Experiment 2
PH3105

12 September

1 Aim

- To find out the operating voltage of the supplied GM tube. Keep the source in front of the GM tube and record different values of the voltage vs the number of counts. From the graph between the count rate and the applied voltage find out the operating voltage of the supplied GM tube.
- To find background counts. Operate the GM tube with the operating voltage. Take reading for about 10 min without the source.
- To calculate the linear attenuation coefficient, mass attenuation coefficient and half value thickness. Now put the source and then the absorber [Aluminum (Al)]. Change the thickness of Al block and determine the count rate at different thickness.
- To verify the inverse square law of radiation.

2 Theory

There are various ways in which radiation interacts with matter, in our experiment the Cesium source emits γ radiation. They can interact with matter, in ways like.

- **Photoelectric effect**: Incoming radiation knocks off an electron from the metal.
- **Compton scattering**: Radiation deflects a charged particle (usually an electron) from it's trajectory.
- **Pair production**: Gamma Rays produce an electron- positron pair when near a large nucleus.

2.1 Attenuation coefficients

An attenuation experiment is one which involves firing a narrow beam of gamma rays at a material and analysing how much radiation would get through. We take the incident intensity to be I_0 and the one which gets through as I_t.

Now if one varies the thickness of a material without changing any of the other properties, we can assume that the change in the intensity through an infinitesimal thickness of that material is proportional to the small thickness and the incident intensity.

$$-dI \propto I.dx$$

We can replace the proportionality with a constant μ.

$$-dI = \mu I.dx$$

This μ happens to be the linear attenuation coefficient of the material.

$$-\frac{dI}{I} = \mu dx \implies -\int_{I_0}^{I_t} \frac{dI}{I} = \mu \int_0^t dx$$

Which gives us,

$$I_t = I_0 e^{-\mu t}$$

The mass attenuation coefficient is μ/ρ.

2.2 Half value thickness

The half value thickness is the thickness at which the intensity drops to half it's incident value.

$$I_t = \frac{I_0}{2} = I_0 e^{-\mu t_{1/2}}$$

$$t_{1/2} = \frac{ln(2)}{\mu} = \frac{0.693}{\mu}$$

2.3 Inverse square law

The inverse square law of Electromagnetic radiation states that the measured intensity of light is inversely proportional to the square of the distance from the source.
EM rays spread their power over the area $4\pi r^2$,

$$I(4\pi r^2) = \textbf{constant} \implies I \propto \frac{1}{r^2}$$

Ideally, the plot of $log(I)$ vs. $log(r)$ should give a slope of -2, but due to scattering and a small data-set, it is natural for it to deviate a bit.

3 Observations

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3.1 Attenuation coefficients

The data was acquired by using a Cesium-137 source placed at an appropriate distance from the GM tube. The thickness of the slab was varied from, 0 to 200 mm.

Thickness	Count	Count rate
0	2221	11.105
1	1306	6.530
2	1203	6.015
3	1132	5.660
4	1121	5.605
5	1076	5.380
8	861	4.305
11	807	4.035
14	802	4.010
17	642	3.210
20	567	2.835
23	498	2.490
26	466	2.330
30	525	2.625
35	394	1.970
40	433	2.165
45	394	1.970
50	409	2.045
55	373	1.865
60	303	1.515
65	242	1.210
70	247	1.235
75	200	1.000
80	186	0.930
90	176	0.880
100	137	0.685
110	130	0.650
120	98	0.490
130	82	0.410
140	81	0.405
150	76	0.380
160	48	0.240
170	61	0.305
180	42	0.210
190	44	0.220
200	32	0.160

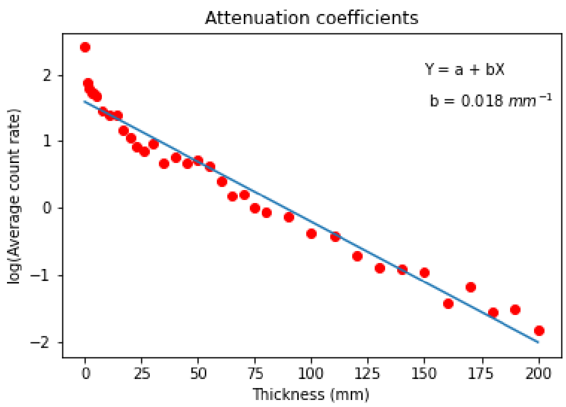

Figure 1: Attenuation coeff plot

3.2 Inverse square law

The aluminium slab was removed and the voltage was kept at **1.5 kV**. The distance from the source was varied from 5 to 51 cm.

