Roll No:_____ **Batch :** _____

Name : _____

ME441 - Nuclear Engg. Lab. Manual

Expt. No	Expt. Name	Marks out of 10	TA sign	Date
1	THICKNESS MEASUREMENT OF PLASTIC FOIL USING BETA BACK SCATTERING TECHNIQUE.			
2	MEASUREMENT OF ASH CONTENT IN COAL USING BETA RAY BACK SCATTERING TECHNIQUE.			
3	GAMMA RAY SPECTROMETER (MULTI CHANNEL ANALYZER).			
4	MEASUREMENT OF THICKNESSBY BETA TRANSMISSION GAUGE.			

EXPT. No. 1

THICKNESS MEASUREMENT OF PLASTIC FOIL USING BETA BACK SCATTERING TECHNIQUE.

Aim: To calibrate the β ray back scattering gauge for measuring the thickness of Plastic foils and to find out the thickness of the unknown Plastic foil and the associated uncertainty.

Theory: Radiation is emitted from a radioactive source in all directions. When any material is interposed in the path of this radiation, which otherwise is traveling in a straight path, two broad interactions can occur.

1. Radiation might be absorbed by the material; thereby intensity of the radiation crossing the material reduces.
2. Scattering can occur, which changes the direction of incident radiation.

Scattering is a random phenomenon, but a fraction getting scattered at any angle can be accurately predicted by statistical considerations. Radiation that is scattered back on the same side of the incident direction is generally termed as back scattered radiation. The β particle entering the material undergoes a series of collisions. The term collision refers to any interaction, coulomb or otherwise, between the β particle, the nuclei and electrons in the material. Net result of collision is not only a change in direction but also decrease in the β energy. Back scattering of β ray depends on:

1. Thickness of backing material,
2. Atomic number of the backing material,
3. Energy of incident radiation,
4. Geometry of the setup.

As the thickness goes on increasing, more and more number of atoms (scattering centers) are available and hence back scattering intensity increases. But the range of β particles sets a limit to the increase of back scattering, which becomes constant after a certain thickness called saturation or critical thickness. Theoretically for normal collisions the thickness should be equal to half the range "R" of the β particles. Since collisions occur in all possible obliquities, the maximum back scattering is obtained for a thickness around 0.2R.

As the atomic number Z of the material increases, the number of positive charges in the nucleus and the electron density increases proportionately. The result is an increase in the back scattering intensity. It varies roughly as Z^n, where n lies between 0.32 to 0.5. The back scattering intensity from a material of thickness $t < t_s$ is given by the following equation.

$$I_t = I_s\left[1 - e^{-(\mu+\mu')t}\right]$$

where

I_t = count rate with backing material of thickness t

I_s = count rate with backing material of thickness t_s

t_s = saturation thickness

μ = absorption coefficient of emitted β particles

μ' = absorption coefficient of back scattered β particles

Usual range of thickness that can be measured by using Sr90 - Y90 source is 30 to 150 mg/cm^2. β back scattering depends upon the thickness and the atomic number of the backing material. By keeping the atomic number constant, i.e., by taking all the samples made of the same material (e.g., Plastic), the effect of atomic number on the back scattering intensity can be kept constant. Thus scattering intensity depends only on the thickness of the back scattering material.

The schematic representation of the experimental setup employed is shown in Fig. 7. This geometry has two advantages:

1. Distance between the back scattering surface and the detector is very small hence the absorption of weak energy back scattered radiation is minimum before entering the detector.
2. The detector presents almost 2π geometry to the incoming back scattering radiation being very close to the scatter surface. This improves the efficiency further.

