EXPERIMENTS WITH
G. M. COUNTER

Center For Medical and Radiation Physics

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GENERAL INFORMATION ON GEIGER - MULLER TUBES

Geiger-Muller radiation counter tubes (G.M. tubes) are intended to detect alpha particles, beta particles, gamma, or X-radiation. A G.M. tube is a gas-filled device that reacts to individual ionizing events, thus 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 by quanta or particles entering the tube through the window or the cathode and colliding with the gas molecules. The gas filling consists of a mixture of one or more rare gasses 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.

DESCRIPTION OF G.M COUNTING SYSTEM GC602A

Geiger Counting system type GC602A is an Advanced Technology based versatile integral counting system designed around an eight-bit microcontroller chip. This system is highly recommended for research work, apart from its usefulness in the academic field of teaching. This system, along with wide-end window G.M. Tube Type GM125 and Lead Castle, will be an excellent Beta Counting System useful for swipe sample counting by Health Physics Labs. This counting system is useful for carrying out a number of Nuclear Physics experiments.

G.M Counting System GC602A Front & Rear panel

ACCESSORIES FOR GEIGER COUNTING SYSTEM:

G.M Detector

Stand for G.M Detector

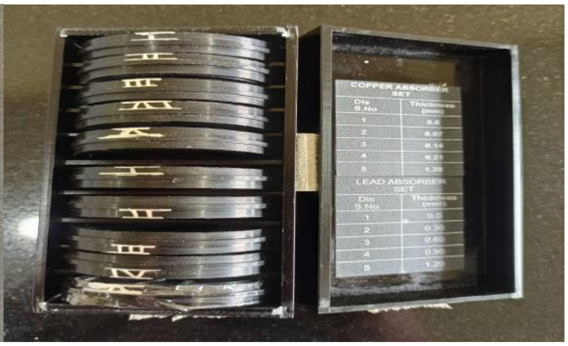
Source kit

Sliding bench for G.M Experiments

ALUMINIUM ABSORBER SET

Disc S.No	Thickness (mm)
1	0.00
2	0.06
3	0.12
4	0.18
5	1.24
6	0.30
7	0.36
8	0.42
9	0.48
10	0.54

Aluminium Absorber Set



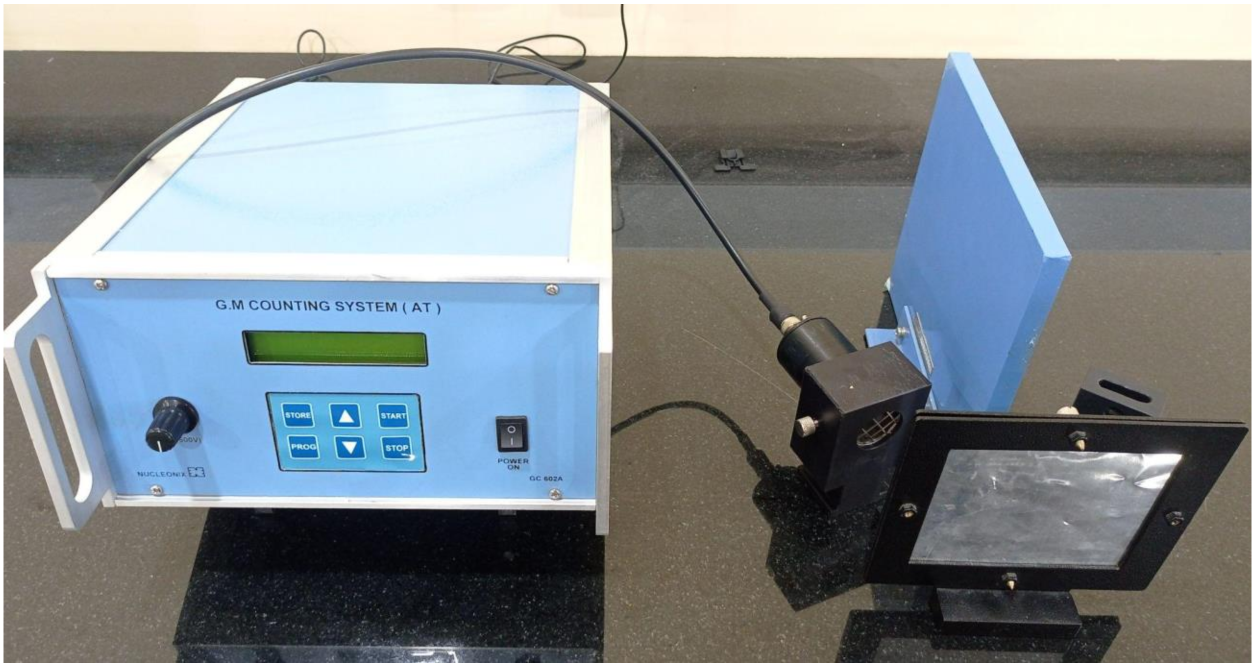
COPPER ABSORBER SET

Dis S.No	Thickness (mm)
1	0.0
2	0.07
3	0.14
4	0.21
5	1.28

LEAD ABSORBER SET

Dis S.No	Thickness (mm)
1	0.0
2	0.30
3	0.60
4	0.90
5	1.20

Copper & Lead Absorber Set



Scatterer Set (For Scattering of Beta Particles Experiment)

Geiger Mueller Counter - GC602A

The G.M. Detector, also known as the Geiger-Mueller counter, is a Gas-filled tube that detects various types of ionizing radiation. This device is named after the two physicists who invented the counter in 1928, and Mueller was a student of Hans Geiger. G.M. Detector is widely used in applications such as radiation dosimetry, radiological protection, experimental physics, and the nuclear industry. A Geiger counter (GM Counting system) consists of a Geiger-Mueller tube (the sensing element that detects the radiation) and the processing electronics display the result.

