Verification Of the Inverse Square Law and Finding a Hidden Source Using Survey Meters

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Objectives:

1. To measure count rate vs. distance from a point source and verify $I \propto 1/r^2$.
2. To quantify deviations due to scattering, attenuation, and finite source/detector size.
3. To practice source localization (triangulation) using count rate measurements.
4. To understand the limitations of survey meters and background influence.
5. To evaluate uncertainty and produce best-fit model parameters.

Theory:

Radiation Survey meters are hand-held ionizing radiation-measuring instruments used to measure radiation levels in environments containing radioactive sources or radiation-generating equipment. These instruments use gas-filled, semiconductor, or scintillation radiation detectors. The Gas-filled radiation detectors are robust, easy to manufacture, cost-effective, and widely used. Gas-filled detectors are classified into three types: the Ionization chamber, the Proportional counter, and the Geiger-Müller (G.M.) counter. They all have different uses and have benefits based on the type of radiation, and they operate within their respective voltage ranges.

Pressurized Ionization Chamber

It operates on the principle of gas ionization. The detector consists of a chamber filled with gas (usually an inert gas) at high pressure. When gamma radiation enters the chamber, it interacts with gas molecules, producing ion pairs (positive ions and electrons). An electric field applied across the chamber collects these charges, producing a small current. This current is directly proportional to the radiation dose rate, which is displayed by the instrument in units such as μSv/h or mR/h.

G.M. based radiation survey meter [Model: RM701N]

Geiger-Müller radiation counter tubes (G.M. tubes) are gas-filled devices that respond to individual ionizing events, enabling them to be counted. A G.M. Tube consists of an electrode at a positive potential (anode) surrounded by a metal cylinder at a negative potential (cathode). The cathode forms part of the envelope or is enclosed in a glass envelope. Ionizing events are initiated when quanta or particles enter the tube through the window or the cathode and collide with gas molecules. The gas filling consists of a mixture of one or more rare gases and a quenching agent. Quenching is the termination of the ionization current pulse in a G.M. tube. Effective quenching in the G.M. tube is determined by the combination of the quenching gas properties and the value of the anode resistor.

Radiation Survey Meter (micro) RM701N is a G.M. Detector-based, battery-powered, handheld, ruggedized general-purpose radiation survey meter used for radiation survey, area monitoring, and ambient radiation monitoring. It uses a thick-walled G. M. Tube with an energy-compensated filter to detect X-ray and gamma radiation in the range from about 60 keV to 1.3 MeV. It has an overall wall thickness of about 1-2 mm of chrome steel. It can measure radiation levels in the range of 0 -10 R/hr.

Exp. 1 INVERSE SQUARE LAW: GAMMA RAYS

1. PROCEDURE

- Make a detector-source arrangement as shown in the figure.
- Without a source, take a few background measurements (about 5) and average them.
- Place a gamma source (Cs-137) in the source holder, and adjust the distance (d) (say 30cm) from the detector.
- Increase the Distance (d) in steps of 5 cm, record the observations for each step, and tabulate the data as shown in the table, until a distance of 75 cm from the detector.
- Subtract the background value from the recorded value, resulting in "Net Dose Rate or Net Count Rate".

