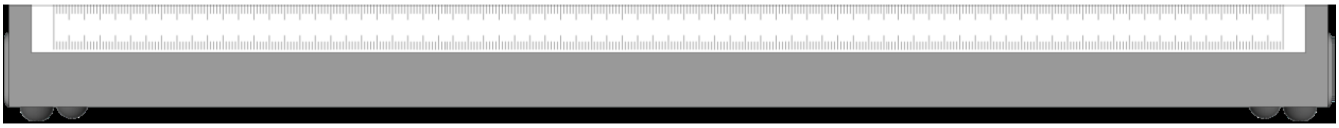
Instruction Manual

Radioactivity Bench

This apparatus is designed to enable a comprehensive range of experimental investigations into the characteristics and properties of radioactive emission to be carried out. Although some experiments are suitable for lower levels, the majority are intended for „A"-level physics students.



Additional items required:

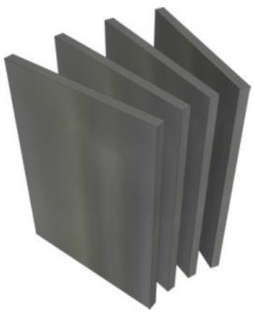
1. A Geiger-Müller tube and holder
2. A compatible rate meter or counter
3. At least one radioactive source
4. Radioactive source handling tool

Caution
Although this apparatus does not contain any hazardous material, all investigations involve a radioactive source. Before acquiring or using such a source, refer to CLEAPSS document *L93: Managing Ionising Radiations and Radioactive Substances in Schools*.
This is a free download and can be viewed here:
http://www.cleapss.org.uk/download/L93.pdf

Apparatus Detail

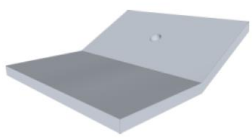
1. The bench is a steel tube with plastic end inserts. A millimetre scale is mounted on a plate attached to the side of the bench. This acts as a guide to align the slotted plastic carriages which clamp magnetically to the bench.
2. The slot on each carriage can accommodate any of the absorption plates, and has a nut so the plate can be held securely upright.
3. There are two source holders. The first has three horizontally collinear holes. The central hole is for alignment with the GM-tube, and the holes off-centre are used with the collimator for experiments involving magnetic deflection of β particles.

Aluminium Absorbers

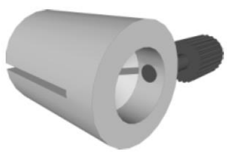


Lead Absorbers

1st Source Holder



2nd Source Holder

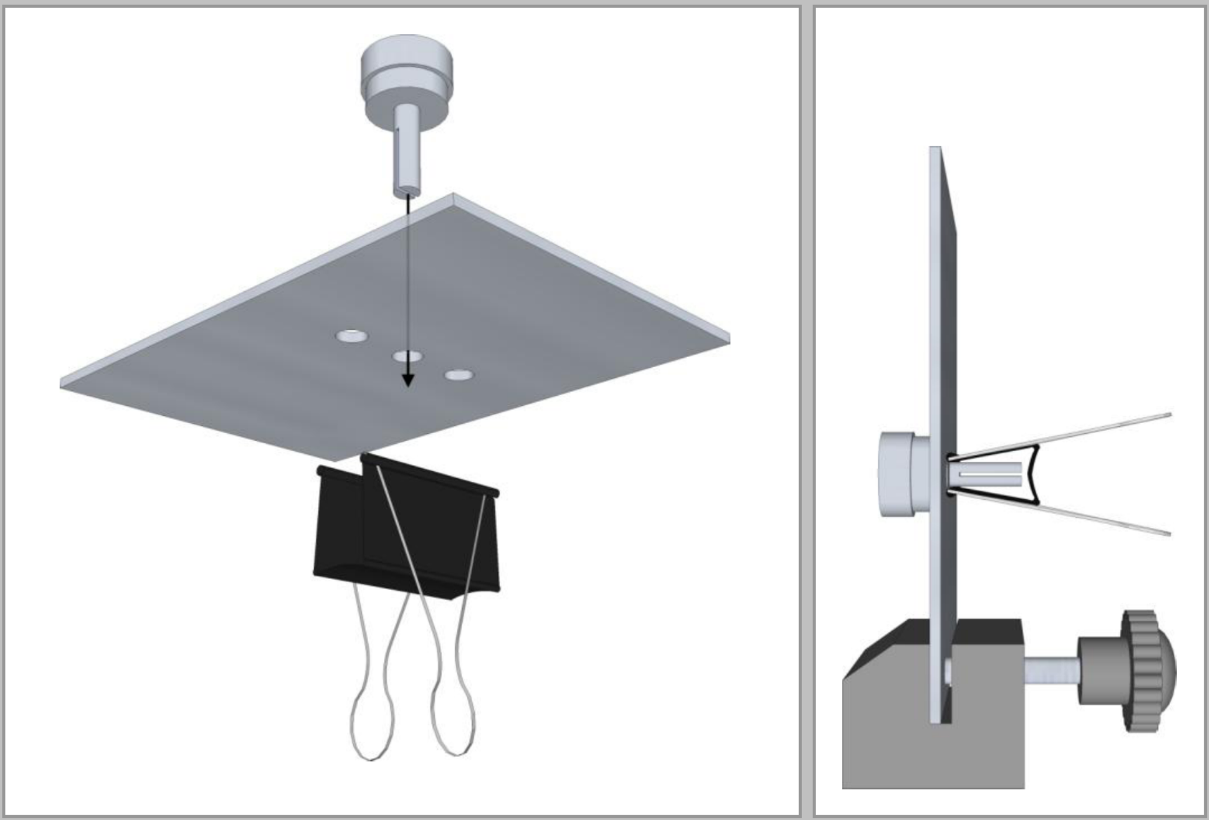


Collimator

4. The second source holder is angled so that the sealed source can be placed beneath the GM tube for back-scattering experiments.

Technical Information:

I. Two “Bulldog” clips are provided to secure the sealed sources in their holders. The holder should be held horizontally, and using a source handling tool, the source should be dropped in to the required hole, then the bulldog clip attached to the back.
Once secured in the holder, it can be turned so the source is horizontal, and then placed in a carriage.



The sealed source is placed in the holding plate, and secured with the bulldog clip. It can then be placed in a carriage.

When setting the voltage on the EHT, 400V is recommended. However, each tube is slightly different, and a higher or lower voltage may be required to obtain optimum response from the tube.

II. RED-ALERT (precaution)

The source should always be handled using the source handling tool. When using α or *β* sources, the grille should be pointed away from people at all times. It is recommended that people remain at least one metre away from the source when measurements are being taken.
When not in use, the source should be returned to its lead “castle” in the hardwood storage box and kept in a locked cupboard away from permanently occupied places.

EXPERIMENTS:

WHICH CAN BE DONE ONLY BY ARRANGING ADDITIONAL ITEMS BY THE EXPERIMENTER ITSELF.

Experiment 1 *Classification of radioactive and non-radioactive solids.*

This is a simple investigation designed to introduce the fact that some materials emit radiation naturally, whereas others do not. It also demonstrates how this radiation can be detected using man-made devices.

Items

1. Normal rocks
2. Radioactive rock specimens
3. Geiger Muller tube and holder
4. Rate meter

RED-ALERT

Although natural radioactive substances are not subject to regulations concerning holding of sources, care should be taken in storing and handling such materials. The rock specimens should be stored in the radioactive storage cupboard, and gloves should be worn when handling so no residue is left on skin.