	Source distance from detector (cm)	1/r² (1/cm²)	Run 1	Run 2	Avg Counts (per sec)
1	5.0	0.200000	67441	67089	672.650
2	6.0	0.166667	45208	45023	451.155
3	7.0	0.142857	32177	32219	321.980
4	8.0	0.125000	23729	24327	240.280
5	9.0	0.111111	18417	18287	183.520
6	10.0	0.100000	14488	14386	144.370
7	11.0	0.090909	11393	11491	114.420
8	12.0	0.083333	9202	9162	91.820
9	13.0	0.076923	7632	7577	76.045
10	14.0	0.071429	5200	6299	57.495
11	15.0	0.066667	5397	5285	53.410
12	16.0	0.062500	4447	4539	44.930
13	17.0	0.058824	3734	3740	37.370
14	18.0	0.055556	3206	3221	32.135
15	19.0	0.052632	2716	2584	26.500
16	20.0	0.050000	2171	2240	22.055
17	21.0	0.047619	1879	1888	18.835
18	24.0	0.041667	1203	1156	11.795
19	27.0	0.037037	760	725	7.425
20	30.0	0.033333	574	553	5.635
21	33.0	0.030303	402	373	3.875
22	36.0	0.027778	288	281	2.845
23	39.0	0.025641	184	213	1.985
24	42.0	0.023810	172	162	1.670
25	45.0	0.022222	121	127	1.240
26	48.0	0.020833	107	111	1.090
27	51.0	0.019608	102	83	0.925

Figure 2: Data for inverse square law verification

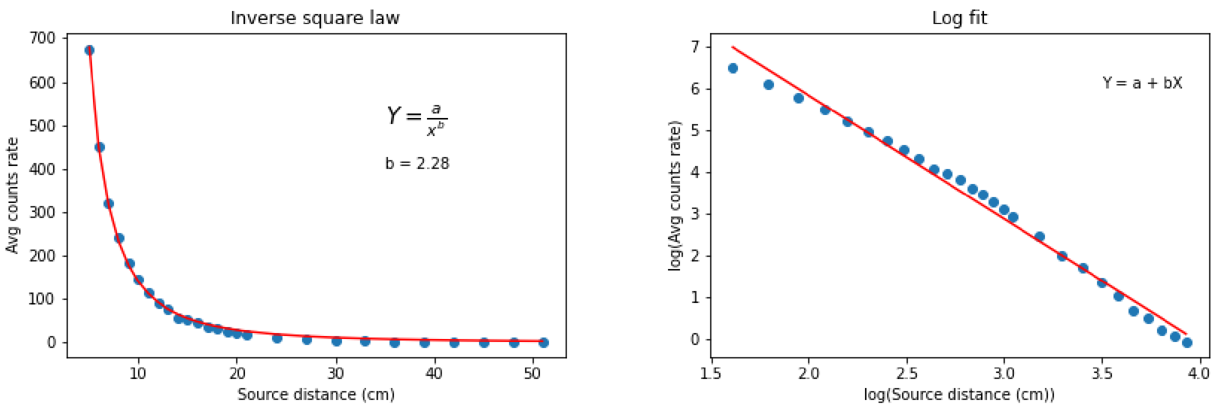

Figure 3: inverse square law plots

4 Analysis

4.1 Attenuation coefficients

For the above graph, the linear attenuation coefficient comes out to be $\mu = 0.018mm^{-1} - 0.18cm^{-1}$.
Therefore, the mass attenuation coefficient $\mu_m = \frac{\mu}{\rho_{Al}}$, the density of Aluminium is $\rho = 2.7g/cm^3$, $\mu_m = 0.18/2.7 = 0.067cm^2/g$.

The half value thickness is $t_{1/2} = \frac{0.693}{\mu} = \frac{0.693}{0.018} = 38.51mm$.

4.2 Inverse square law

Fitting the data for a $Y = \frac{a}{X^b}$ curve, we get a power of $b = 2.28$. The ideal slope for a $log(I)$ vs. $log(r)$ should be -2.

5 Error analysis

The data and it's results do not match with the literature values completely, that could be because

- Poor data quality due to smaller run times.
- Experimentally, this could happen becuase of some higher order effects like scattering and non-uniform material being used (assuming the simulation software accounts for these effects).

6 Conclusion

- The linear attenuation coefficient for Aluminium: $\mu - 0.18cm^{-1}$.
- The mass attenuation coefficient: $\mu_m = 0.067cm^2/g$.

- Half value thickness: $t_{1/2} = 38.51mm$.
- The slope of $log(I)$ vs. $log(r)$ curve was -2.28. Which might differ from the ideal -2 due to additional higher order perturbations.