Fig. Setup for Verification of Inverse Square Law

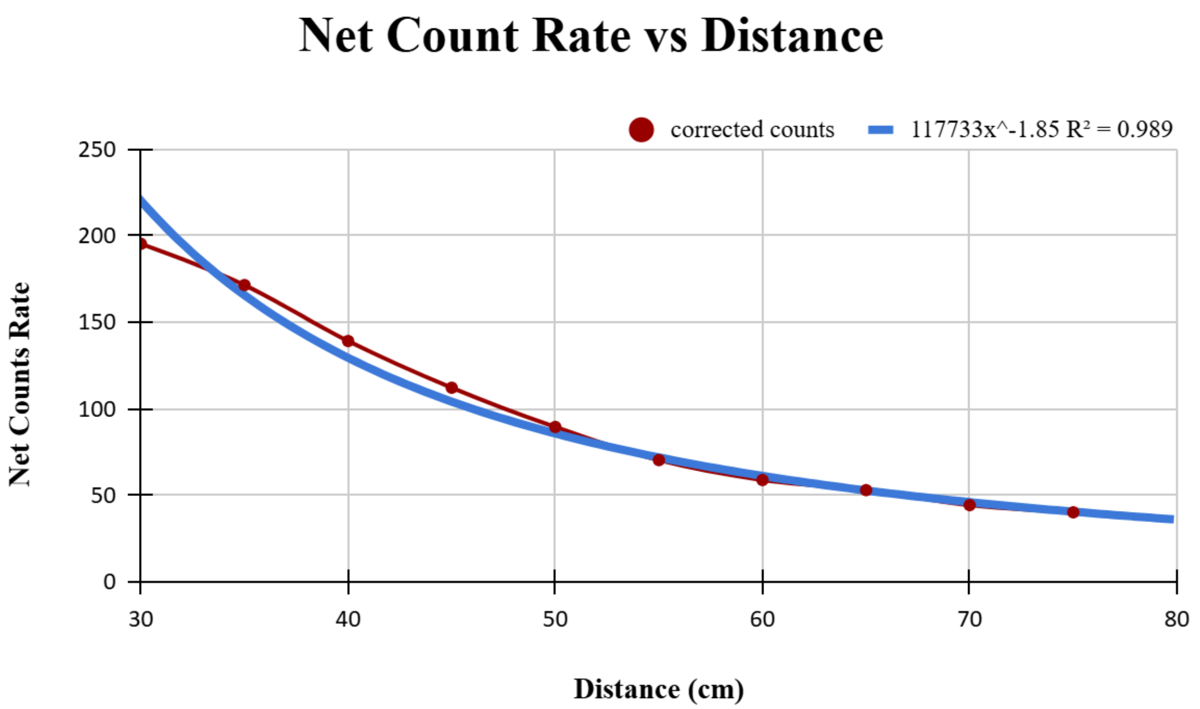
2. COMPUTATION & ANALYSIS

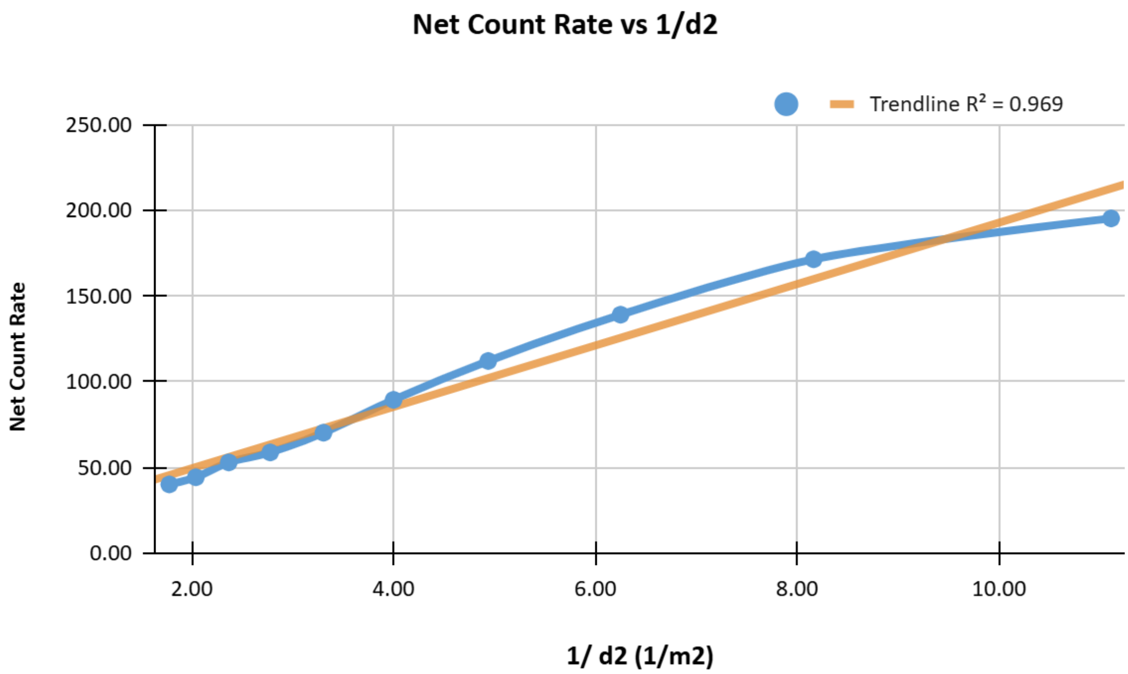
- Compute and tabulate 'Net count rate' (R), 'Distance', transformation ($1/d^2$), etc., as shown in the table. Plot a graph of Net count rate (R) Vs. distance (d) in cm. The figure shows that the product $R.d^2$ is constant.
- An alternative analysis method involves transforming the data so that the results lie in a straight line. For this purpose, “Net Count Rate” vs. “Reciprocal of the distance square” (1/d2) are plotted. This will be a straight line.

