Name: ___________________________ Teacher:___________________ Class:_____________

Testing the Inverse Square Law for Gamma Radiation

Practical skills covered

A – use of analogue equipment to record a range of measurement
B - use of digital equipment to obtain measurements
K – Use of data logger and associated software to process results
L – use ionising radiation, including detectors

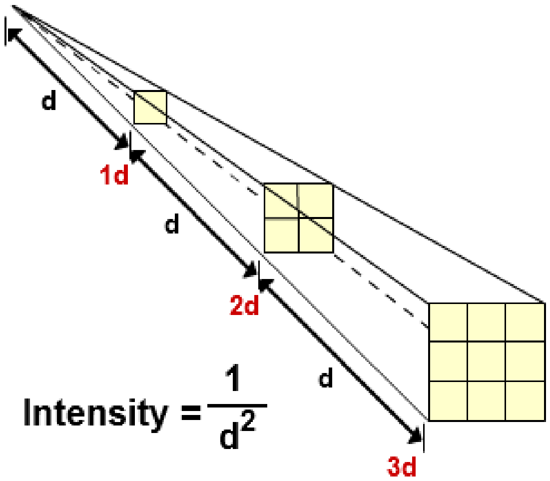
Endorsement skills being assessed

1 – Follows written procedures
3 – Safely completes practical
4 – Makes and records observations – Practical Skills Guide: Tables p.4 - 5

Investigation

You are to undertake an investigation to measure how the intensity of gamma radiation varies with distance from the source.

Theory



Any point source which spreads its influence equally in all directions, without a limit to its range, will obey the inverse square law. This comes from strictly geometrical considerations. The intensity of the influence at any given radius (r) is the source power divided by the area of the sphere. Being strictly geometric in its origin, the inverse square law applies to diverse phenomena. Point sources of light, sound, and radiation obey the inverse square law.

The theory therefore indicates that if a source of gamma radiation is emitted equally in all directions, and not absorbed by the material it passes through, then the intensity of the radiation decreases according to the inverse square law:

$$I = \frac{k}{x^2} \quad \text{.............................(i)}$$

Where I is the intensity of the gamma radiation in $Js^{-1}m^{-2}$, k is a constant and x is the distance to the source. The following experiment is designed to test this relationship between intensity and distance.

The equipment used in the experiment is shown in figure 1 below.

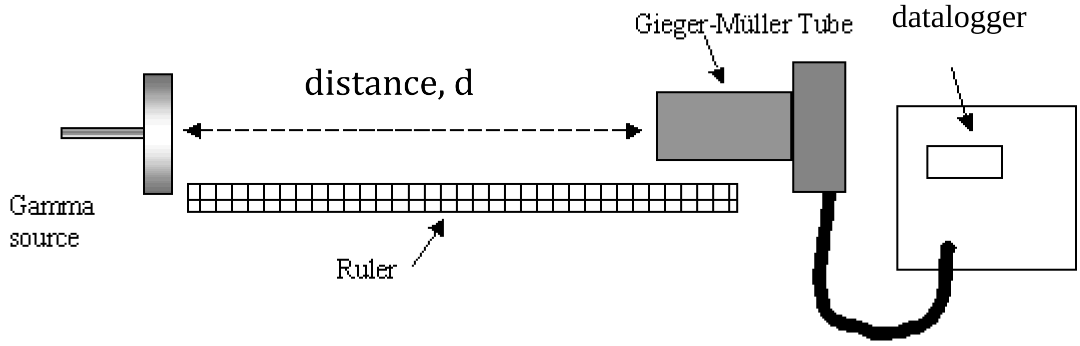


Figure 1 Experimental set up to measure the dependence of gamma radiation intensity on distance between the source and GM tube detector.

The gamma radiation source is a sealed 60Co sample, the detector is a Geiger Muller (GM) tube and a datalogger is used to record the number of intensity counts. The distance d, labelled in the diagram, is the approximate distance between the front of the gamma radiation source and the GM tube. The point of gamma ray emission may in fact lie a few mm behind the front of the source. The point of detection may also lie some distance from the front of the GM tube detector. In order to take account of these differences in distance, x could be written as:

$$x = d + d_0 \quad \text{.....................................(ii)}$$

where x is the actual distance between the point source and the point of detection, d is the distance between the front of the gamma source and front of the GM tube, d_0 is the difference between x and d.

