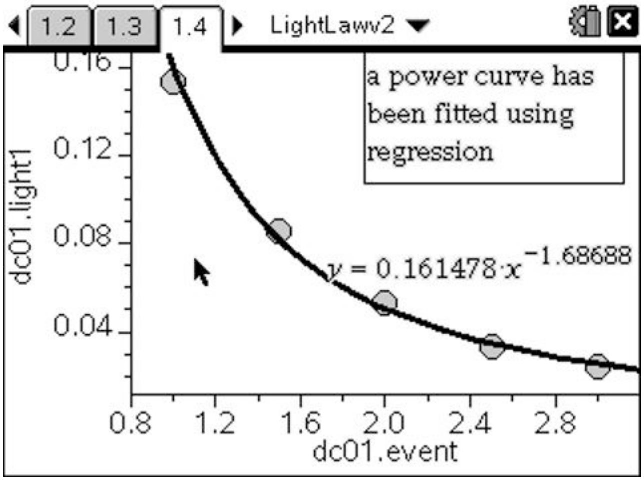
	A dc01.e...	B dc01.li...	C	D
◆				
1	1.	0.153508		
2	2.	0.053594		
3	1.5	0.085561		
4	2.5	0.033467		
5	3.	0.024404		

Step 2: Analysing the data

Insert a Data & Statistics page and plot the light intensity recorded against the distance (here called event).

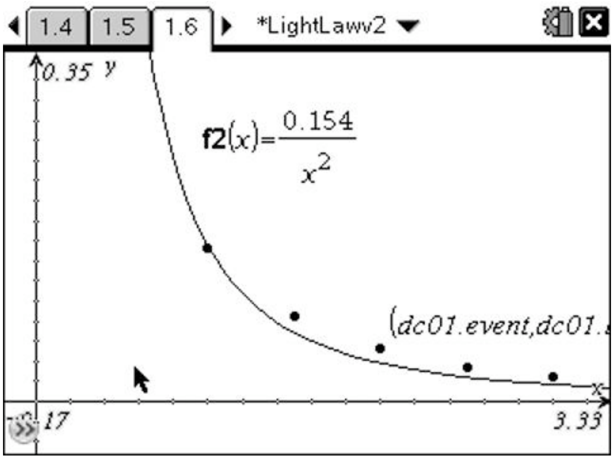


What sort of relationship is represented? Start by trying to fit a power function to the data: press (menu) and select *4:Analyse, 6:Regression, 7:Show Power*.



The regression curve is y= $K/x^{1.69}$ which is close to y=K/x^2 where *K* is a constant.

Now plot the points by creating a scatterplot on a Graphs page and try to fit an inverse square function to the data. Note that when x is 1 the value of y is 0.154, so plotting y=$0.154/x^2$ may provide a good fit.



The function may be moved up or down by adding or subtracting a constant in order to get a better fit to the data. There will be ambient light in the room which can be taken into account this way.

Yet another way of showing that we have an inverse square function involves plotting the measured light intensity against the inverse of distance squared and checking whether a straight line results. Go back to the list of data (page 1.2) and create a third column with the values 1/(distance^2). On a new Graphs page you can now plot a scatter graph and the points appear to be fairly linear. You could carry out a linear regression or alternatively draw a line of best fit by eye. To do this draw a straight line graph by entering, for example f4(x)=0.2x. It can then be moved around in two ways: dragging a point towards the middle of the line will move it horizontally or vertically, whereas by selecting a point near the end of the line it's gradient can be changed. Thus the line can be moved until there is a good fit with the plotted data points and the resulting straight-line function leads to an approximation to the relationship between the measured light intensity and the distance.