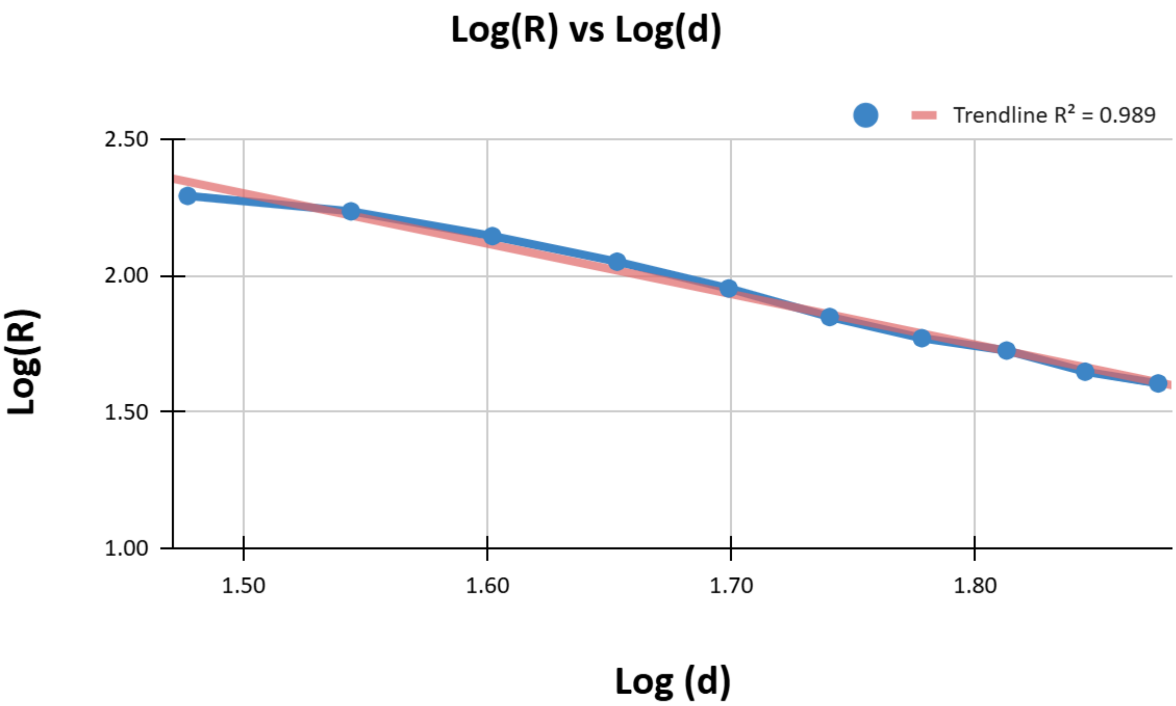
Table: Data for Inverse Square Law Experiment

Instrument: Pressurized Ionization Chamber Background = $\frac{12+11+13+10+9+11}{6}$ = 11

Sr. No.	Distance in cm (d)	Dose Rate/Count Rate	Net Dose Rate(R)/ Net Count Rate	$1/d^2$ in ($1/m^2$)	Log d	Log R	$R.d^2$
1	30	206	195	11.11	1.48	2.29	17.58
2	35	183	172	8.16	1.54	2.23	21.01
3	40	150	139	6.25	1.60	2.14	22.27
4	45	123	112	4.94	1.65	2.05	22.71
5	50	101	90	4.00	1.70	1.95	22.38
6	55	81	70	3.31	1.74	1.85	21.28
7	60	70	59	2.78	1.78	1.77	21.18
8	65	64	53	2.37	1.81	1.72	22.39
9	70	55	44	2.04	1.85	1.65	21.72
10	75	51	40	1.78	1.88	1.60	22.59