Geiger counter can detect ionizing radiation such as alpha particles, beta particles, and gamma rays using the ionization effect produced in a Geiger-Muller tube, which gives its name to the instrument. The voltage of the detector is adjusted so that the conditions correspond to the Geiger-Mueller region.

Applications - Detection of Alpha, Beta, and Gamma Radiation.

G.M. Detectors are mainly used in portable and installed radiation measuring instruments due to their sensitivity, simple counting circuit, and ability to primarily detect low-level to high-level gamma radiations. Although the major use of Geiger counters is probably in individual particle detection, they are also used in gamma Survey Meters, Contamination Monitors, Area Gamma Monitors, and a host of Health Physics instruments.

They can detect almost all the basic types of radiation, but there are slight differences in the construction of the Geiger-Mueller tube. Depending on the application to detect low or high gamma radiation, the construction of the wall material size of the detector varies, and for Beta-Gamma detection thin-walled G.M. Detector is employed. Whereas thin-end window detectors are used for Beta detection, G.M. Detectors are almost never used for Alpha detection. Also, the Geiger-Mueller tube cannot distinguish between different types of radiation, such as Alpha, Beta, and Gamma Radiation. However, detection efficiency varies depending on the type of radiation.

There are two main types of Geiger tube construction:

End-Window type: For alpha and beta particles to be detected by Geiger counters, they must be given a thin window. This "end-window" must be thin enough for the alpha and beta particles to penetrate. However, a window of almost any thickness will prevent an alpha particle from entering the chamber. The window is usually made of mica with a density of about 1.5 -2.0 mg/$cm^2$to allow low-energy beta particles (eg., from carbon-14) to enter the detector. The efficiency reduction for alpha is due to the attention though the distance from the surface being checked also has a significant effect. Ideally, a source of alpha radiation should be less than 10mm from the detector due to attenuation in the air. Tubular Windowless type: Gamma rays have very little trouble penetrating the metal walls of the chamber. Therefore, Geiger counters may be used to detect gamma radiation and X-rays (thin-walled tubes) collectively known as photons, and for this, the windowless tube is used.

A thick-walled tube is used for gamma radiation detection above energies of about 25 KeV, and this type generally has an overall wall thickness of about 1-2 mm of chrome steel.

A thin-walled tube is used for low-energy photons (X-rays or gamma rays) and high-energy beta particles. The transition from thin-walled to thick-walled design occurs at 300-400 KeV energy levels. Above these levels, thick-walled designs are used, and beneath these levels, the direct gas ionization effect is predominant.

Sometimes, a **"pancake" design** of the Geiger-Mueller tube is preferred. This detector is a flat Geiger tube with a thin mica window of a larger area. Flat Geiger tubes like this are known as "pancake" tubes. Such tubes are fitted with a wire screen to protect them. This design provides a larger detecting area and, thus higher efficiency to make checking quicker. However, the pressure of the atmosphere against the low pressure of the fill gas limits the window size due to the limited strength of the window membrane.

Exp: 1. STUDY OF THE CHARACTERISTICS OF A G.M. TUBE

1.1 PROCEDURE

- Make the connection between the counting system and G.M. Detector by MHV to UHF co-axial cable. Also, connect the main chord from the counting system to 230V A.C. Power.
- Place a Gamma or Beta source facing the end window of the detector in the source holder of the G.M. stand or optical bench at about 2 cm (for Gamma source) or four cm (for Beta source) approximately from the end window of the detector. (For Beta source, ensure the count rate is less than 200 CPS at 500V), As shown in figure 1.1.
- Now power up the unit and select menu options to PROGRAM On the keypad of the G.M. Counting System and select 30-sec preset time typically (It can be in the range of 30 to 60 sec.) [For all command button functions, refer to G.M. Counting System GC601A/GC602A user manual.

Experiment Setup for Characteristic of GM Tube (Figure 1.1)

- Now press the "START" button to record the counts, and gradually increase the HV by rotating the HV knob until the unit starts counting. Now, Press the "STOP" button.
- Now, take a fresh reading (STARTING VOLTAGE) and record the observations in the format in Table 1.1.
- Also record for each HV setting, corresponding background counts without keeping the source.