Substituting equation (ii) into equation (i) gives the expression:

$$I = \frac{k}{(d + d_0)^2} \quad \text{.....................................(iii)}$$

Rearranging equation (iii) for d gives the expressions:

$$I^{1/2} = \frac{k^{1/2}}{(d + d_0)}$$

$$I^{1/2}(d + d_0) = k^{1/2}$$

$$d = k^{1/2}\frac{1}{I^{1/2}} - d_0 \text{ ....(iv)}$$

where k and d_0 are both constants.

Relate equation (iv) to the equation of a straight line:……………………………………………..

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What graph will you plot to find k and d_0?: ………………….. against ………………

How will you determine the values of k and d_0 from your graph?

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Equipment

Gieger-Muller Tube Gamma Source Tweezers
Ruler Datalogger

Method

SAFETY: Radioactive sources

Follow the local rules for using radioactive sources, in particular do not handle radioactive sources without a tool or place them in close proximity to your body. Deliberately placing a radioactive source in contact with the skin would increase your dose of ionising radiation unnecessarily and increase the risks to your health.

Measure the Background Count Rate at Different Distances

1. With the detector in place and **no radioactive source present**, measure the counts collected in 3 min 20s using the datalogger. See handout on how to use the datalogger.

Background Counts in 200 s = ………………………

2. Work out the average background count rate (counts s^{-1})

Background Count Rate = ………………………

Measure the Count Rate at Different Distances

1. Using long tweezers to handle the gamma source, place it in the holder.
2. With the detector and the radioactive source both in place, measure the counts collected in 200 s at six different distances between the front of the source and the front of the detector, in the range of 0.020 – 0.300 m., using the datalogger.
3. Record all the distances in metres and the corresponding count rates in an appropriate table on page 6.
4. Repeat the measurements at each distance and calculate an average count rate, recording all values in your table.
5. Calculate the corrected count rates at the different distances by subtracting the background count rate from each value. Record the values of corrected count rates in the table on page 6.

How has your approach to finding the count rate reduced the uncertainty in the measured values?

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Data analysis

1. Plot your results on a graph with d on the y-axis and $1/I^{1/2}$ on the x-axis.
2. Draw a line of best fit to your data points.
3. Explain if your results confirm that the inverse square law applies well to gamma radiation from a radioactive source?

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4. Use your graph to determine the value of d_0

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5. Use your graph to determine the value of k

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6. Compare the intensity (corrected count rate) at a distance of $x = 1$ mm to the intensity at $x = 1$ m

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Table:

Extension Task

Finding the Power in an Equation using logarithms

1. Use the value of d_0 that you obtained to evaluate x at each distance of d in the table below.

d/m	x = $(d + d_0)$/m	I = $(C-C_B)$/Counts s^{-1}	ln (I)

2. If the relationship between I and x was unknown for the gamma source, the following expression could be used:

   $I = kx^p$ ………………………….(v)

   where I is the intensity at a distance x from the source and k is a constant.

3. Taking logs of both sides of equation (V) gives:

   $\ln I = \ln k + p \ln x$ ………………………….(vi)

4. Relate equation (vi) to the equation of a straight line:………………………………

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5. What graph will you plot to find k and p?: ………………… against ………………

6. Plot this graph and determine the values of k and p.

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7. Compare your results with those from the previous section.