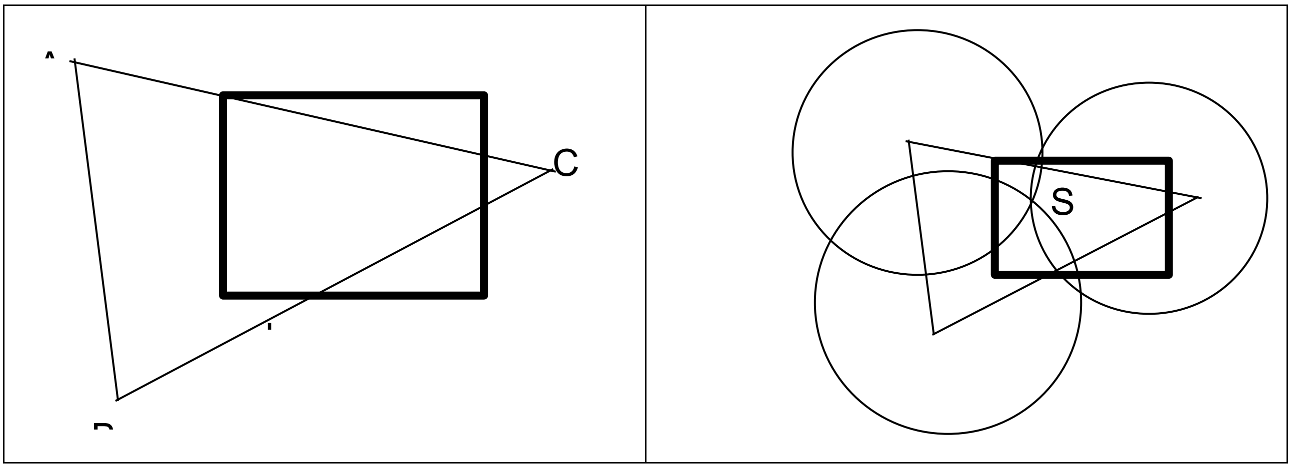



Net Count Rate vs 1/d2
Trendline R^2 = 0.969
Net Count Rate
250.00
200.00
150.00
100.00
50.00
0.00
2.00
4.00
6.00
8.00
10.00
1/ d2 (1/m2)


Log(R) vs Log(d)
Trendline R^2 = 0.989
Log(R)
2.50
2.00
1.50
1.00
1.50
1.60
1.70
1.80
Log (d)

EXP 2: FINDING THE HIDDEN SOURCE BY TRIANGULATION METHOD

1. PROCEDURE
    - Take a cardboard box (In which a radioactive source is hidden).
    - Switch on the pressurized ion chamber and see its response.
    - Move the ion chamber around the box and mark three points A, B, and C such that the reading shown in the chamber is the same for these points.
    - Measure the distance between these points, suppose a, b, and c.
    - Measure the radius of the circumcircle.



2. MEASUREMENT
   Instrument: Pressurized Ion Chamber
   Reading at A, B, C point = 70µR/h
   Distance between A and B (a) = 76cm, B and C (b) = 120cm, A and C (c) = 120cm

3. CALCULATION
    - Calculate S = $\frac{a+b+c}{2} = \frac{76+120+120}{2}$ = 158cm
    - Area A = $\sqrt{s(s-a)(s-b)(s-c)}$ = 4325.33cm^2
    - Radius R = $\frac{a.b.c}{4\,A} = \frac{76\,x\,120\,x\,120}{4\,x\,4325.33}$ = 63.26cm

   Since, at points A, B, and C, the dose rate is the same, they will all be at the same distance from the source. That is R = 63.26cm

   Now take the points A, B, and C as the origin and draw a circle of radius R = 63.26cm. Since these circles intersect at point S, our source will be there.