M_5: Determination of background radiation and verification of the inverse square law of gamma radiation

Theory:

The elements those exhibits radioactivity are known as radioactive substances. When the nucleus of an atom emits α, β and γ-radiation, the process is known as radioactive decay. Geiger Müller (G-M) counter is an instrument used for measuring ionization radiations (α,β,γ).

The intensity of electromagnetic radiations like γ-rays, X-rays and ordinary light falls off inversely as the square of the distance from the source of radiation. γ-rays emitted by a radioactive source (*i.e.,* ^{137}Cs) and a G-M counter are used to study the variation of γ-rays intensity in air and hence to prove the inverse square law.

To prove this law let us assume that the intensity (*I*) varies inversely as some power *m* of the distance (r) between the source and the detector. Or,

$$I \propto \frac{1}{r^m}$$

$$I = \frac{K}{r^m} \ldots\ldots\ldots\ldots\ldots\ldots (1) \qquad \text{[K = proportionality constant]}$$

Taking logarithm on both sides,

$$\ln I = \ln\left(\frac{1}{r}\right)^m + \ln K$$

$$\ln I = m \ln\left(\frac{1}{r}\right) + \ln K \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Equ. (2) is similar in form to that of an equation of a straight line. If the logarithmic value of γ-ray intensity ($\ln I$) is plotted along the Y-axis and the logarithmic value of inverse of the distance $ln\ \left(\frac{1}{r}\right)$ is plotted along the X-axis on a graph paper, resulting graph will be a straight line. In this experiment, γ-ray intensity is determined by counts per minute, which is recorded using GM-counter. The objective of this experiment is to find the slope of the straight line which should ideally be 2.0 (two) so that Equ. 1 reduces to,

$$I = \frac{K}{r^2} \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

This will verify the inverse square law of radiation,

Apparatus:

i. G-M counter
ii. ^{137}Cs radioactive source

Prepared by - Department of Physics, BUET
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<u>Procedure:</u>

(i) Open the GM counter box, set it on and wait for **5 minutes**.

(ii) Press the **"DISPLAY SELECT"** button of the counter, take the pointer at the "**HIGH VOLTAGE"** position and set the operating voltage at **840 volts** using **"UP/DOWN"** buttons.

(iii) Now by pressing the **"DISPLAY SELECT"** button take the pointer at **"TIME"** position and set the time at **200 sec**.

(iv) Press the "**COUNT"** button, wait until **200 sec** is over. Take the pointer at **"COUNTS"** position by **"DISPLAY SELECT"** button and record the background count. The background count is due to the cosmic ray and radioactive substances present in the building material and environment, etc.

(v) Take background counts for **3 (three) times** by repeating the procedure (*iv*).

(vi) After each background count, reset the **"COUNTS"** by **"RESET"** button.

(vii) Place the source at 10th shelf (From top shelf), so that the source to detector distance is maximum. Record number of counts for **200 sec**.

(viii) Observe the count rate at different source to detector distances r (At 9th shelf), as decreasing the source to detector distances.

(ix) Plot a graph with $\boldsymbol{ln\, I}$ along the Y-axis and $\mathbf{ln}\left(\frac{\mathbf{1}}{\boldsymbol{r}}\right)$ along the X-axis on a graph paper. The graph will be a straight line as shown in *Figure: 1*. The slope of the line which will give the value of ***m***, which should be equal to **2**.

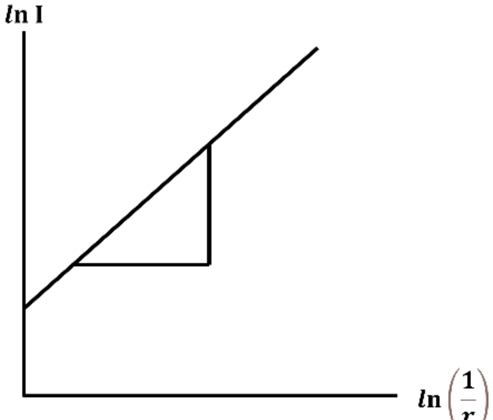

Figure: 1

Table 1: Determination of background count rate

Operating Voltage (Volts)	Background counts for 200 sec		Mean counts per min (I_B)
840	*(i)*		
	(ii)		
	(iii)		

Table 2: Table for intensity vs. distance for the verification of inverse square law

No of obs.	Source to detector distance, r_{cm}	$\ln\left(\frac{1}{r}\right)$	Count for 200 sec	Mean count per min (I_M)	Net count per min, ($I=I_M- I_B$)	*ln I*
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Calculation:

From the graph $\ln I \ vs. \ \ln\left(\frac{1}{r}\right)$, slope, $m =$………

Results:

The power of r in the equation $I = \frac{K}{r^m}$ is ………

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