DEPARTMENT OF PURE & APPLIED PHYSICS

LAB MANUAL

On

Basic Nuclear Physics Lab

B.Sc. 6th Semester (Physics)

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DEPARTMENT OF PURE AND APPLIED PHYSICS
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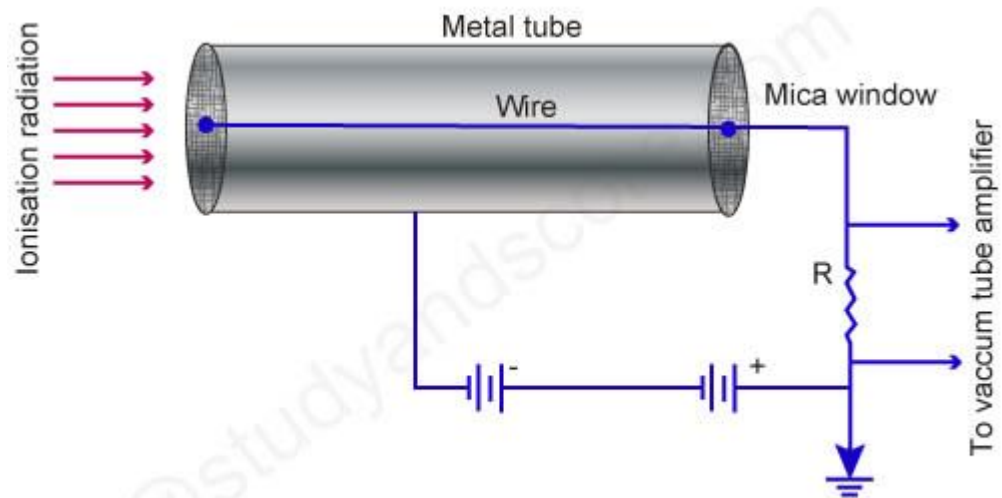
Basic Nuclear Physics Lab

LIST OF EXPERIMENTS

1. **To study the variation of count rate with applied voltage of Geiger-Müller counter and there by determine its plateau, operating voltage and slope of plateau.**

2. **Verify the inverse square law for γ-ray using Geiger-Müller counter.**

3. **To estimate the efficiency of GM detector for beta and gamma source.**

4. **To perform energy calibration of NaI detector and determine the energy resolution of known decay transition.**

5. **To perform spectrum analysis of ^{60}Co and ^{137}Cs with NaI detector using single channel analyzer.**

6. **To determining the efficiency of a given unknown alpha emitting radio isotope.**

- **Objective:** - To study the variation of count rate with applied voltage of Geiger-Müller (GM) counter and there by determine its plateau, operating voltage and slope of plateau.

- **Apparatus required:** - Radioactive source, GM Counter, GM Tube, Display panel, Power supply etc.

- **Theory and Formula used:** - GM counters were invented by H. Geiger and E.W. Müller in 1928, and are used to detect radioactive particles like Alpha, Gamma and Beta radiations.GM counter consists of a metallic chamber with a thin central tungsten wire insulated from the outer chamber. The central wire is at positive with respect to the outer chamber and hence the central wire acts as anode while the outer serves as cathode. If the outer chamber is made out of glass, then its inner surface is wanted with some conducting material to serve as cathode. Geiger-Muller Counter is usually filled with noble gases such as argon, neon etc. When ionizing radiation such as an alpha, beta or gamma particle enters the tube, it can ionize some of the gas molecules in the tube. From these ionized atoms, an electron is knocked out of the atom, and the remaining atom is positively charged. The high voltage in the tube produces an electric field inside the tube. The electrons that were knocked out of the atom are attracted to the positive electrode, and the positively charged ions are attracted to the negative electrode. This produces a pulse of current in the wires connecting the electrodes, and this pulse is counted. After the pulse is counted, the charged ions become neutralized, and the Geiger counter is ready to record another pulse. In order for the Geiger counter tube to restore itself quickly to its original state after

radiation has entered, a gas is added to the tube. For proper use of the Geiger counter, one must have the appropriate voltage across the electrodes.

Plateau length and slope: In order to decide the operating voltage of the GM tube, a graph between anode voltage (X axis) and count rate (Y axis) is plotted. After applying minimum voltage to initiate Geiger discharge, the no. of pulses shall remain same in fixed radiation field exposure. But due to formation of short pulses during recovery time there is variation in count rate. Thus, one of the quality parameters deciding the operation of GM tube is that plateau slope shall be less. Usually 2-3% plateau slope is a good choice. As we go on applying voltage to the anode, the tube starts entering continuous discharge region. Thus, the slope gets worsened. The region or length of voltage region during which the plateau slope remains in desired value is called as plateau length and usually the operating voltage is chosen at the midpoint of plateau length.