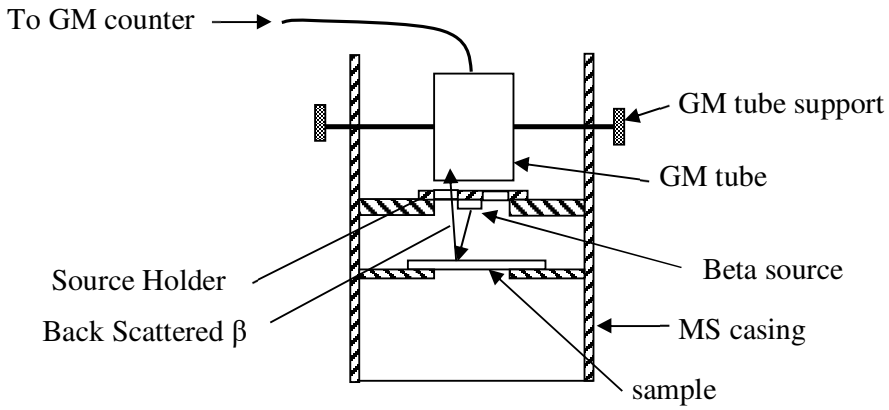

Figure 1: Back scattering gauge setup

Apparatus :

1. Back scattering setup with GM detector & source.
2. Geiger counting setup.
3. Plastic foils of known thickness and a foil whose thickness is to be determined.

Procedure:

1. Connect the back scattering setup to the counter system.
2. Put on the power supply of the system and adjust the EHT to the operating voltage (350V - 450V) of the GM tube used.
3. Put the function knob to time mode, time to 100 sec and paralysis to 250 μ seconds.
4. Take the first reading without placing any foil for 100 seconds. This gives the background count.
5. Place the first Plastic foil at a suitable distance below the source using the holder as shown in the Fig. 1. Take count rate for 100 seconds.
6. Repeat the procedure for all the known foils as well as the unknown foil.
7. Bring down the EHT voltage to zero and put off the mains.

Observation & Calculations

Tabulate the thickness and count rate for different foils as shown below.

Density of Plastic foil : 1.280g/cm^3 Background count (Nb):_____

Saturation Count (Ns):_____

Sr. No.	Foil Thickness (mg/cm^2)	Counts (N)	Corrected Counts (Nc) (N-Nb)	Count Ratio (Nr) (Nc/Ns)	1-Nr	Ln(1-Nr)
1	12.8					
2	28.16					
3	35.84					
4	48.64					
5	60.16					
6	85.76					
7	106.24					
8	128					
9	156.16					
10	194.56					
11	271.36					
12	307.2					
13	430.08					
14	Unknown					

$$Saturation\ Count\ (N_{Sc}) = \frac{\left(Sum\ of\ counts\ of\ last\ 5\ N_c readings\ \ (Sr.No.9\ to\ Sr.No.13)\right)}{5}$$

Unknown thickness Measured using micrometer

t1 (mm)	t2 (mm)	t3 (mm)	t4 (mm)	Mean (mm)

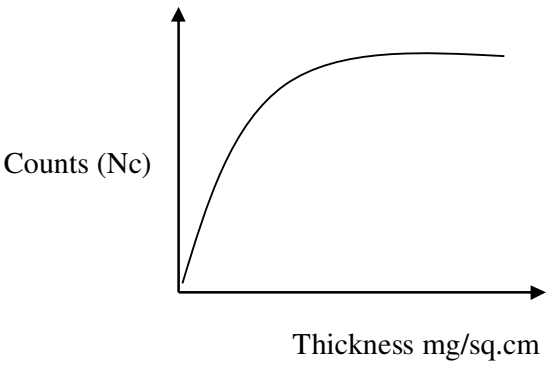

Fig. 1 Variation of counts with thickness

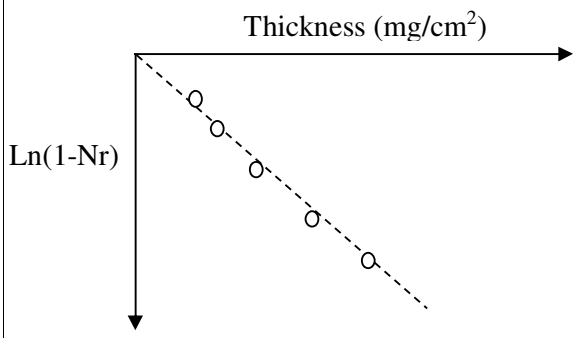

Fig.2: Graph of thickness v/s Ln(1-Nr)

Results:

Plot the graph of Counts V/s Thickness (mg/cm^2) as shown in Fig. 1 and Thickness (mg/cm^2) v/s Ln(1-Nr) as shown in Fig. 2.From the second graph find out the thickness of the unknown foil. Measure the actual thickness of the foil using a micrometer and find out the percentage error in the thickness measurement using β back scattering technique.