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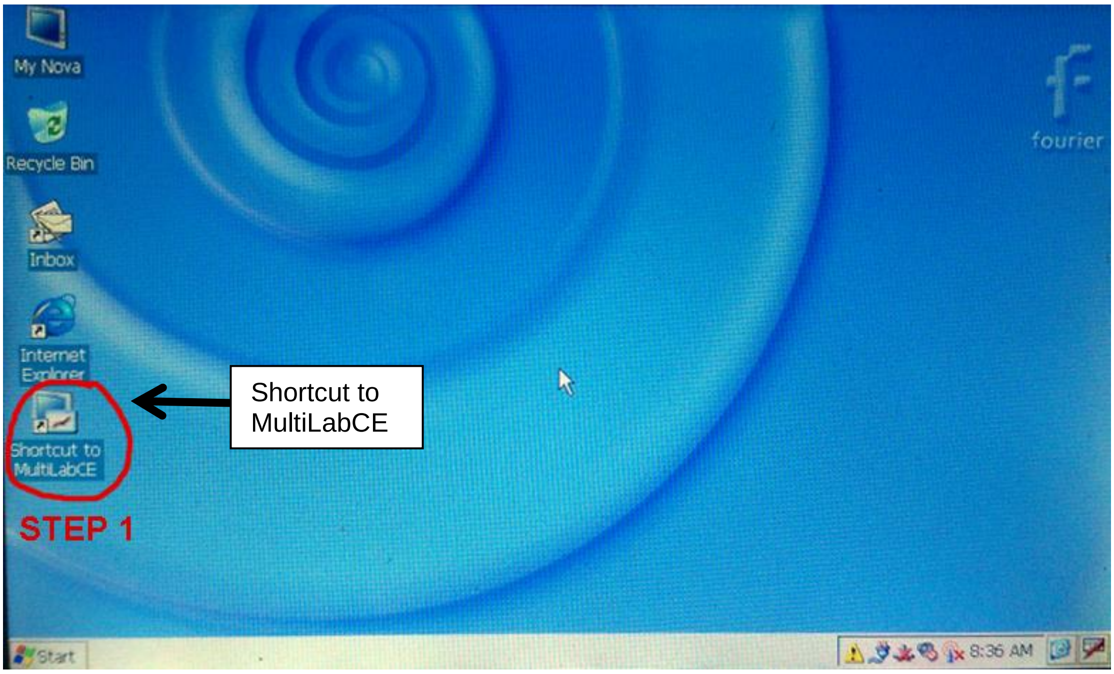
How to Use the Datalogger

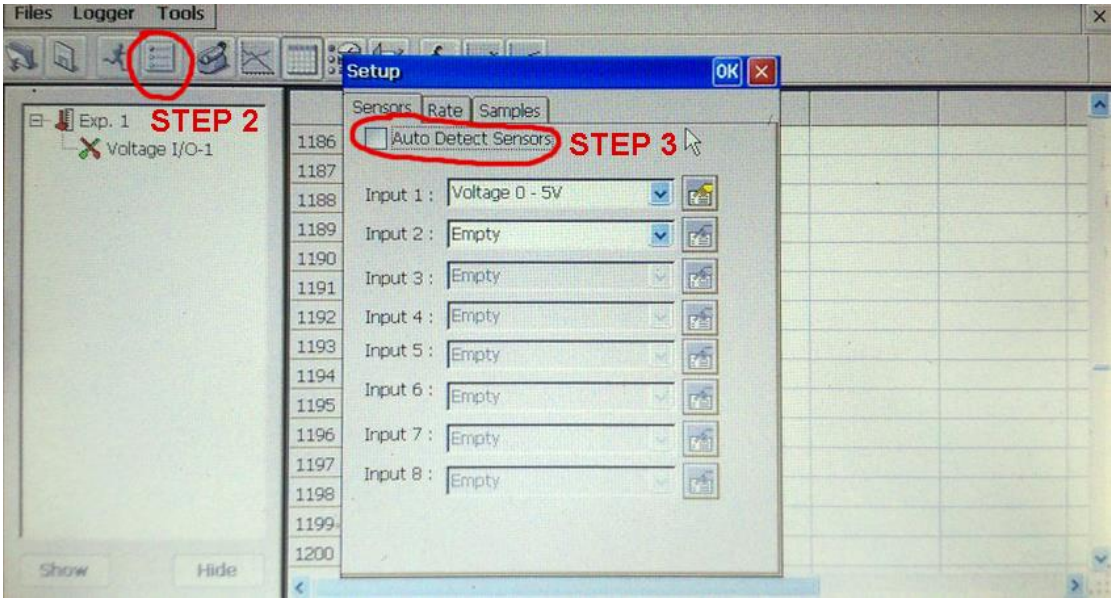
1. You are now going to open the data logging software and input the parameters for the data logger to operate under.