Fig.1 Block Diagram of GM Counter

The Geiger Plateau Curve

Showing the characteristic curve of a GM tube with a constant radiation source with change in tube voltage

Starting voltage - where the most energetic pulses exceed the threshold set in the processing electronics

Geiger plateau practical working limits

Plateau slope Change of count rate with increase in voltage

"Knee"

Pulse rate rapidly rising due to increasing efficiency of detection

Onset of continuous discharge

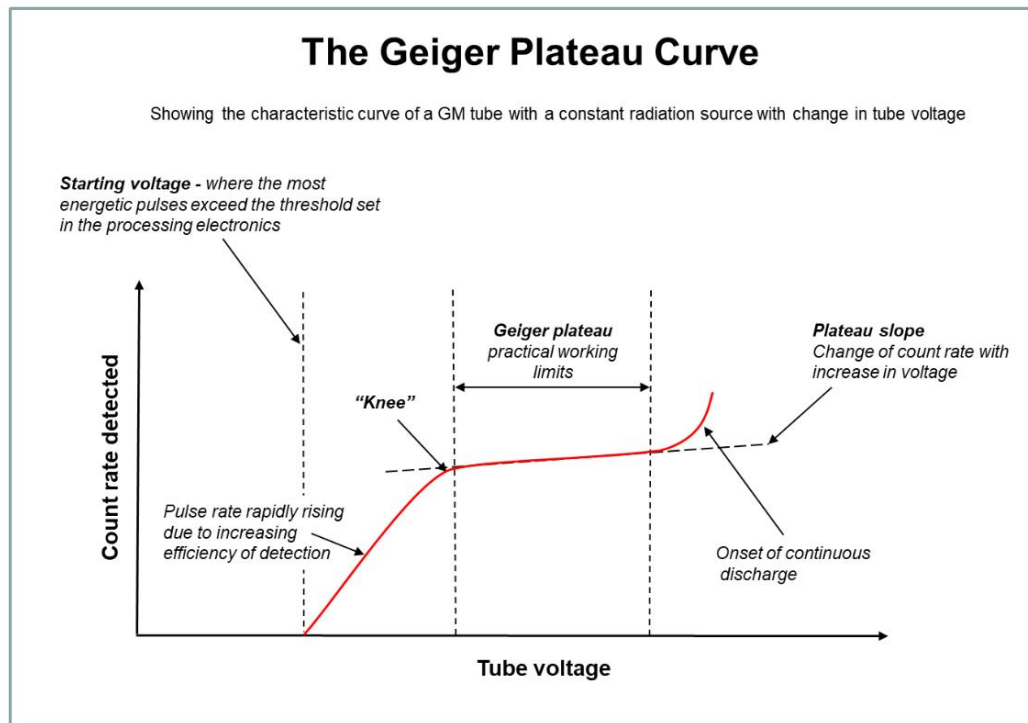Count rate detected

Tube voltage

Fig. 2 Plateau Charecteristic of GM Counter

- **Procedure:-**
1. GM Tube is connected to the radiation counter to detect incident radiations.
2. Voltage range is set from 700-1000on display panel, and the interval to 10s.
3. Firstly, the background radiations are detected and measured by STX without placing any radiation source in GM tube.
4. Note the reading of counts for different value of voltages.
5. Now a gamma source is placed within the Geiger Muller tube.
6. Radiation produced by the source are detected by the tube and measured by the computer as X as illustrated by X in column in the observation table.
7. Difference between the counts for without and with source is calculated as Real Counts Y as illustrated by Y in column in the observation table.
8. Finally, a graph is plotted between voltage on x-axis and real counts on y-axis, known as plateau curve.

- **OBSERVATION TABLE:**

S. No.	Voltage	Count without sample (X)	Count with sample (Y)	Real count (Y-X)

- **Calculation:**

- **Results:**

Voltage is slowly varied and counting rate is measured. Counting rate against the increasing operating voltage give optimized operating voltage. For low voltages, no counts are recorded. This is because the electric field is too weak for even one pulse to be recorded. As the voltage is increased, eventually one obtains a counting rate. The voltage at which the GM tube just begins to count is called the starting potential. The counting rate quickly rises as the voltage is increased. The Plateau curve obtained has one extra region except the saturation, operating and breakdown region showing the steady flow of electrons in GM Tube.

- **Precautions:**

1. Do not let anything touch the window. It is very fragile.

2. Do not ever apply a high voltage beyond the plateau region, as the tube will be damaged.

3. Count rates of more than 100000/min will likely be subject to some coincidence error.

- **Objective:** - Verify the inverse square law for γ-ray using Geiger-Müller (GM) counter.