Thickness of the foil (experimental)= ……. mg/cm^2

Thickness of the foil (Measured) = ……..... mg/cm^2

Percentage error = ……. %

Once β is established, and if N_c is the corrected count for the unknown foil and N_{sc} is the saturated count, then percentage measurement uncertainty is given by $\frac{\sqrt{N_c}}{\beta t(N_{Sc}-N_c)}$x100

Measurement uncertainty =.....%

(Details to obtain the expression will be explained during the lab session)

Conclusions:

Space for
Graph paper

EXPT. No. 2
MEASUREMENT OF ASH CONTENT IN COAL USING BETA RAY BACK SCATTERING TECHNIQUE.

Aim: To calibrate the β ray back scattering gauge for ash content in coal and find out the percentage of ash content in the given coal sample.

Theory:

Coal as a fossil fuel is used to supply heat energy in many power plants, boilers and furnaces in various industries all over the world. Coal ash is the oxidized residue left after burning coal and is an important factor in determining the calorific value of coal. Coal ash consists mainly of alumina, silica and iron oxide with small quantities of many other metal oxides. Ash determining by chemical method is very time consuming and one cannot have an on-line analysis, and therefore, does not give a good idea of ash for the entire lot of coal.

Method of on-line measurement of ash content in coal by back scattering is based on the difference in atomic number(Z) of coal and ash constituents. The atomic number of elements O_2, Al, Si, Fe of which ash is essentially composed, differ quite extensively from the atomic number of carbon and therefore those interactions of radiation with matter, which depend upon the atomic number can be utilized to determine the ash percentage in coal. The components of the coal (H, C, N, O) have lower atomic number than those of ash (Mg, Al, Si, S, Ca, Fe). This makes it a two component system. The intensity of the reflected beam with the same ash composition is a function of the ash content. Also the rapidity of the measurement is a great advantage, because it allows online adjustment of power plant operation parameters to the instantaneous ash content, whereby the operation of a power plant becomes more economical. β back scatter and γ transmission techniques can be used for ash content determination of coal.

For the ash analysis one would choose a high energy β source with a fairly large half life to minimize the error due to decay. Activity should be high enough to give required count in reasonable time limit. The ideal selection is Sr90-Y90. (half life = 28 years, E_{max} = 2.2 Mev and of activity 4 μ curie.)

GM tube is used as the detector with the necessary counting system. The operating voltage of the detector has to be within the plateau region. Various coal samples of known ash content are prepared. The thickness of the sample should be more than the saturation thickness to ensure that the back scattered intensity is independent of the thickness of the sample. Iron-Silicon ratio of the samples should be same. The sample should be mixed homogeneously. Particle size of the samples should be identical and less than 0.2 mm. Packing density should be same for all samples. Sample should be packed and sealed properly and if possible dried to remove moisture content.

Apparatus:

1. Back scattering setup with GM detector and radioisotope
2. Geiger counting system
3. Coal samples of known ash content and a sample whose ash content is to be determined.

Procedure:

1. Connect the GM tube of the back scattering setup to the GM counting system.
2. Put on the power supply of the system and adjust the EHT to the operating voltage (350V - 450V) of the GM tube used.
3. Put the function knob to time mode, time to 200 sec and paralysis to 250 μ sec.
4. Keep the coal sample at a suitable distance above the source as shown in the Fig. 1. Take count rate for 200 sec.
5. Repeat the procedure for all the known samples as well as the unknown sample.