   Follow steps 1-5 from the pictures below and **make sure you press 'OK'** when you have finished to store the settings.

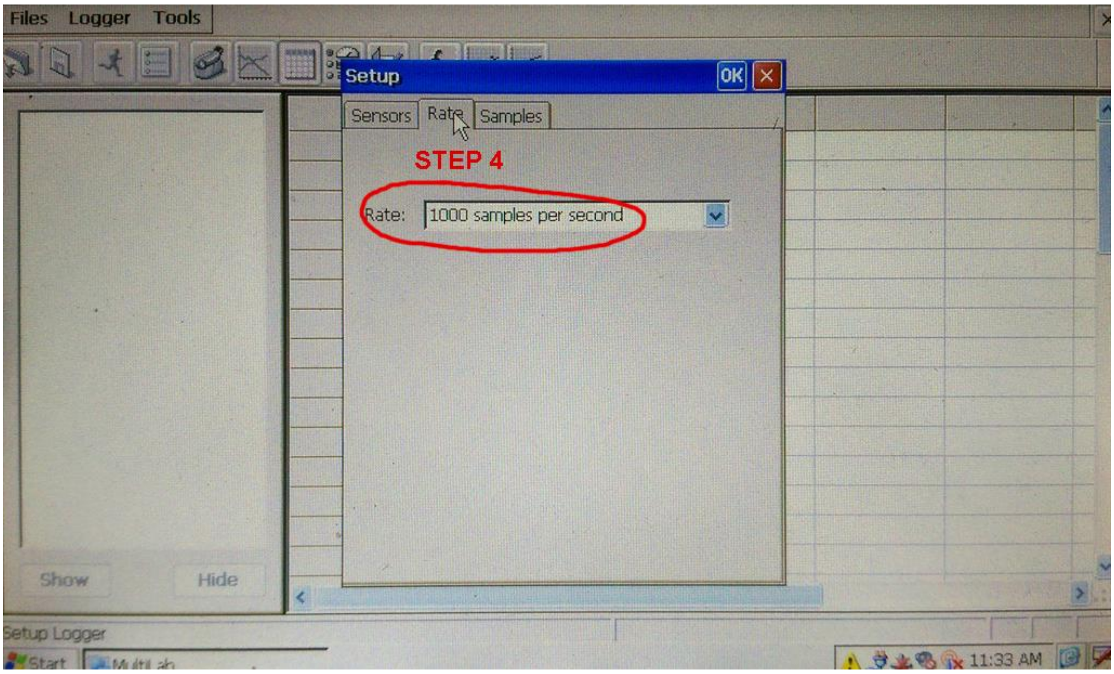
Step One



Steps Two & Three

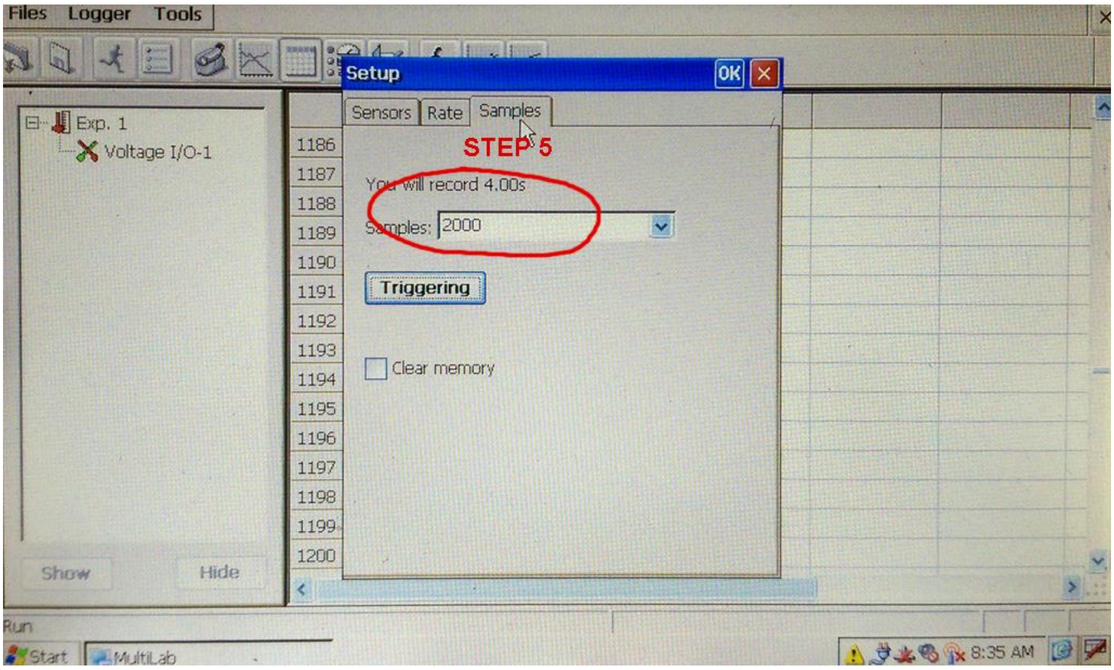


Step Four



Change this to 10 samples per second

Step Five



Select 2000 samples for a measurement over 200 s