- Continue to take these readings in steps of 30V and for the same preset time, keep observing counts & tabulate the data, with and without source.
- Within 2 to 3 readings, counts will steeply increase and remain constant with marginal increase (maybe within 10%). After a few readings, one will find a steep increase as one enters the discharge region. Take just one or two readings in this region and reduce the HV bias to O volts. It is important to note that operating the G.M detector in the discharge region for a longer time can reduce the life of the tube or can result in permanent damage to the detector.
- Now tabulate the readings and plot a graph of voltage against counts (corrected counts). This graph should look as shown in Figure 1.2.
- Identify from the graph / tabulated data
    - Starting Voltage
    - Lower threshold voltage (V_1)
    - Upper threshold voltage (V_2). It is called the Breakdown threshold voltage
    - Discharge region
- Calculate plateau length, percentage slope, and operating potential.

Table - 1.1: G.M. Characteristics Data

Sl. No.	EHT(Volts)	Counts in 30 sec N	Background Counts 30-sec N_b	Corrected Counts N_c= (N-N_b) 30 sec
1	343	0	29	29
2	373	6003	31	5972
3	403	6379	33	6346
4	433	6446	35	6411
5	463	6577	38	6539
6	493	6636	41	6595
7	523	6843	44	6799
8	553	7082	46	7036
9	583	7183	49	7134
10	613	7352	50	7302
11	643	7585	55	7530
12	673	13200	59	13141

1.2 ANALYSIS & COMPUTATIONS

Estimate from the tabulated readings:

$$V_1 = Starting\ voltage\ of\ the\ plateau = 403\ V$$

$$V_2 = Upper\ threshold\ voltage\ of\ the\ plateau = 613\ V$$

$$Plateau\ Length = V_2 - V_1 = 210\ V$$

$$Operating\ Voltage = V_0 = V_1 + \frac{V_2 - V_1}{2} = 508\ V$$

$$Slope\ Percentage = \frac{N_2 - N_1}{N_1} X \frac{100}{V_2 - V_1} = \frac{7302 - 6302}{6302} X \frac{100}{613 - 403} = 7.2\ \%$$

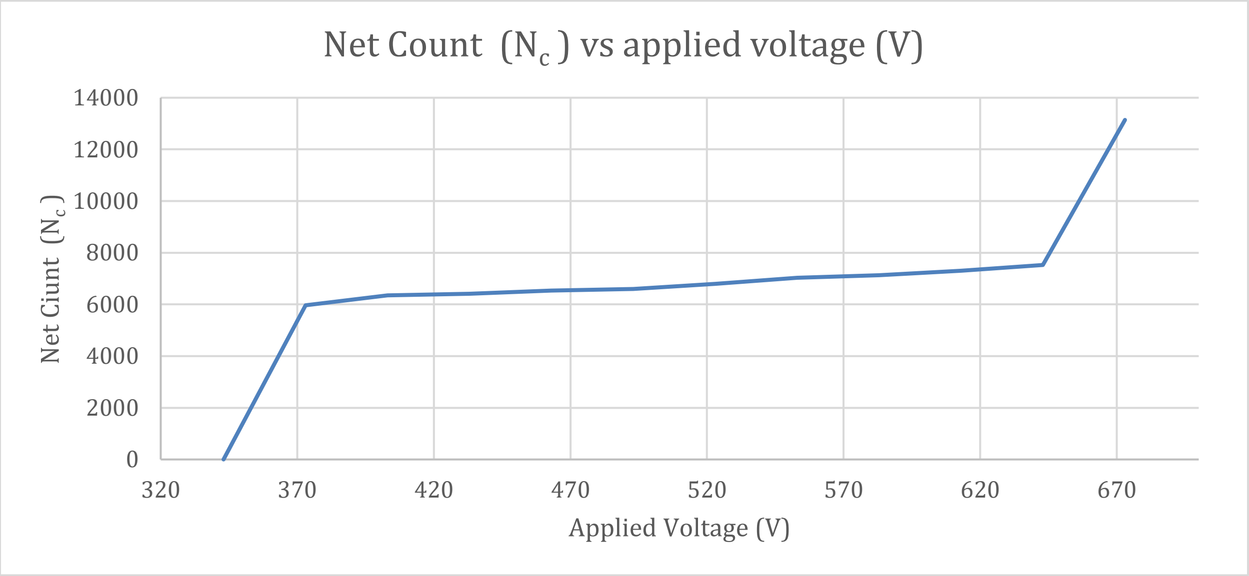


Figure 1.2

Exp: 2. INVERSE SQUARE LAW: GAMMA RAYS

1. PROCEDURE

- Make detector-source arrangement and power up the unit.
- Without a source, make a few (about 5 readings) background measurements and take an average of them for a preset time of, say 60 sec.
- Compute Average background counts in 60 sec Ba = $(b_1+b_2+b_3+b_4+b_5)$ /5. Compute Background rate = Ba/t (t =60 sec).
- Place a gamma source in the source holder, and adjust the distance (d) from the detector end window to be 7 cm away from the center of the source holder as shown in Figure 2.1.

Experiment Setup for Inverse Square Law (Figure 2.1)

- Set the HV to Operating Voltage (say 500 V), program 'preset time' to 60 sec, and record the data counts by pressing the ‘START’ button.
- Increase the Distance (d) in steps of 1 cm, and for each step, record the observations, and tabulate the data as shown in Table (2.1) till you reach 16 to 17 cm from the detector face.
- Subtract the background counts from the recorded counts, resulting in "corrected counts" (N) in 60 sec. From this, obtain Net Count Rate (R) per second.