6. Bring down the EHT voltage to zero and put off the mains.

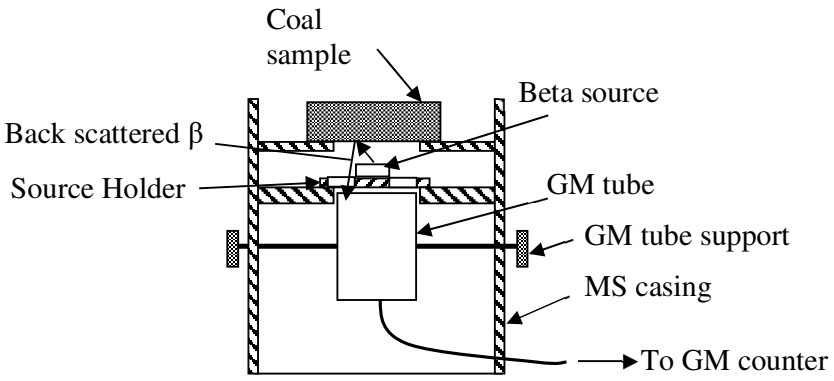

Fig.1: Beta backscattering set up for ash measurement in coal

Observations:
Tabulate the count rates corresponding to different ash content.
Time = 100 sec

Sr. No.	% of ash in coal	Counts
1	0	
2	5	
3	10	
4	20	
5	25	
6	30	
7	40	
8	45	
9	Unknown	

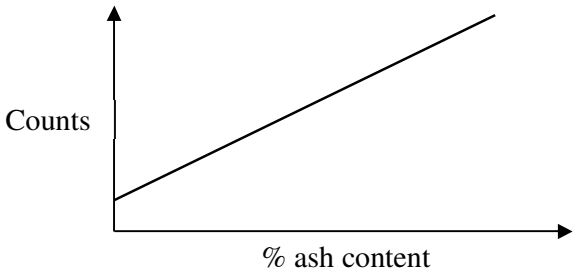

Fig. No. 2. Graph of ash content v/s count rate

Results:

1. Plot the graph of Ash content v/s count rate, and from the graph find out the Ash content of the unknown coal sample.
2. Ash content of the unknown coal sample (a) = …….
3. Measure the slope in the graph that has been plotted
4. Compute Measurement uncertainty = $\frac{\sqrt{N}}{a * slope} * 100$

=.....%

(*The method to obtain the expression will be explained during the lab session)

Conclusions:

Space for
Graph paper

EXPT. No. 3

GAMMA RAY SPECTROMETER (MULTI CHANNEL ANALYZER).

Aim:
To calibrate the Multi Channel Analyzer with known γ energy sources and to determine the unknown energy of a given isotope.

Apparatus

1. NaI(Tl) scintillation detector with photo multiplier tube, with PC.
2. Radio-isotopes of known energies and an unknown radio-isotope.

Radio Isotope name	Energy (KeV)
Na-22	511 and 1275
Co-57	122
Co-60	1170 and 1330
Cs-137	Unknown

Theory: Scintillation detector mainly consists of a sodium iodide (thallium activated) crystal enclosed in Aluminum can with glass window. This window is optically coupled by silicon oil to photo-cathode of the photo-multiplier tube. The photo-multiplier tube is fixed to a small chassis, which contains cathode follower unit. The schematic of a Gamma ray spectrometer is given in Fig. 1.

