Inverse Square Law

Several of the fundamental force laws are of the form of inverse square laws where the strength of the force varies as one over the distance squared. Gravitational, electrical and magnetic forces all have this dependence on $\frac{1}{r^2}$. In other words, if you double the distance between two masses or two charges, the force one exerts on the other is reduced by $\frac{1}{4}$ instead of $\frac{1}{2}$. We shall examine this performing two exercises. One is experimental and the other is theoretical.

Experiment #1 – Measuring Visible Light

You should have a light sensor connected to a Pasco Interface unit (Likely a 750 or an 850 unit). The cord from the sensor should be connected to the **A connector**. The Pasco unit should be connected to one partner's NMU computer using the **USB** cord. The computer should be running Capstone, and you should have loaded the set-up file for this experiment. Capstone should show a text box which provides the % of light intensity being measured. The sensitivity switch on the light sensor should be set to **1**.

Set up the light source at one end of the track. Note the distance where the light leaves the source. Start with the light sensor approximately **80 cm** away from the light source. Is the light intensity as measured on Capstone about 7**%**? Does the value decrease as you move away from the light source? Does it increase as you move closer to the light source? If the intensity value is not changing with small movements of the light sensor towards or away from the light source, you are too far away. Try moving closer to say **60 cm** and see if you now get changes in light intensity with small movements of the light sensor. When you find this distance where you still get light intensity changes, this is your **Far Distance**!

Now move the light sensor as close to the light source but keep the light intensity below **93%**. Once again, move the light sensor towards and away from the light source, does the value change with small movements? When you have found the closest distance, you can be to the light source and still get changes in light intensity, you have found your **Near Distance**!

Now that you have the extreme distances, subtract them and divide that answer by 10! The formula below gives you the distance to move the sensor as you go from the near point (ND) towards the far point (FD).

$$\Delta \boldsymbol{d} = \frac{\boldsymbol{FD} - \boldsymbol{ND}}{\mathbf{10}}$$

For example, let's say you found FD is 80 cm and ND is 14 cm, then your distance to move the sensor would be

$$\Delta \boldsymbol{d} = \frac{\boldsymbol{FD} - \boldsymbol{ND}}{\mathbf{10}} = \frac{\mathbf{80}\ \boldsymbol{cm} - \mathbf{14}\ \boldsymbol{cm}}{\mathbf{10}} = \frac{\mathbf{66}\ \boldsymbol{cm}}{\mathbf{10}} = \mathbf{6.6}\ \boldsymbol{cm}$$

You would start the data collection by putting the light sensor at 14.0 cm and move it 6.6 cm each time and record the light intensity ignoring the % sign. So, you would start at 14.0 cm, then move to 20.6 cm, then 27.2 cm, and so on until you reached 80.0 cm which will result in about 11 data points of distances and light intensities. The light intensities will not be in standard units, but they will work for what we are trying to see. Put your data in the table 01 on the data sheet. At each distance, be sure you have kept the light sensor centered in the light path. To check, move the sensor across the track and find the largest intensity measured and use that. Be sure the sensor is pointing parallel to the track.

Produce a plot of Intensity vs. Distance. Do not add a trendline. Clearly the plot is not linear. Be sure to use the proper formats for Axis Labels and the Plot Titles.

Complete filling out the data table by finding the natural logarithms of the intensity and the distance.

Produce a plot of Ln(Intensity) vs. Ln(Distance). This time add a properly formatted trendline. Be sure to use the proper formats for Axis Labels and the Plot Titles.

Now complete the table Data Table 02 which is based on this Ln-Ln Plot.

Experiment #2 – Theoretical Determination of Electrical Charge

In this exercise, consider that two identical charges (same sign and same strength) were placed at different distances apart from each other. The resulting electrical force either one exerts on the other is measured and the results are presented in the table below:

r (m)	Force (N)
0.15	2.70
0.23	1.15
0.41	0.36
0.49	0.25
0.55	0.20
0.7	0.12
0.76	0.11
0.84	0.09
0.96	0.07

Produce a plot of Electrical Force vs. Distance. Do not add a trendline. Clearly the plot is not linear. Be sure to use the proper formats for Axis Labels and the Plot Titles.

Complete filling out the data table by finding the natural logarithms of the force and the distance.

Produce a plot of Ln(Force) vs. Ln(Distance). This time add a properly formatted trendline. Be sure to use the proper formats for Axis Labels and the Plot Titles.

Now complete the table Data Table 02 which is based on this Ln-Ln Plot. To find the charge involved remember to write out Coulomb's Law for this situation and then where does Q show up in the Ln-Ln equation theoretically? Take your value from your plot's trendline and then determine Q. Show this work on your data sheet you will be turning in.