Procedure

1. Connect the GM tube holder to the rate meter
2. Mount the GM tube into its holder
3. Set the EHT supply on the rate meter to 400V, and the count range to 250s-1
4. Read and record the rate in the absence of a sample and the rate of click from the loudspeaker.
5. Place each sample in turn in close proximity to the window of the GM tube.
6. Record the new count rate and the rate of clicking of the loudspeaker.
7. Classify the samples into radioactive and non-radioactive samples.

Example Results

Background count: $2s^{-1}$

Specimen	Pitchblende	Monazite	Slate	Concrete
Count rate (s^{-1})	83	70	2	3
Corrected count rate (s^{-1})	81	68	0	1

Experiment 2 *To study the randomness of radiation emitted by a Cobalt-60 source*

Requirements

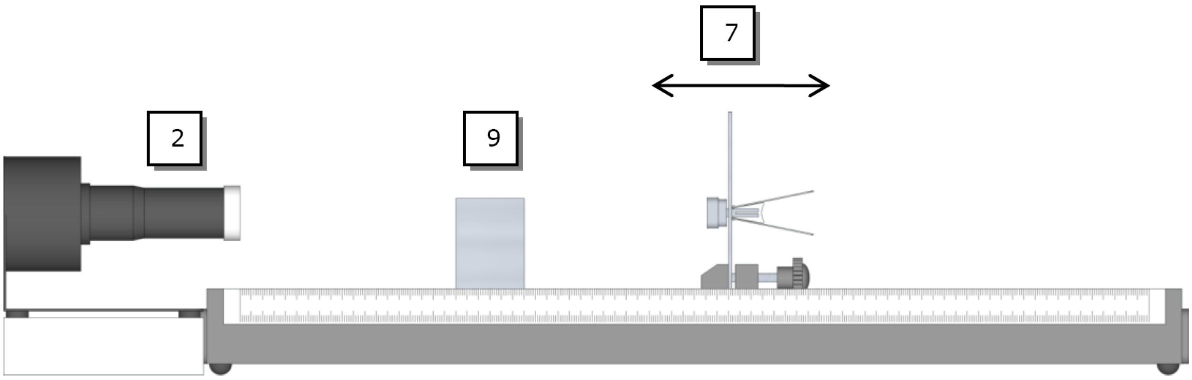
1.Radioactivity Bench
2.Geiger Müller tube and holder
Source handling tool
3.Rate meter
4.Lead block
5.Aluminium block
6. Bulldog clip
7.5μCi cobalt-60 source

Before proceeding with this experiment, read the cautions on page 2.

Operating procedure

1.Connect the GM tube holder to the rate meter.
2.Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.

3.Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window
4.Using the source handling tool, mount the cobalt-60 source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube
5.Set the EHT supply on the rate meter to 400V and set the range to 250s-1
6.Switch on and allow the rate meter to stabilise
7.Adjust the separation of the GM tube and source to give a reading on the order of 200s-1. Record the number of counts observed every 10 seconds, taking several 10 second samples.
8.Turn the loudspeaker on and listen to the clicks
9.Stand the aluminium block between the source and GM tube and observe the change to speaker output and count rate.
10.Replace the aluminium block with the lead block and again observe the changes.



Theory

The radiation emitted from this source is random in nature; Which atoms decay 1st is a matter of chance. The laws governing the emission are statistical laws which apply when there is a very large number of random events.

Experiment 3 *To Compare the activity of emitters*

Requirement

1.Radioactivity bench
2.Rate meter
3.Geiger Müller tube and holder
4.Source handling tool
5. Bulldog clip
6.5μCi americium-241 source
7.5μCi strontium-90 source
8.5μCi cobalt-60 source

Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

1. Connect the GM tube holder to the rate meter.
2. Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3. Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, mount one source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.
5. Set the EHT supply on the rate meter to 400V and set the range to250s^{-1}
6. Switch on, allow the rate meter to stabilise, and take a note of the activity.

7. Repeat steps 1-6 with each source.
8. Identify the most active of the three sources and mount it in the holder as before.
9. Adjust the distance between the source and the tube so that the meter reading is the maximum for that source.
10. Using this separation, determine the count rate for the other sources.

Example Results

Background count: Background count: $2s^{-1}$

Source	Cobalt-60	Strontium-90	Americium-241
Count rate (s-1)	240	135	2
Corrected count rate (s-1)	238	133	0

Experiment 4 *To Reduce the intensity of radiation emitted by a source.*

Apparatus

1.Radioactivity bench
2.Rate meter
3.Geiger Müller tube and holder
4.Source handling tool
5. Bulldog clip
6. 5μCi cobalt-60 source
7. 5μCi strontium-90 source
8. Set of solid blocks

Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

1.Connect the GM tube holder to the rate meter.
2. Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3.Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, mount one source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.
5. Set the EHT supply on the rate meter to 400V and set the range to $250s^{-1}$
6.Switch on, allow the rate meter to stabilise, take a note of the activity.
7.Adjust the separation of the GM tube and source to give the maximum possible reading on the rate meter.
8.Record the count rate.
9.Place each solid block in turn between the source and GM tube, with the block in close proximity to the source.
10. Record the count rate for each solid.

Example Results

Background count: 1s-1

Block	None	Polystyrene	Wood	Aluminium	Lead
Count rate (s^{-1}) Co60	240	150	7	5	2
Count rate (s^{-1}) Sr90	240	190	3	1	1

Extension
The relationship between the activity from a source and the source-counter separation can be investigated.
Operating Procedure
1. Connect the GM tube holder to the rate meter.
2. Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3. Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, mount one source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.
5. Set the EHT supply on the rate meter to 400V and set the range to $250s^{-1}$
6. Switch on, allow the rate meter to stabilise, and take a note of the activity.
7. Adjust the separation of the GM tube and source to give the maximum possible reading on the rate meter.
8. Record the count rate.
9. Increase the source-counter separation in 50mm steps and record the corresponding count rates.

Example Results

Background count: $1s^{-1}$

Separation	100	150	200	250	300	350	400
Count rate (s-1) Co60	240	137	98	57	37	27	20
Count rate (s-1) Sr90	240	87	52	33	22	16	12

Experiment 5 *To estimate the range of α particles in air*

Requirements

1. Radioactivity bench
2. Rate meter
3. Geiger Müller tube and holder
4. Source handling tool
5. Bulldog clip
6. 5μCi americium – 241 source
7. Tissue paper

Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

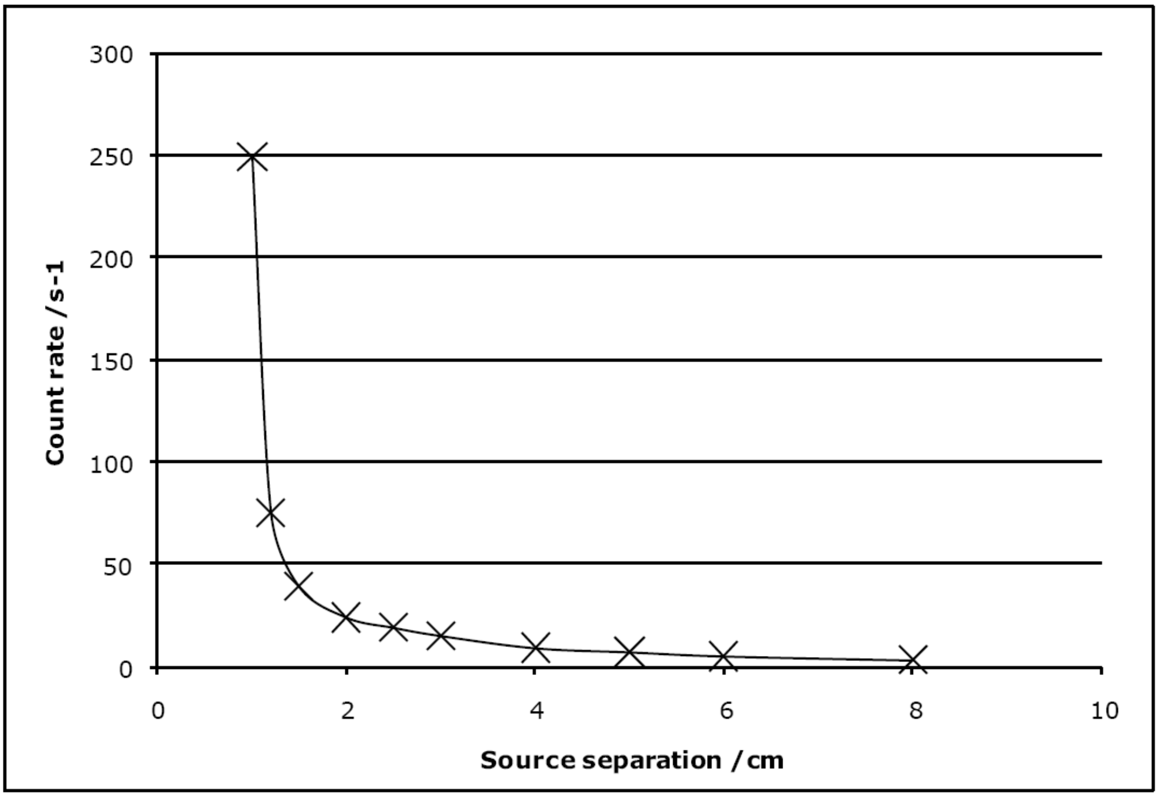
1.Connect the GM tube holder to the rate meter.
2.Mount the GM tube in Its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3. Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, mount one source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.
5. Set the EHT supply on the rate meter to 400V and set the range to $250s^{-1}$.
6. Switch on and allow the rate meter to stabilise.
7. Carefully remove the grille from the end of the GM tube
8. Adjust the separation of the GM tube and the source to get the maximum count rate on the rate meter. Do not allow the source to be brought too close to the unprotected window of the GM tube, as it is very delicate.
9. Increase the source/tube separation in steps, and record the reading from the rate meter against the distance of the source from the tube, changing the range on the counter if necessary

NOTE: Remember to replace the protective grille on the end of the GM tube at the end of this experiment.

Results

Background count: $1s^{-1}$

Source-tube separation (cm)	1.0	1.2	1.5	2.0	2.5	3.0	4.0	5.0	6.0	8.0
Count rate (s-1)	250	75	39	24	19	15	9	7	5	3
Corrected count rate (s-1)	249	74	38	23	18	14	8	6	4	2



Theory

α particles cause heavy ionisation of the air as they pass through it, losing their energy after travelling a relatively short distance (i.e. they have a very short range in air).

The window of the GM tube is a very effective absorber of the energy of α particles and is equivalent to a few centimetres of air (depending on the type of GM tube being used).

Extension *To study the absorption of α particle energy by tissue paper*

10. Adjust the separation of the GM tube and the source to get the maximum count rate on the rate meter. Do not allow the source to be brought too close to the unprotected window of the GM tube, as it is very delicate.
11. Introduce one thickness of a 10 x 10cm sheet of tissue paper between the source and the GM tube, and record the new rate meter reading.
12. Fold the tissue paper once, place this double layer of paper between the source and GM tube again, and record the new rate meter reading.

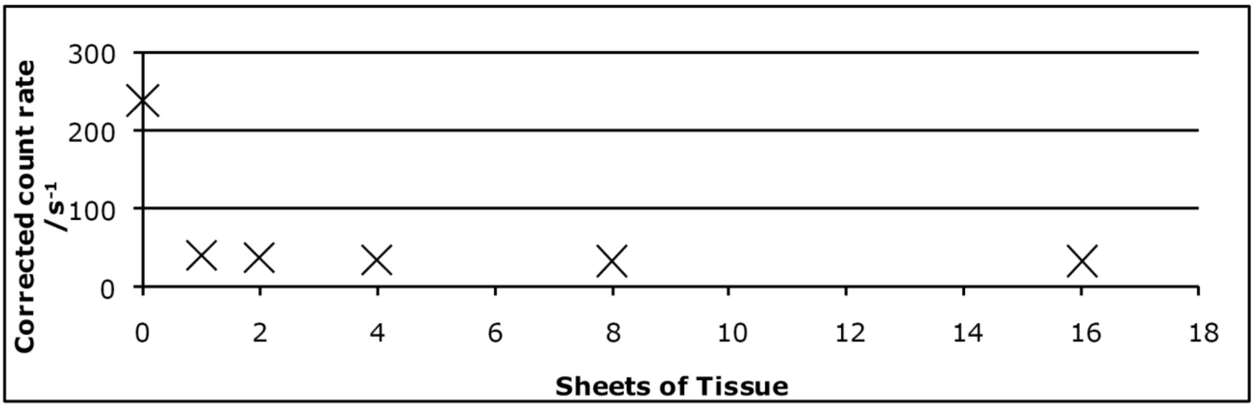
13. Continue to fold the paper and place the new thickness between the source and GM tube.

NOTE: Remember to replace the protective grille on the end of the GM tube at the end of this experiment.

Example Results

Background count: $1s^{-1}$

Sheets of Tissue	0	1	2	4	8	16
Count rate (s-1)	240	41	37	35	33	33
Corrected count rate (s-1)	239	40	36	34	32	32



Note

1. The count rate falls significantly when a single thickness of tissue is placed between the source and the tube, but subsequent layers of tissue have little effect. This suggests that all α particle energy is absorbed by a single layer of tissue and the window of the GM tube, and that remaining incident radiation is not α radiation.
2. Americium-241 emits low energy γ rays as well as α particles.

Experiment 6 To study *the absorption of β particles in metal*

Requirements

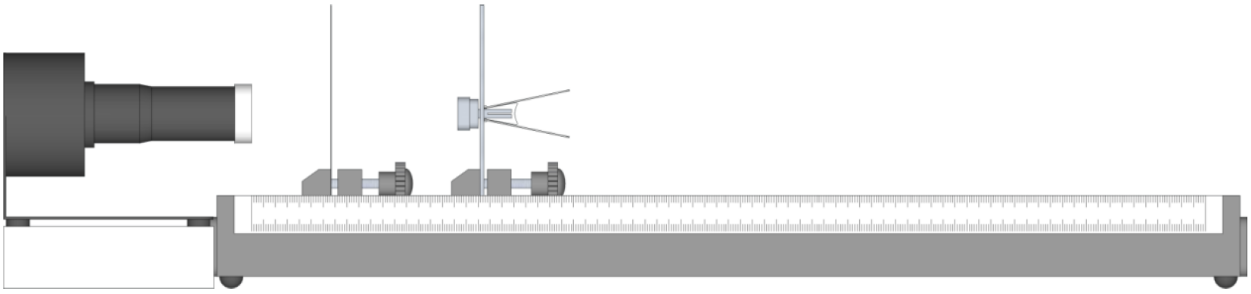
1.Radioactivity bench
2.Geiger Müller tube and holder
 Source handling tool
3.Rate meter
5. Bulldog clip
6. 5μCi strontium-90 source
 Set of aluminium plates
7. Micrometer