2. COMPUTATION & ANALYSIS

1. Compute and tabulate 'Net count rate' (R), 'Distance,' transformation ($1/d^2$), etc., as shown in Table (2.1). Plot a graph of Net count rate (R) Vs. distance (d) in cm. (Figure 2.2). It can be seen from the figure that the product, $R.d^2$ is a constant.

2. 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” ($1/d^2$) are plotted (refer to Figure 2.3). This will be a straight line passing through the origin (0, 0) as this point corresponds to a source-detector distance of infinity.

Table (2.1): Data for Inverse Square Law Experiment

Sl. No.	Distance in cm (d)	Net Counts in 60 sec.	Net Count Rate	$1/d^2$ in $1/m^2$	Log d	Log R	$R.d^2$
1	7	1061.5	17.691	204.081	0.845	1.247	866.89
2	8	842.5	14.041	156.25	0.903	1.147	898.66
3	9	672.5	11.208	123.456	0.954	1.049	907.87
4	10	566	9.433	100	1	0.9746	943.33
5	11	497.5	8.291	82.644	1.0413	0.9186	1003.29
6	12	400	6.666	69.444	1.0791	0.823	960
7	13	337.5	5.625	59.171	1.1139	0.750	950.62
8	14	258	4.3	51.020	1.1461	0.633	842.8
9	15	217	3.616	44.444	1.1760	0.558	813.75
10	16	216.5	3.608	39.062	1.2041	0.557	923.73