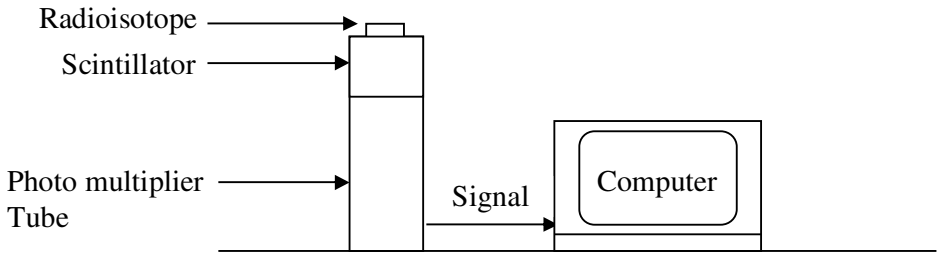

Figure 1: Schematic of a Gamma ray spectrometer

When a γ ray interacts with scintillator, it knocks off electrons, which in turn lose their energy in exciting the scintillator. The scintillator emits light photons during de-excitation, which are almost completely collected on the photo-cathode of the photo-multiplier tube. The photo-electrons emitted from the cathode due to the scintillation light photons falling on it are multiplied through secondary emission in the dynode system of the photo-multiplier tube. These electrons give negative pulses at the plate of the tube. The negative pulse is passed through the cathode follower, then amplified by a linear amplifier and finally fed to a single channel analyzer or a multi channel analyzer.
A single channel pulse height analyzer is an electronic instrument designed to give an output pulse only when the pulse fed to it has amplitude between V and V+ΔV, where V is the base line setting and ΔV the channel width or window of the analyzer. By changing the base line setting in steps

and keeping the channel width fixed, one gets the pulse height spectrum of the pulses fed to the analyzer. This corresponds to the energy distribution of γ ray emitted from the source.
The γ rays interact with the crystal in one of the following ways.

1. Photo-electric effect, in which all the γ ray energy is dissipated inside the crystal,
2. Compton effect, where only part of the incident photon energy is lost in crystal, and
3. Pair production, which is possible for γ ray of energy above 1.02 MeV, and where a pair of positron and electron is formed from the γ ray.

Typical shape of γ ray spectra is shown in Fig. 2

In the present experiment we shall use a multi channel analyzer, which has several channels with different discriminator levels that are simultaneously activated to get the entire spectrum automatically.

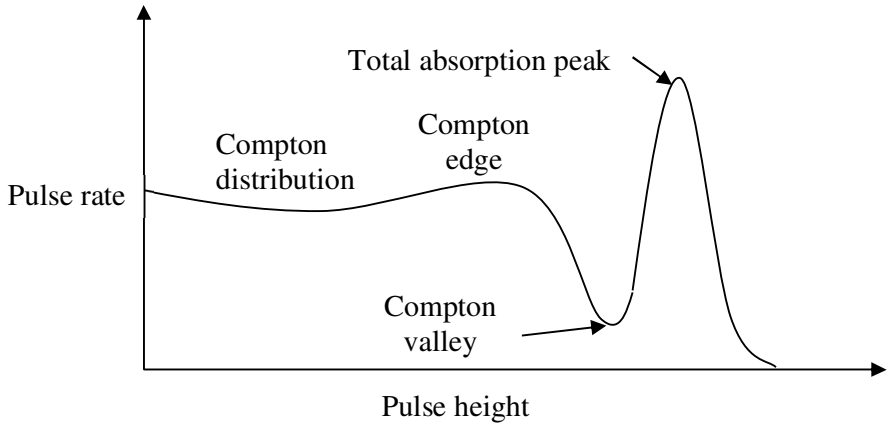

Figure 2: Typical shape of γ ray spectra

Procedure:

1. Connect the Scintillation device via a USB cable to the computer.
2. Start the Spectrum Acquisition and Analysis.

To calibrate the Multi-Channel Analyzer with known γ energies and to determine the unknown energy of a given isotope.

1. Go to Spectrum acquisition and analysis software.
2. Go to Acquisition and set Parameters.
3. Set the Mac Settings. Set high voltage – (550 – 700)V. Set Gain .Set LLD .Select the Real time acquisition.
4. Now go to Control .Go to Acquisition tab set the active buffer to 1.Select Pr. Time (sec) to 100.
5. Start the acquisition by pressing Start Acquisition Button.
6. The data will be acquired for the 100 sec in the software and will be shown on the screen.
7. Select ROI (Region Of Interest).
8. Select the region by just clicking at the two locations on x axis.
9. Go to Math function, select calibration put the energy values of the known isotope in the centroid region.
10. Close the math function menu.
11. Now go to the control window option, go to Region of interest and press analyze.
12. Report will be generated showing the values for count and the channel number.

13. Plot the energy calibration curve with centroid channel number as abscissa and the corresponding gamma energies as ordinate on a linear graph paper. Typical energy calibration curve is shown in Fig.3.
14. Acquire a spectrum for each of unknown gamma sources given and note down its peak channels.
15. Use the calibration curve prepared to determine the energy of unknown source.
16. Bring the HV voltage down and disconnect the detector.