4.Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

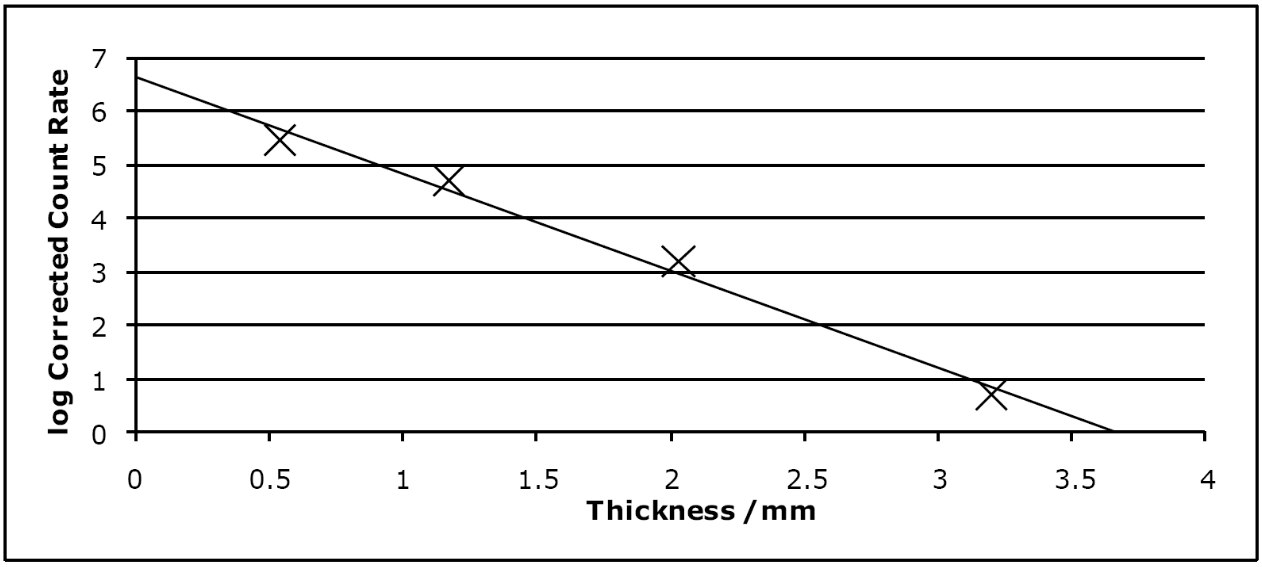
1. Connect the GM tube holder to the rate meter.
2.Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3.Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4.using the source handling tool, mount the source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.

5. Set the EHT 5.supply on the rate meter to 400V and set the range to 250s-1
6. Switch on and allow the rate meter to stabilise.
7.Adjust the separation of the GM tube and the source to get the maximum count rate on the rate meter, and make a note of this rate.
8. Use the micrometer to measure the thickness of the aluminium plates.
9. Mount each plate in turn into a carriage, and place it between the source and the GM tube.
10.Record the rate on the rate meter against the thickness of the aluminium plate (x).



Example Results

Thickness (mm)	0.54	1.17	2.03	3.20
Count Rate (s-1)	237	110	25	3
Corrected count rate (s-1)	236	109	24	2
Natural log	5.46	4.69	3.17	0.69



Theory

The absorption of β particle is approximately exponential:

$$I = I_0 e^{-\mu x}$$

I_0 is the intensity of β particle passing through the aluminium.

Taking the natural log of this equation:

$$\ln I = \ln I_0 - \mu x$$

So that gradient of the graph above is $-\mu$.

The half thickness (X1/2)is the thickness at which the intensity of the transmitted β particle is half the incident intensity ,and is given by:

$$\frac{1}{2} I_0 = I_0 e^{-\mu x_{\frac{1}{2}}}$$

$$\ln\frac{1}{2} = \ln 1 - \mu x_{\frac{1}{2}}$$

$$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$$

Experiment 7 To *Investigate the attenuation of γ rays in lead*

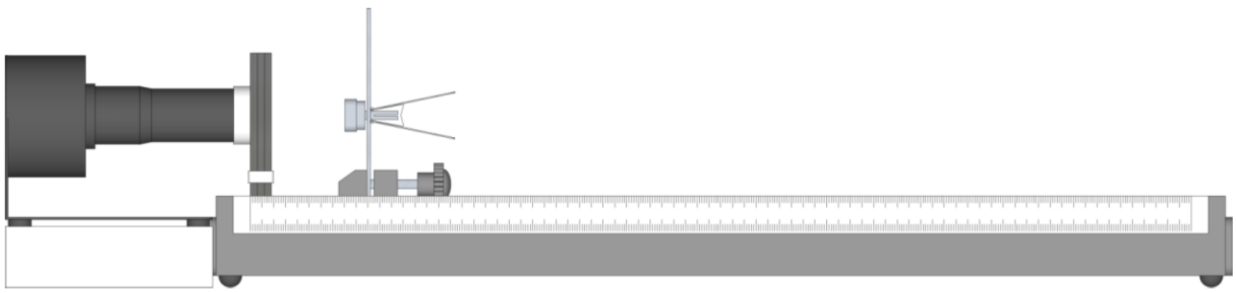
Requirements

1.Radioactivity bench
2.Geiger Müller tube and holder
3.Bulldog clip
4.Source handling tool
5.rate meter
6. Set of lead plates
7.Micrometer
8. Rubber band
9.5μCi cobalt-60 source

Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

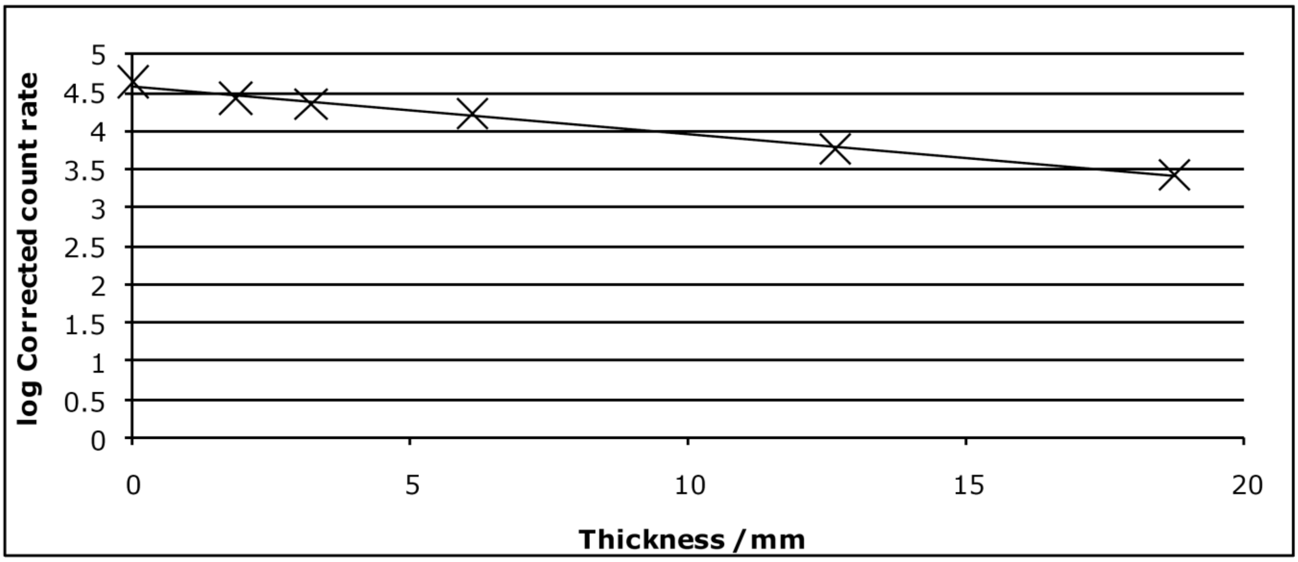
1.Connect the GM tube holder to the rate meter.
2.Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3. Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, mount the source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.
5. Set the EHT supply on the rate meter to 400V and set the range to 250s^{-1}
6.Switch on and allow the rate meter to stabilise.
7.Adjust the separation of the GM tube and the source to get the maximum count rate on the rate meter, allowing sufficient space to space between the GM tube and the source to introduce the two thickest lead plates between them.
8.Record the count rate without any lead plates.
9.Measure the thickness of the thinnest lead plate, mount it in a carriage, and place it on the bench between the source and GM tube. Record the new count rate.
10.Alternate the lead plates, to get various thicknesses. Measure the thickness and secure the plates with a rubber band near the base. Carefully stand the plates between the source and GM tube and record the count rate for each thickness.
11. Remove the source and record the count rate to determine the background count.