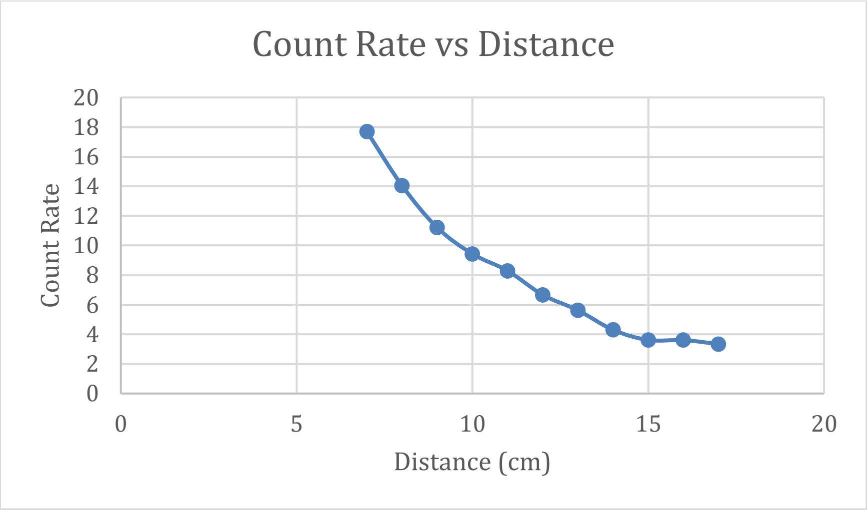


Figure 2.2

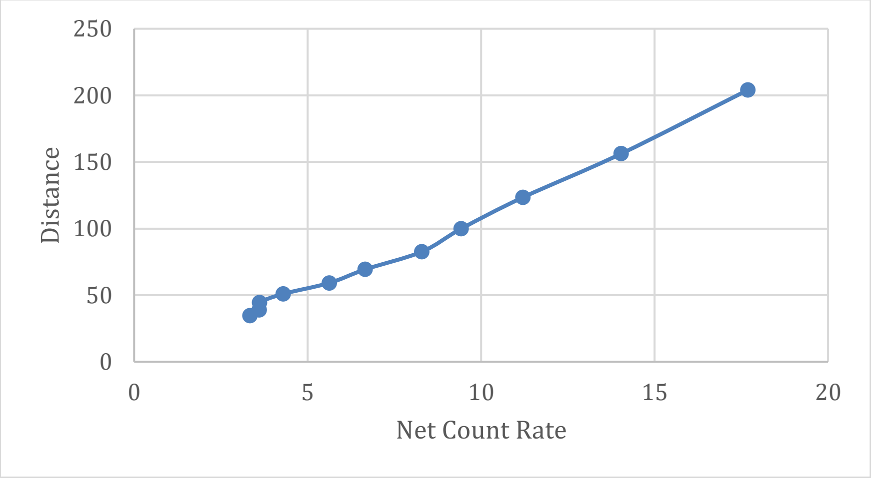


Figure 2.3

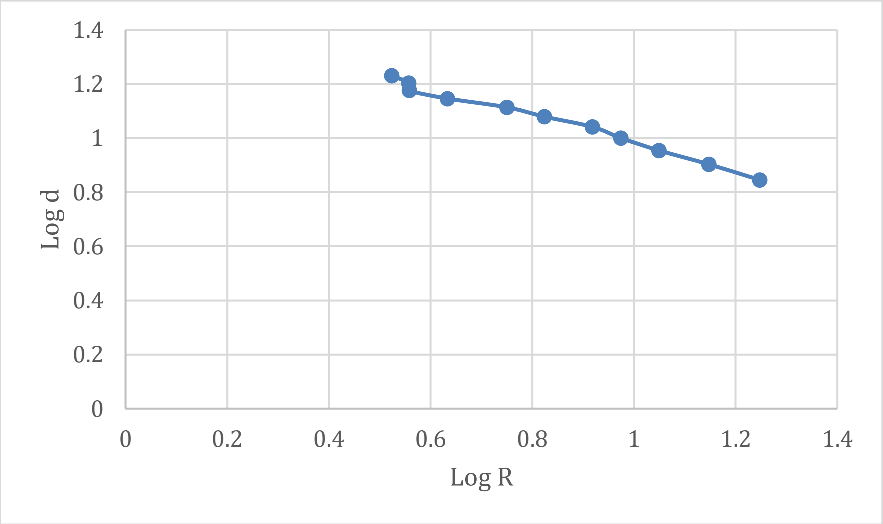
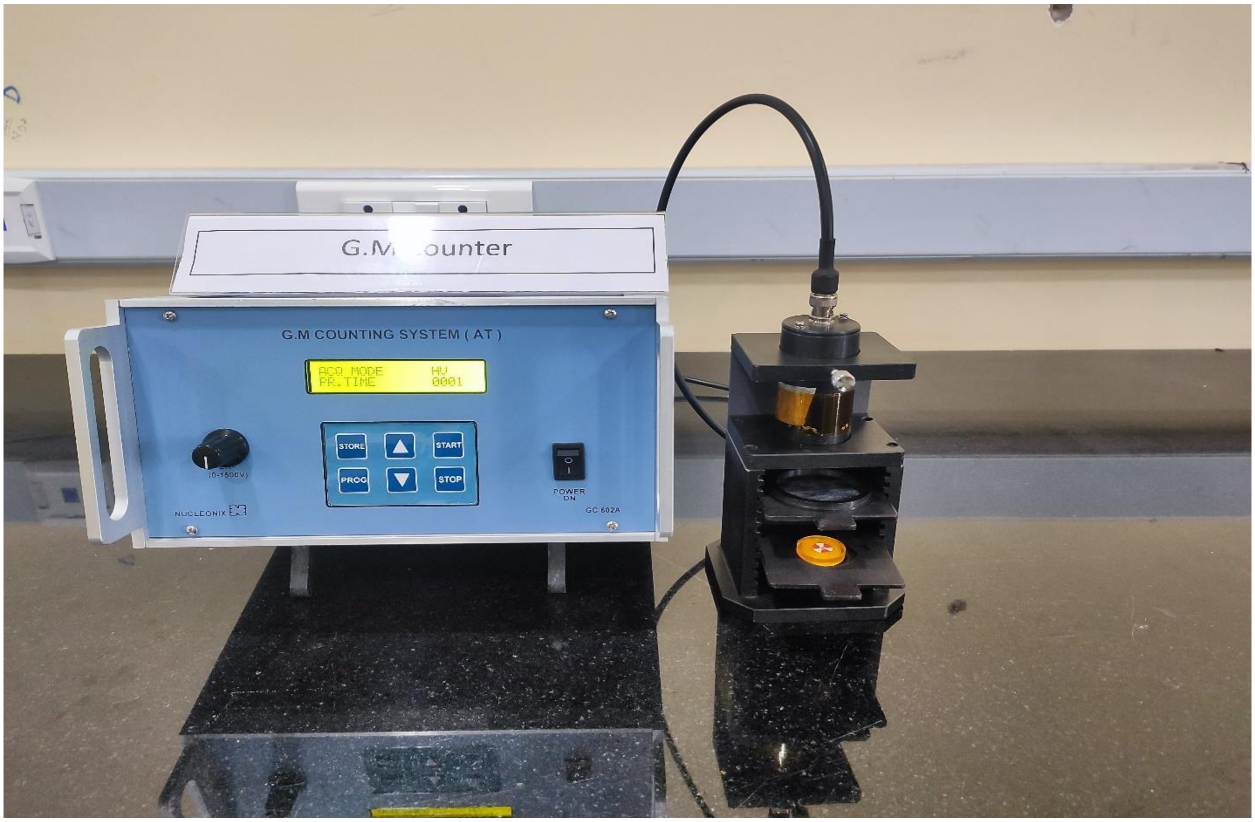


Figure 2.4

Exp: 3. TO STUDY DETERMINATION OF BETA PARTICLE RANGE AND MAXIMUM ENERGY (BY HALF-THICKNESS METHOD)

1. PROCEDURE
    - Make standard connections and arrangements between the G.M. Counting system detector, absorber, and source.
    - Set the GM voltage at the operating voltage of the GM tube.
    - Without source, make a few (about 5 readings) background measurements and take an average of them for a preset time of say 60 sec.
    - Compute Average background counts in 60 sec ($Ba = (b_1+b_2+b_3+b_4+b_5)/ 5$). Compute Background rate = Ba/t ($t = 60$ sec).
    - Place a Beta source in the source tray at about 3 cm from the end window of the GM tube.
    - Place an aluminum absorber of zero thickness in the absorber holder at about 2 cm from the end window of the GM tube and record the counts. Make a setup arrangement as shown in figure 3.1.