Observation table:

Sr. No.	Isotope Name	Energy (KeV)	Centroid Channel		Counts from Report
			Calibration	Report	
1.	Na-22	511			
2.	Na-22	1275			
3.	Co-57	122			
4.	Co-60	1170			
5.	Co-60	1330			
6.	Cs-137				

Graph:

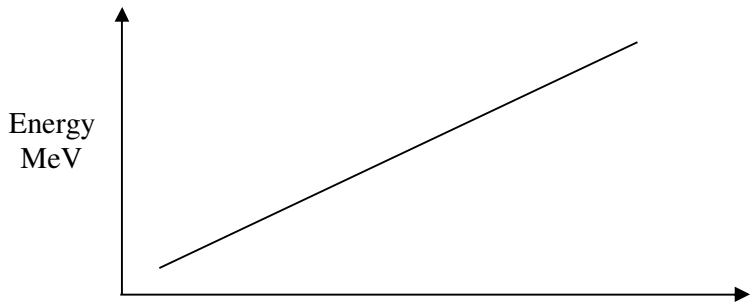

Figure3: Energy Calibration curve

Results:

Energy of the _____ Isotope is _____

Conclusions:

Space for
Graph paper

EXPT. No. 4

MEASUREMENT OF THICKNESSBY BETA TRANSMISSION GAUGE.

Aim: To calibrate the thickness gauge and use it for measurement of thickness and the associated uncertainty by β ray transmission technique.

Theory: The principle of a transmission gauge is based on the fact that radiation suffers a reduction in intensity as a result of transmission through a solid, liquid or gas. Transmission gauges are mainly of four types. They are:

1. Thickness gauges,
2. Density gauges,
3. Composition gauges and
4. Level gauges.

For γ rays, Bremsstrahlung and X-rays the radiation attenuation follows the law:

$$I = I_o \beta e^{-\left(\frac{\mu}{\rho}\right)\rho x}$$

where

I : the transmitted intensity.
I_o: the intensity at the detector without absorber,
μ : linear absorption coefficient [cm^{-1}]
μ/ρ : the mass absorption coefficient [sq.cm/gm]
ρ : the density of the absorbing material [gm/cm^3]
x : the thickness of the absorber [cm]
β : the buildup factor due to scattering effects. [Close to unity]

Thickness gauges can be classified as α gauges, β gauges, Bremsstrahlung gauges and γ gauges. The choice of suitable radioisotope depends upon the thickness of the material for which the gauge is to be used.

Beta Gauges:

Beta thickness gauges are normally used for the measurement of thickness of foils in the ranges of 0 to 1300~mg/cm^2. Different sources are needed to cover the required range for measuring a particular thickness of material with the best possible accuracy. It is desirable to choose a source of β particle for which at least 50% particles are absorbed in the thickness to be measured.

It is found generally that β particles from a given source can be used successfully for measurement from 0.2 to 4 times the half thickness and the best results are obtained [±1%] at the equivalent thickness of 0.5 to 2 half thicknesses. Approximate useful range of application for Sr90-Y90 (half-life = 28 years, E_{max} = 2.27 MeV) is 100 -600 mg/cm^2.

As it is known, the transmission of β rays depends upon thickness of material and atomic number. By keeping the atomic number constant i.e., by taking samples of the same material and by varying the thickness, count rate can be made independent of atomic number. This principle is used in this experiment.

Apparatus:

1. GM detector with counting system.
2. Radiation source.
3. Set of Aluminum foils of known thickness and a foil of unknown thickness.