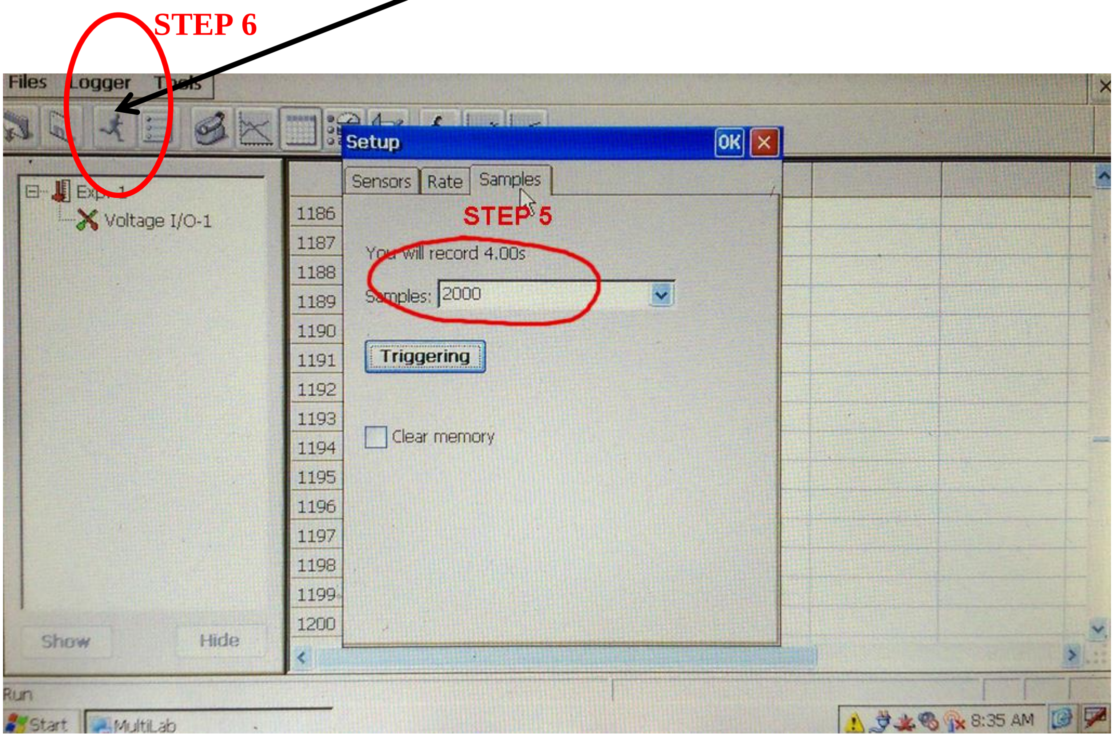
Or

Select 1000 samples for a measurement of 100 s

Press OK

Step Six

Start collecting data by pressing the running person icon.



Step Seven

After collecting all the data select tools → Analysis -→ Statistics

Make a note of the value of the sum, to give you the total number of counts in the time window set.