Experimental Setup for Beta particle Range (Figure 3.1)

- The absorber thickness is increased in steps of 0.05 mm and every time counts are recorded.
- This process is repeated until the count rate becomes less than half the count rate with zero absorber thickness.
- Data will be collected for the standard and second sources.
- In this case, the standard source is Tl -204 and the second source is Sr-90.
- Tabulate the data as shown in table 3.1 and 3.2.
- Density of Aluminium =2.71g/cm³ (g/cm. cube).
- The below data is taken with Thallium (Tl-204).

Table :3.1

Counting Time : 120 sec Absorber : Aluminium

Background : 145 counts Source : Tl-104 (3.7KBq)

Absorber Thickness (in mm)	Absorber Thickness in mg/cm^2	Counts	Net counts (counts - BG)
0	0	15220	15075
0.06	16.26	11087	10942
0.12	32.52	8614	8602
0.18	48.78	6408	6263
0.24	65.04	4979	4834
0.30	81.3	3763	3618
0.36	97.56	2734	2589
0.42	113.82	1967	1822
0.48	130.08	1421	1276
0.54	146.34	1030	885

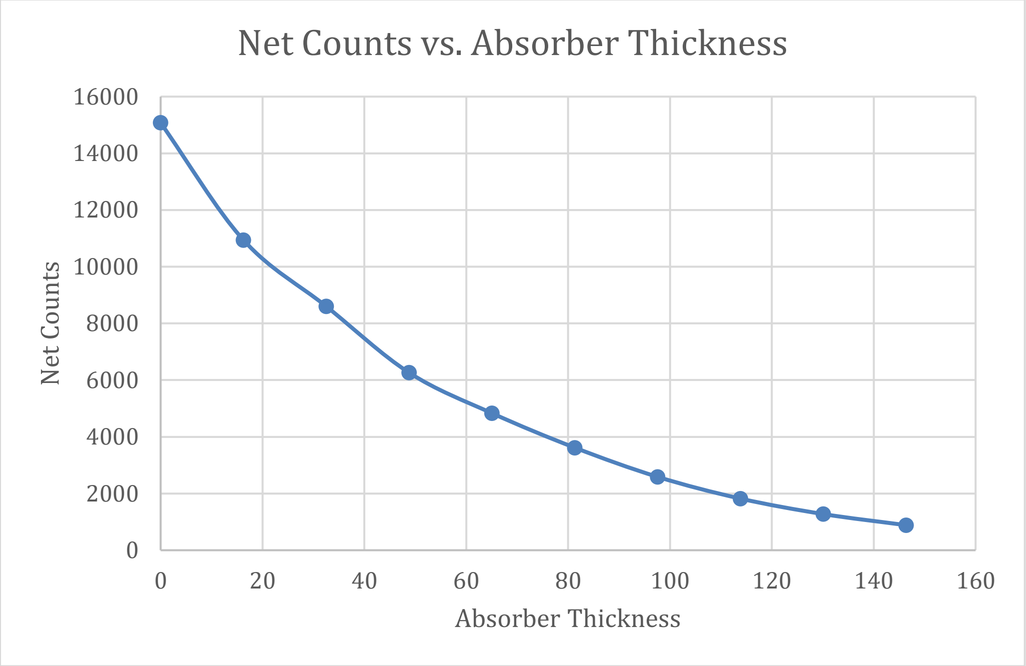


Figure 3.2

The below data is taken with Strontium (Sr^{90}- Y^{90})

Table : 3.2

Counting Time : 120 sec Absorber : Aluminium

Background : 145 counts Source : Sr-90

Absorber Thickness (in mm)	Absorber Thickness in mg/cm^2	Counts	Net counts (Counts - BG)
0	0	16557	16412
0.06	16.26	13571	13426
0.12	32.52	11868	11723
0.18	48.78	10252	10107
0.24	65.04	9324	9179
0.30	81.3	8386	8241
0.36	97.56	7716	7571
0.42	113.82	7254	7109
0.48	130.08	6671	6526
0.54	146.34	6369	6224