Example Results

Background count: $1s^{-1}$

Thickness (mm)	0	1.85	3.21	6.10	12.65	18.75
Observed count rate (s^{-1})	105	85	78	70	44	32
Corrected count rate (s^{-1})	104	84	77	69	43	31
Natural log	4.64	4.43	4.34	4.23	3.76	3.43



THEORY

The attenuation of Y ray through lead is approximately exponential:

$$I = I_0 e^{-\mu x}$$

I is the intensity of y ray passing through the lead.

Taking the natural log of this equation:

$$\ln I = \ln I_0 - \mu x$$

So that gradient of the graph above is $-\mu$.

The half thickness (X1/2)is the thickness at which the intensity of the transmitted γ particle is half the incident intensity ,and is given by:

$$\frac{1}{2} I_0 = I_0 e^{-\mu x_{\frac{1}{2}}}$$

$$\ln \frac{1}{2} = \ln 1 - \mu x_{\frac{1}{2}}$$

$$x_{\frac{1}{2}} = \frac{\ln 2}{\mu}$$

Experiment 8 To *Investigate the relationship between the intensity of γ rays at a point and the distance of that point from the source*

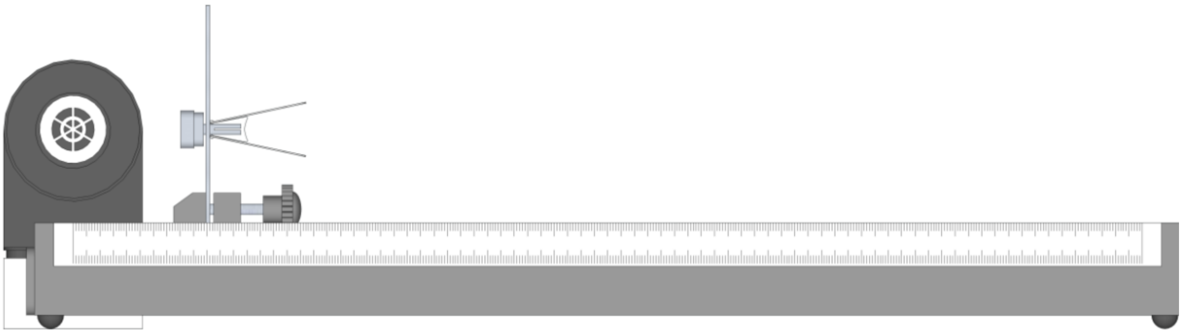
Requirements

1.Radioactivity bench
2.Geiger Müller tube and holder
3.Rate meter
4.Source handling tool
5.Bulldog clip
6.5μCi cobalt-60 source

Before proceeding with this experiment, read the precautions on page 2.

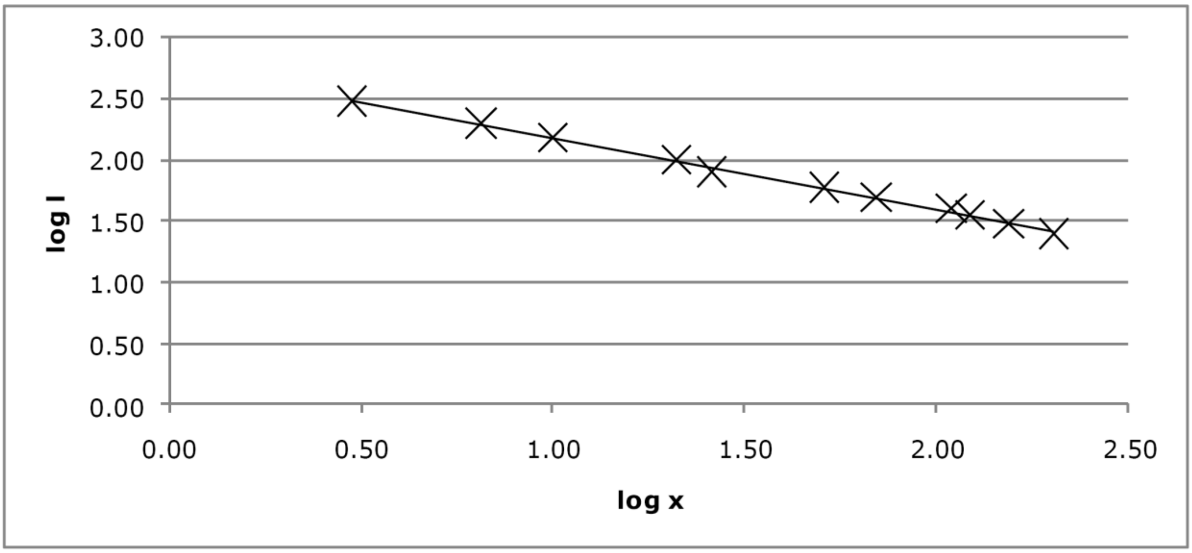
Operating Procedure

1. Connect the GM tube holder to the rate meter.
2.Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the axis of the GM tube is perpendicular to the scale and vertically above the scale zero.
3.Secure the source holder in a bench mount with its line of holes horizontal and with the central hole co-linear with the axis of the GM tube. Use the source handling tool to place the cobalt-60 source in the central hole with the grill facing the end window of the GM tube. Secure the source with a bulldog clip.
4.Set the EHT supply on the rate meter to 400V and set the range to $250s^{-1}$
5.Switch on and allow the rate meter to stabilise.
6.Adjust the separation of the GM tube and the source to give a large reading on the ratemeter, towards the higher end of the range.
7. Record the distance (x) of the source from the GM tube, and the reading on the ratemeter.
8.Increase the separation of source and GM tube initially in 5mm steps, then 10mm, 20mm 50mm and finally 100mm steps, recording count rate against separation. Adjust the range on the ratemeter to $50s^{-1}$ when the count rate falls below $50s^{-1}$.
9.Remove the source and record the count rate to determine the background count.
10.Determine the corrected count rate (I) by subtracting the background count from the observed rate.