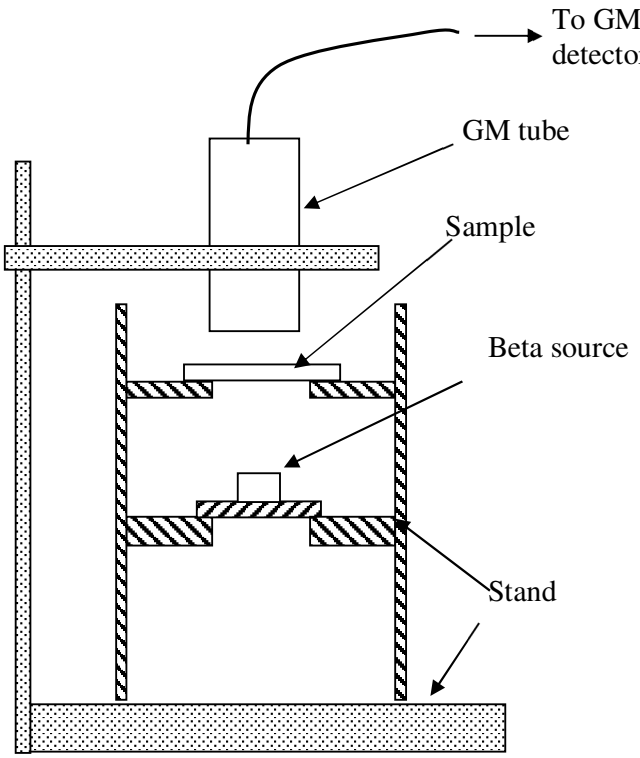

Figure 1:β Ray Transmission gauge setup

Procedure:

1. Connect the GM detector to the system as shown in the figure given above.
2. Place the source below the detector at suitable distance.
3. Put **ON** the Geiger counting system.
4. Set the EHT at the operating voltage (350V - 450V).
5. Keep the function knob to TIME mode, timer to 200 sec, and paralysis knob to 250 microseconds.
6. Keep the Aluminum foil (No. 2) in between the source and the detector as shown in the Fig. 1and press the start button and take count rate. Take natural log of the measured counts.
7. Replace the Aluminum foil by the next foil and repeat the procedure in step (6).
8. After taking reading for all the known foils place the unknown foil and repeat step (6).
9. Bring down the EHT to zero and switch off the counting system.

Observation and Calculation:

Density of Aluminum = 2.7 g/cm^3

Tabulate the thickness and count rate for different foils as shown below.

Sr. No.	Foil Thickness	Counts	Ln (counts)
1	0		
2	84.5		
3	219		
4	243		
5	432		
6	540		
7	709		
8	Unknown		

Unknown thickness Measured using micrometer

t1 (mm)	t2 (mm)	t3 (mm)	t4 (mm)	Mean (mm)

Results:

Plot the graph of thickness (mg/cm^2) v/s ln of count rate and from this graph find out the thickness of the unknown foil. Measure the thickness of the foil by using a micrometer and compare this with your result. Typical plot of ln of count rate v/s thickness of foil is shown in Fig. 2.

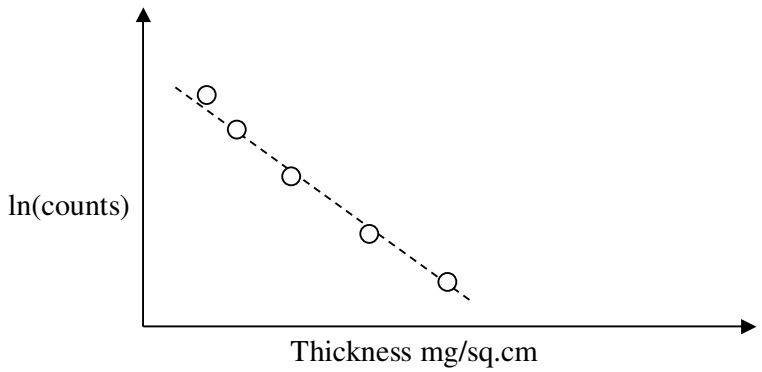

Figure 2: Plot of count rate v/s Thickness of foil for β ray transmission gauge

Thickness of Aluminum foil (experimental value)= …….mg/cm^2

Thickness of Aluminum foil (measured) = ……....mm

Thickness of Aluminum foil (measured) =…….mg/cm^2

Percentage error.= …….

Measurement uncertainty = $\frac{1}{-\frac{\mu}{\rho} * \sqrt{N} * (\rho x)} * 100$

=.....%

(The method to obtain the expression will be explained during the lab session)

Conclusions:

Space for
Graph paper