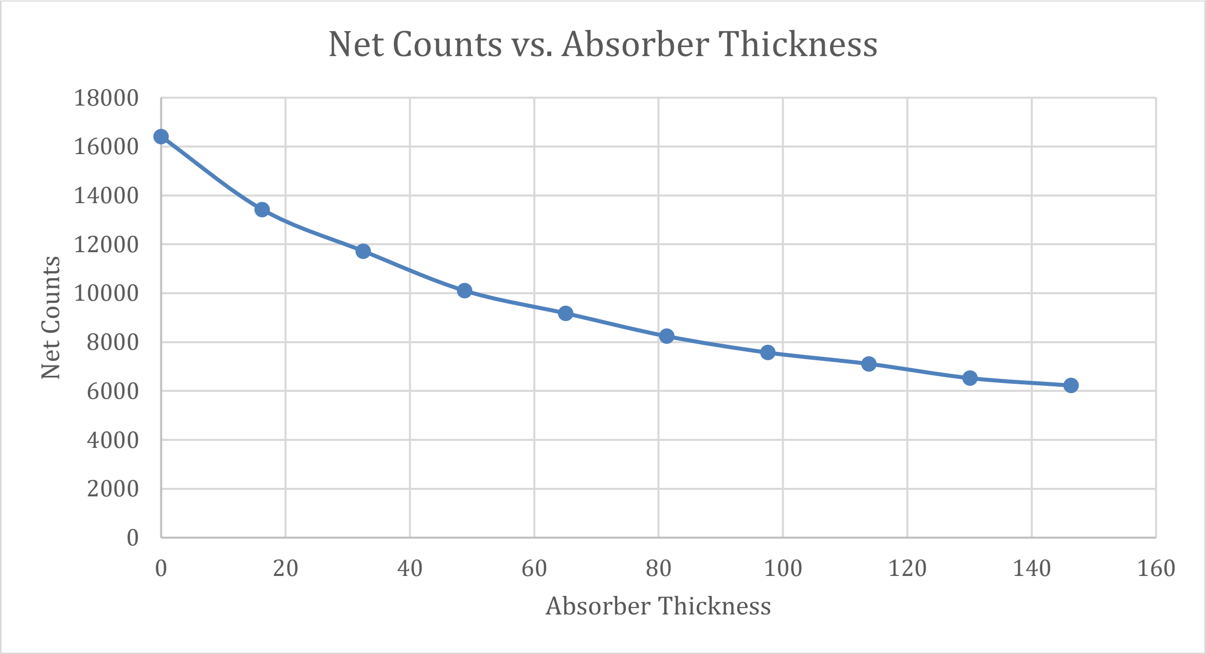
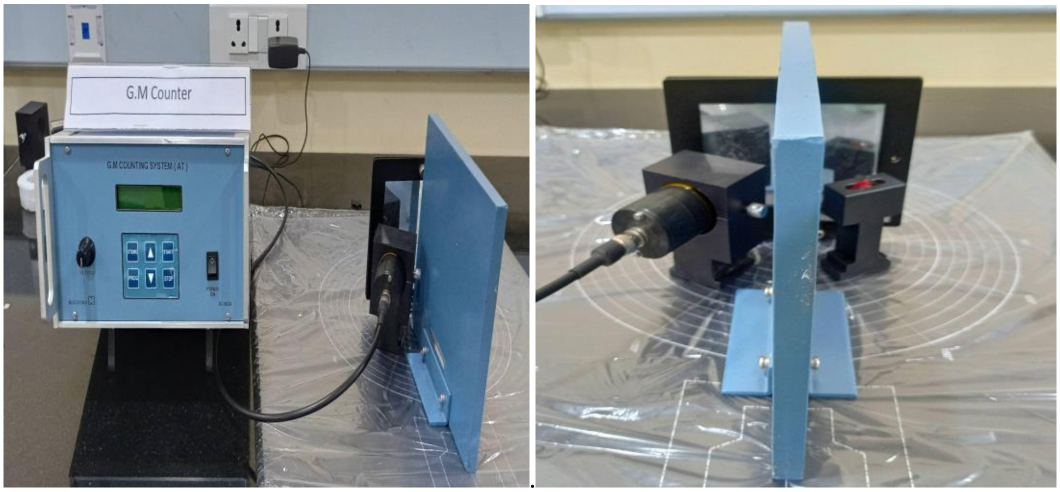

Net Counts vs. Absorber Thickness
Net Counts
Absorber Thickness
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
0
20
40
60
80
100
120
140
160

Figure 3.3

EXP: 4. BACKSCATTERING OF BETA PARTICLES

1. PROCEDURE

- Make standard setup by connecting G.M. Counting System (GC602A) with G.M Detector (GM125).
- In this experimental setup, the detector, Beta source, and scatterer stand with the scatterer placed, as shown in Figure 4.1.
- A lead block is placed between the Beta source and Detector so the detector does not receive any direct radiation from the Beta source.
- Switch ON the GC602A Electronic Unit and set the operating High voltage at 500V.
- To start with, remove the scatterer stand and measure the counts for 200 secs.
- Now place the scatterer stand and load Aluminum foil (scatterer) of thickness 0.05mm.
- The apparatus is first set up to give maximum count rate by adjusting the source/ detector positions.
- After doing this, record the counts for 200 secs. Then increase the thickness of the scatterer in steps of 0.05mm by adding one foil to the previous scatterer, and observe the counts each time for 200 secs. Tabulate the data as shown in Table 4.1



Experimental setup

Figure 4.1

2. EXPERIMENTAL DATA

Source	Sr-90	Unit	GC602A
Activity	3.7KBq	Detector	GM125
Preset Time	200 Sec	Sliding Bench	