Background count: $2s^{-1}$

Separation	25	30	35	40	50	60	80	100	150	200	300
Observed count rate (s^{-1})	205	157	125	112	72	53	28	23	12	8.5	5.0
Corrected count rate (s^{-1})	203	155	123	110	70	51	26	21	10	6.5	3.0
log I	2.31	2.19	2.09	2.04	1.85	1.71	1.41	1.32	1.00	0.81	0.48
log x	1.40	1.48	1.54	1.60	1.70	1.78	1.90	2.00	2.18	2.30	2.48



Theory

The intensity of any electromagnetic radiation at a point varies inversely as the square of its distance from that point. If γ emission is electromagnetic radiation, it must comply with this law and the slope of the graph obtained by plotting the natural logs of count rate against separation should be -2.

Experiment 9 *To Monitor the distribution in space of the emission from a radiation source*

Requirements

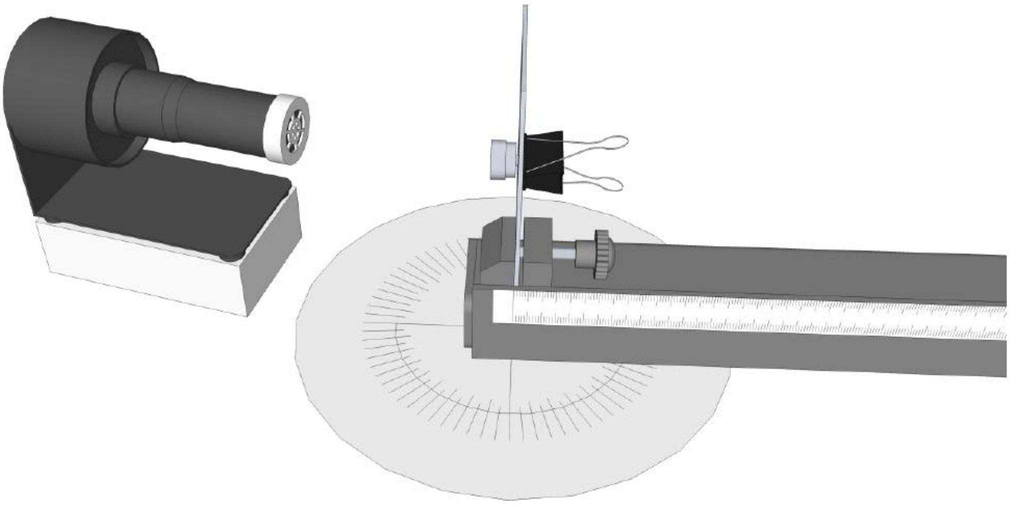
1.Radioactivity bench
2.Geiger Müller tube and holder
3.Source handling tool
4.Rate meter
5. Bulldog clip
6. 0.5m ruler
7. 5μCi americium-241 source
8. Protractor (full circle)

4. Before proceeding with this experiment, read the precautions on page 2

Operating Procedure (illustration on next page)

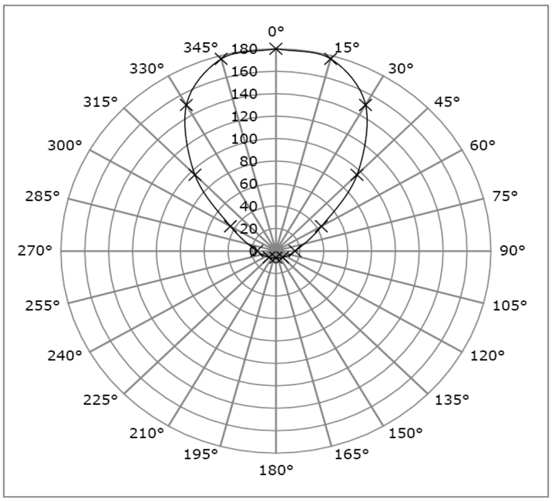
1. Connect the GM tube holder to the rate meter.
2. Place the paper protractor under the radioactivity bench so that the 0 -0° line is directly below the central axis of the bench and the centre of the circle is directly below the scale zero.
3. Use the source handling tool to place the cobalt-60 source in the central hole of the source holder. Secure the source with the bulldog clip. Place the source holder in a bench mount so that its line of holes is horizontal and the source is directly above the centre of the protractor and in line with the 0 -0° line.
4. Mount the GM tube in its holder and place the GM tube stand on the 0 -0° line of the protractor scale, with the end window positioned so that it is vertically above the outer edge of the protractor markings.
5. Set the EHT dial to 400V and the count rate range selector to 250s-1
6. Switch on and allow the rate meter to stabilise.
7. Take the reading.

8. Place the GM tube on the 15° radial line so that the axis of the GM tube lies directly above and is parallel with that line, whilst the end window of the GM tube is vertically above the outer edge of the angle markings. Record the angle (θ) between the axis of the source and the axis of the GM tube together with the observed count rate.
9.Repeat step 8, increasing the angular separation of the axis of the source and the axis of the GM tube in 150° steps, recording the angle (θ) and the corresponding count rate. Adjust the rate meter range to $50s^{-1}$ when the rate falls below $50s^{-1}$.
10.Remove the source and record the count rate to determine the background count.
11.Plot the polar diagram with the intensity plotted radially at the corresponding angle.



Example Results

Angular separation (°)	0	15	30	45	60	90	135	180
Observed count rate (s^{-1})	182	179	152	98	46	18	10	8
Corrected count rate (s^{-1})	180	177	150	96	44	16	8	6



Experiment 10 *To Investigate the deflection of a stream of β particles in a magnetic field*

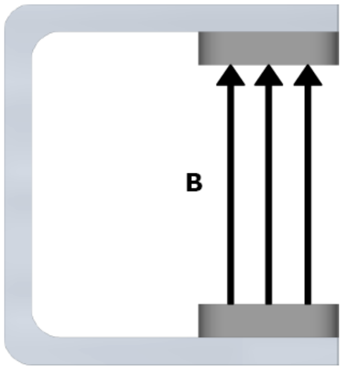
Requirements

1.Radioactivity bench
2.Geiger Müller tube and holder
3.Rate meter 8. Pair of Magnadur magnets
4.Source handling tool
5.Bulldog clip
6. 5μCi strontium-90source
7. Pair of magnadur magnets mile steel yoke
8. Collimator
9. Mile steel yoke

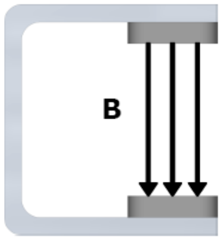
Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure (illustrations on next page)

1. Connect the GM tube holder to the rate meter.
2. Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.
3. Secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, secure the strontium-90 source in the collimator and mount it in the outermost hole in the source holder with the collimator facing the GM tube end window. Rotate the collimator about its axis so that the collimator slot is vertical, then hold the source and collimator in place with the bulldog clip.
5. Position the source holder at 70mm on the scale.
6. Place the magnets inside the steel yoke, so that the opposite poles are facing each other, thus setting up a magnetic field as illustrated.



7. Set the EHT dial to 400V and the count rate range selector to $50s^{-1}$
8. Switch on and allow the rate meter to stabilise.
9. Record the count rate.
10. Place a second bench mount between the GM tube and the source holder and slide the magnet in position with the field vertical and parallel to the collimator slit. vertical adjustments of height may be made by placing lead plates between the magnet and the bench mount.
11. Adjust the position of the magnet so that the collimator slit is in the centre of the Magnadur magnet pole pieces.
12. Record the count rate.
13. Remove the magnet and invert it to reverse the direction of the magnetic field between the pole pieces as illustrated, then repeat steps 11 and 12.