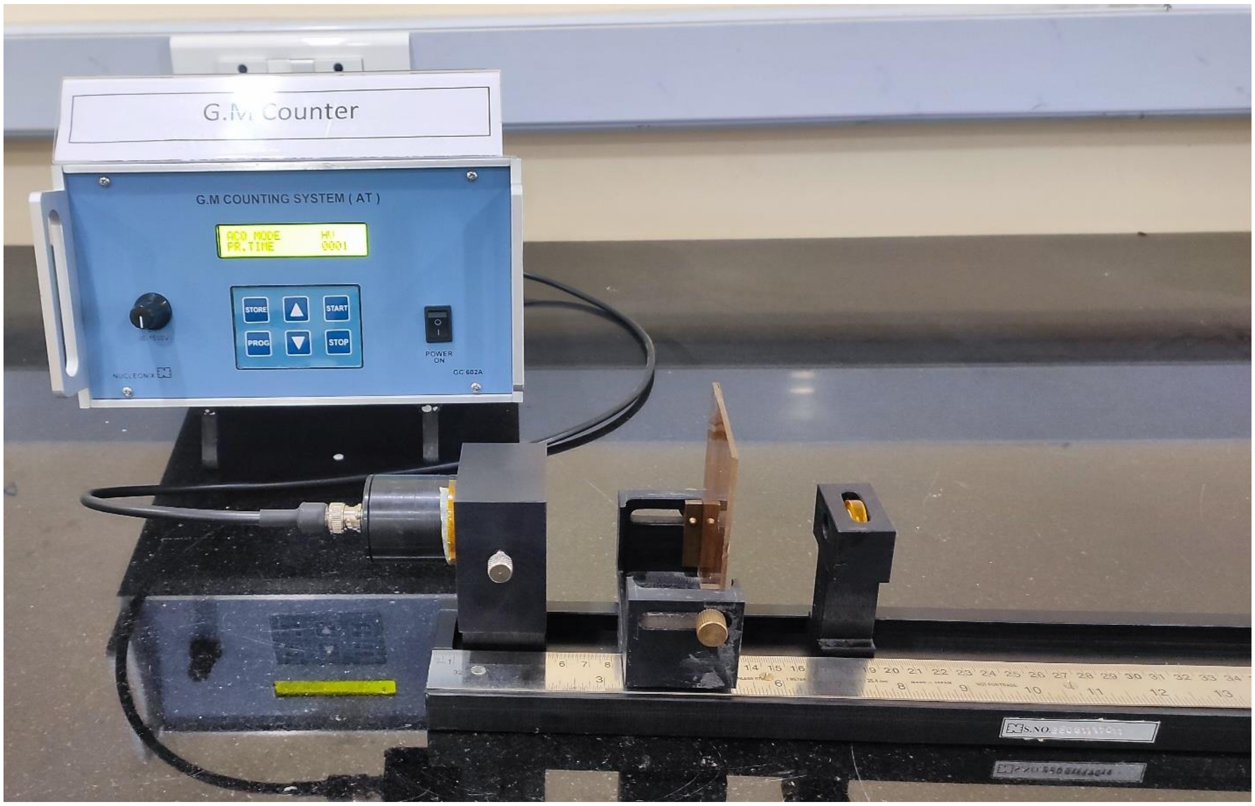
Table 4.1

Sl. No	Material	Thickness (mm)				Net counts
			i	ii	Average	
1	Al	0	304	322	322	313
2	Al	0.05	356	340	348	35
3	Al	0.10	371	350	360.5	47.5
4	Al	0.15	377	365	371	58
5	Al	0.20	378	386	382	69
6	Al	0.25	392	380	386	73
7	Al	0.30	379	399	389	76
8	Al	0.35	378	422	400	87
9	Al	0.40	401	418	409.5	96.5
10	Al	0.45	402	423	412.5	99.5
11	Al	0.50	424	421	422.5	109.5

Exp:5. PRODUCTION AND ATTENUATION OF BREMSSTRAHLUNG

5.1 PROCEDURE

- Make a standard setup by connecting GM Counting system GCG02A with G.M Detector (GM125) placed in the optical bench, As shown in figure 5.1.



Experiment setup for production and attenuation of Bremsstrahlung (Figure 5.1).

- Switch ON the GC602A Electronic Unit and set the operating High Voltage at 500V. An absorber consisting of two materials with widely different atomic numbers, say, Perspex (1.8mm thick) and Aluminum (0.7 mm thick) is used and the count rate is measured with the absorber and then with the absorber reversed.
- The absorber thickness must be such that each sheet of absorbent material has about the same mass per unit area.
- The experiment is conducted with following three combinations of materials
    - Al (0.7mm) & Perspex (1.8mm)
    - Perspex (1.8mm) & Cu (0.3mm)
    - Al (0.7mm) & Cu (0.3mm)

5.2 EXPERIMENTAL DATA & RESULTS

Source: Sr-90 Distance between source and detector: 6cm.

Activity: 0.1 mCi Preset Time: 300 sec BG: $\frac{b1+b2+b3+b4+b5}{5}$ = 353

For Al (0.7mm) & Perspex (1.8mm) combination:

Sl. No	Absorber position	Counts	Net Counts
1	Without Absorber	10070	9717
2	Perspex facing source	655	302
3	Al. facing source	928	575

For Perspex (1.8mm) & Cu (0.3mm) combination:

Sl. No	Absorber position	Counts	Net Counts
1	Without Absorber	10070	9717
2	Cu facing source	576	223
3	Perspex facing source	547	194

For Al (0.7 mm) & Cu (0.3mm) combination:

Sl. No	Absorber position	Counts	Net Counts
1	Without Absorber	10070	9717
2	Al facing source	532	179
3	Cu facing source	566	213