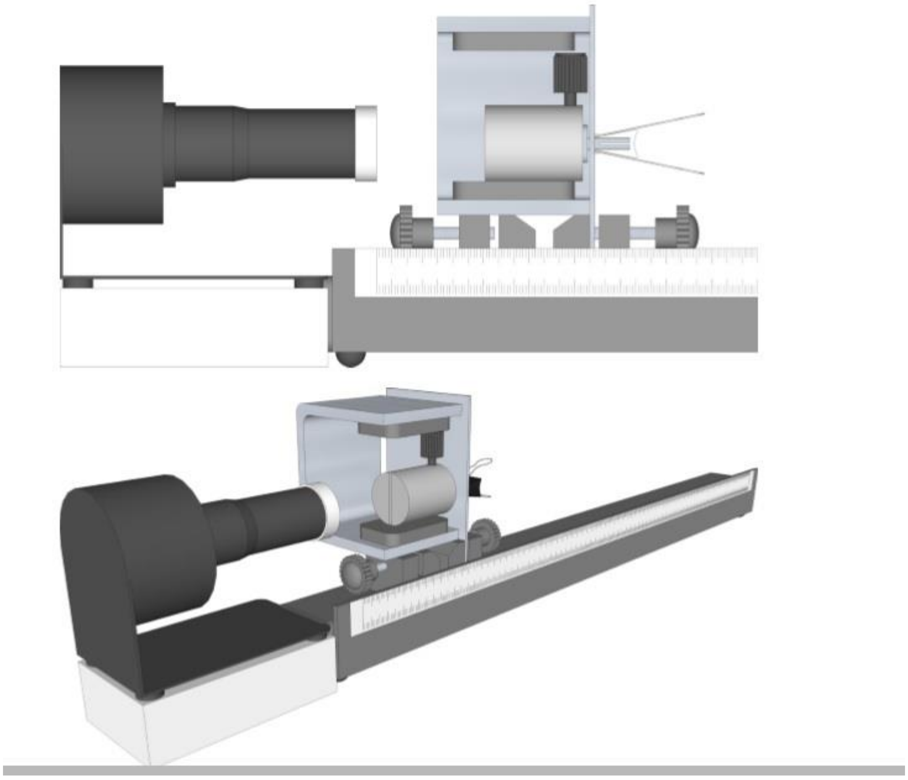


14. Remove the magnet, then place the source and collimator in the other outermost hole in the source holder, without moving the GM tube and holder. Repeat steps 11 to 13.

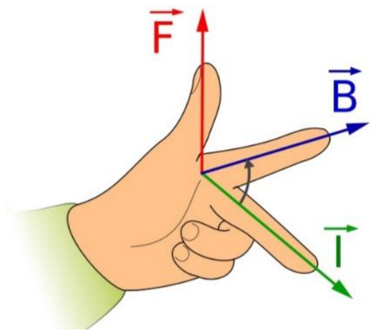
Example Results

Background count: $1s^{-1}$

Source position	Furthermost hole			Nearest hole		
Magnetic field direction	Upwards	None	Downwards	Upwards	None	Downwards
Count rate (s^{-1})	48	22	9	7	15	39
Corrected count rate (s^{-1})	47	21	8	6	14	38



Theory



The stream of β-particles will be observed to be deflected in the magnetic field. Application of Fleming"s left-hand rule for motors indicates that the stream of β-particles is equivalent to a flow of positive charge entering the source.

However, as β-particles are leaving the source, they must be negatively charged. *Illustration available on Wikipedia, by User:Jfmelero*

In this case, the force **F** works to deflect the β-particles leaving the source, the current **I** is the conventional current (i.e. in the opposite direction to the β-particles) and **B** is the magnetic field between the Magnadur magnets.

Experiment 11 *TO Investigate back scattering of β radiation by solids*

Requirements

1.Radioactivity bench	5. Set of solid block
2.Geiger Müller tube and holder	6. Set of aluminium plates
3.Rate meter	7. 5μCi strontium-90
4.Source handling tool	8. Micrometer

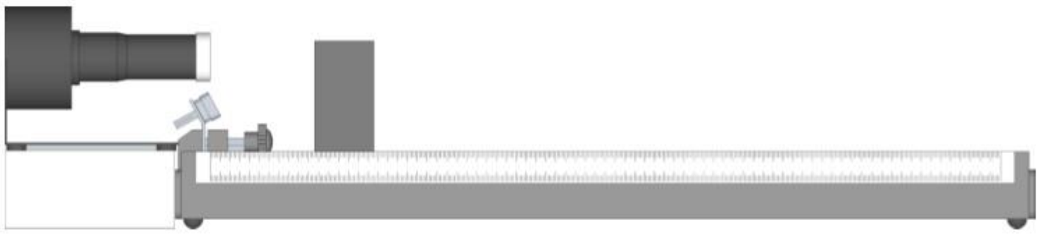
Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

1.Connect the GM tube holder to the rate meter.

2.Mount the GM tube in its holder and place it at the zero end of the scale of the bench so that the window of the GM tube is vertically above zero on the scale.

3.Secure the inclined source holder in a bench mount and, using the source handling tool mount the strontium-90 source in it so that the plane of the grill is immediately below the end window of the GM tube, and facing in the same direction as the end window.
4.Set the EHT dial to 400V and the count rate range selector to 250s-1
5.Switch on and allow the rate meter to stabilise.
6.Read and record the count rate in the **absence** of a backscatterer.
7.Place the lead block on a bench mount and adjust the separation of the block and the GM tube so that the maximum count rate is observed.
8.Read and record the distance between the face of the lead block nearest the GM tube and the GM tube itself, and the count rate.
9.Replace the lead block with each solid in turn, making sure the separation of the GM tube and the nearest face of the solid is the same each time.
10.Record the count rate for each solid.
11.Subtract the count rate observed in step 7 from that observed in step 10 to determine the corrected count rate.



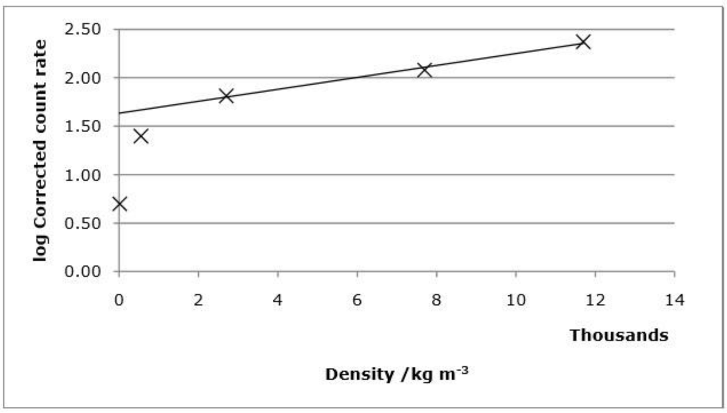
Extension 1 *To study investigate the variation of the backscattering of β- particles by a solid with the density of that solid*

12. Determine the volume and mass of each solid, and calculate the density ρ of that solid.
13.Take logs of the corrected count rate, and plot a graph of the log of the count rate against the density

Example Results

Background count: 15s^{-1}

Solid	Lead	Steel	Aluminium	Wood	Expanded Polystyrene
Count rate (s^{-1})	250	135	80	40	20
Corrected count rate (s^{-1})	235	120	65	25	5
Density (kg m^{-3})	11700	7700	2700	550	15
log Corrected count rate	2.37	2.08	1.81	1.40	0.70



Extension 2 *To study investigate the variation of backscattering of radiation by aluminium with the thickness of that aluminium*

14.Use the micrometer screw gauge to measure the thickness of the thinnest plate,and mount it in the bench mount.

15.Record the thickness of the plate and the count rate.

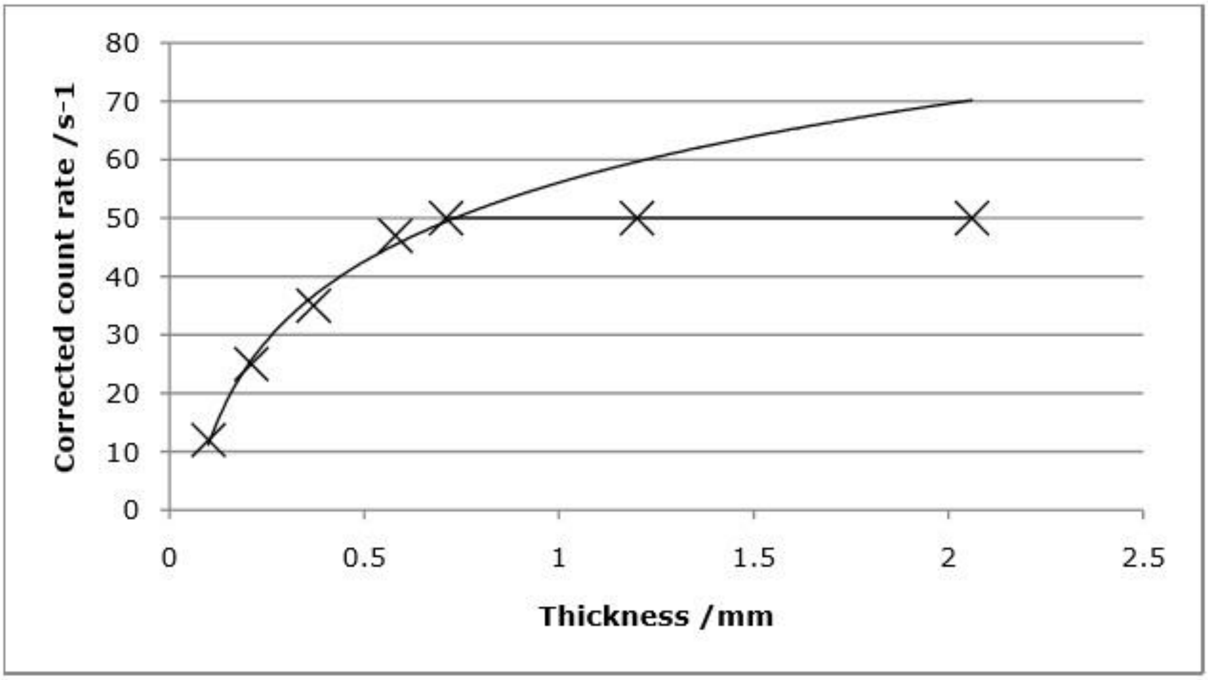
16.Repeat steps 14 and 15 for each of the plates.

Plot a graph of thickness against count rate.

Example Results

Background count: 15s^{-1}

Thickness mm	0.1	0.21	0.37	0.58	0.71	1.2	2.06
Count rate (s-1)	27	40	50	62	65	65	65
Corrected count rate (s-1)	12	25	35	47	50	50	50



It can be seen from the graph that the thickness of aluminium plates can only be gauged by back-scattering of β-particles up to thicknesses of about 0.5mm.

Experiment 12 *To estimate the thickness, by transmission of β-particals*

Requirements

1.Radioactivity bench
2.Geiger Müller tube and holder
Source handling tool
3.Rate meter
4.Bulldog clip
5.Set of solid blocks
6.Set of aluminium plates
7.Micrometer
8. Aluminium foil, foil dishes and milk
9. bottle cap
10 .5μCi strontium-90 sourc

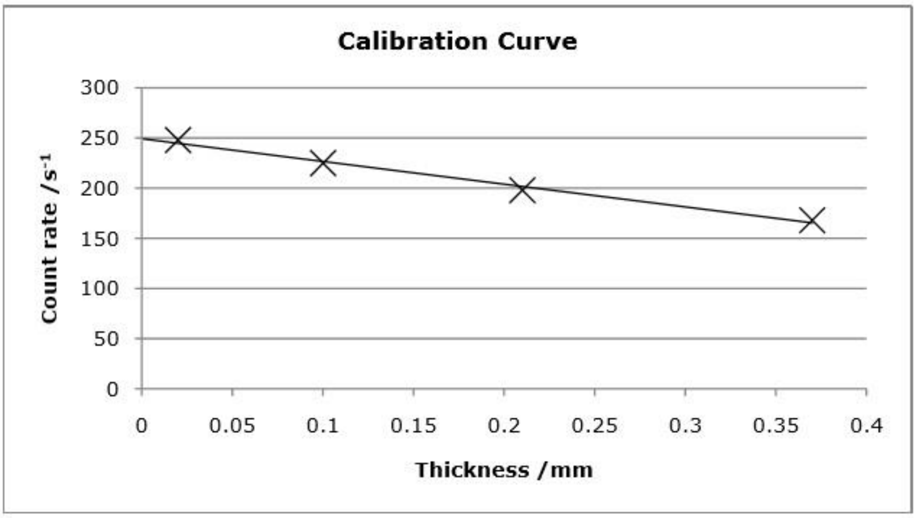
Before proceeding with this experiment, read the precautions on page 2.

Operating Procedure

1.Connect the GM tube holder to the rate meter.

2.Mount the GM tube in its holder and place it at the zero end of the scale of the bench o that the window of the GM tube is vertically above zero on the scale.
3.secure the source holder in a carriage with its line of holes horizontal, and the central hole in line with the GM tube window.
4. Using the source handling tool, mount the source in the central hole of the holder as illustrated on page 2, with the grille end facing the window of the GM tube.
5.Use the micrometer screw gauge to measure the thickness of a piece of aluminium kitchen foil, then mount it in a bench mount between the GM tube and the source.
6. Set the EHT supply on the rate meter to 400V and set the range to 250s-1
7. Switch on and allow the rate meter to stabilise.
8. Adjust the separation of the GM tube and source, until the reading is at the top of the range.
9. Record the thickness of the foil, and the count rate.
10. Take the same measurements for the three aluminium plates.
11. Plot a calibration curve of count rate against thickness.
12.Mount the milk bottle cap in a bulldog clip and secure one leg of the bulldog clip in the bench mount between the source and the GM tube. Record the count rate.
13.Secure a foil dish in a bench mount and mount it between the source and the GM tube so that the β-rays pass through the base of the dish and record the count rate.
14. Repeat step 13 for other foil dishes.
15.Estimate the thickness of the milk bottle cap and the foil plates by seeing where the corresponding count rates lie on the curve plotted in step 11.
16.Check the accuracy of your estimates by measuring the thicknesses using the micro meter screw gauge.

Note
It is possible to plot a calibration curve using folded aluminium kitchen foil to produce 1, 2, 4 and 8 et seq. thicknesses of foil.



Example Data

Plate thickness (mm)	0.02	0.1	0.21	0.37
Count rate (s-1)	248	225	198	168

Specimen	Count rate	Thickness gauged	Thickness measured
Milk bottle cap	240	0.045	0.05
Foil pie dish	234	0.065	0.06-0.07
Multi-purpose dish	227	0.09	0.08-0.09