- **Apparatus required:** - Radioactive source, GM Counter, GM Tube, Computer with STX software, Power supply etc.

- **Theory and Formula used:** - GM counters were invented by H. Geiger and E.W. Müller in 1928, and are used to detect radioactive particles like Alpha, Gamma and Beta radiations.GM counter consists of a metallic chamber with a thin central tungsten wire insulated from the outer chamber. The central wire is at positive with respect to the outer chamber and hence the central wire acts as anode while the outer serves as cathode. If the outer chamber is made out of glass, then its inner surface is wanted with some conducting material to serve as cathode. Geiger-Muller Counter is usually filled with noble gases such as argon, neon etc. When ionizing radiation such as an alpha, beta or gamma particle enters the tube, it can ionize some of the gas molecules in the tube. From these ionized atoms, an electron is knocked out of the atom, and the remaining atom is positively charged. The high voltage in the tube produces an electric field inside the tube. The electrons that were knocked out of the atom are attracted to the positive electrode, and the positively charged ions are attracted to the negative electrode. This produces a pulse of current in the wires connecting the electrodes, and this pulse is counted. After the pulse is counted, the charged ions become neutralized, and the Geiger counter is ready to record another pulse. In order for the Geiger counter tube to restore itself quickly to its original state after

radiation has entered, a gas is added to the tube. For proper use of the Geiger counter, one must have the appropriate voltage across the electrodes.

Inverse square law: When the radioactive source is confined so that it acts as a point source, the diminution in the number of photons incident on a given area is such that the intensity is inversely proportional to the square of its distance from the source.
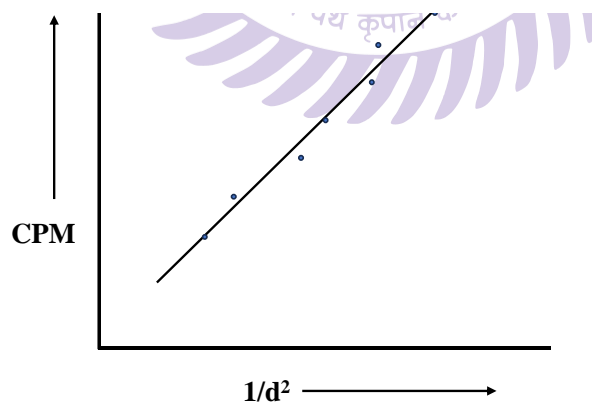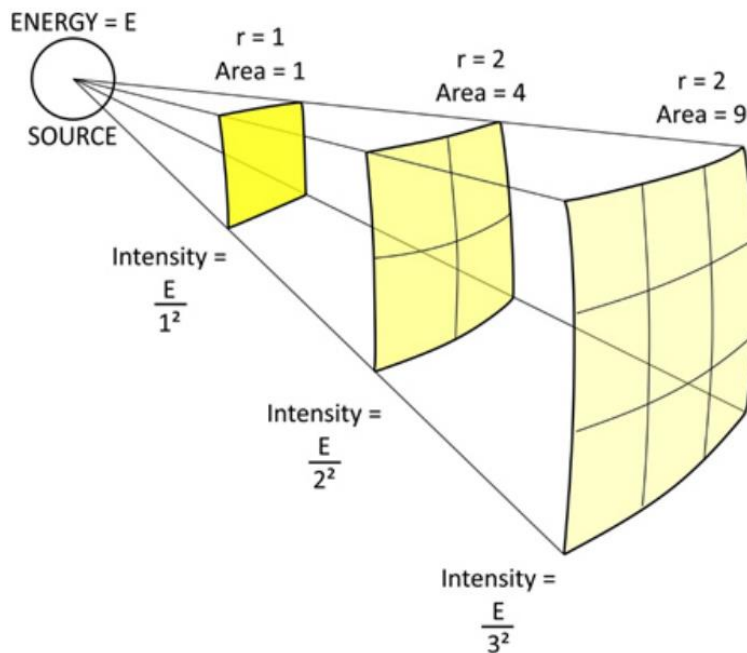
- **Procedure: -**

  Mark the distances away from the side of the Geiger counter wand. Place the gamma ray source at each distance mark and take five CPM readings.

Average the results and fill in the table below. Once the table is filled, perform the calculations; d^2, $1/d^2$. Use this information to graph your results.

- **OBSERVATION TABLE:**

S. No.	Distance (d)	d^2	$1/d^2$	CPM

- **Calculation:**

- **Results:**

- **Precautions:**

1. Do not let anything touch the window. It is very fragile.

2. Do not ever apply a high voltage beyond the plateau region, as the tube will be damaged.

3. Count rates of more than 100000/min will likely be subject to some coincidence error.

- **Objective:** - To estimate the efficiency of GM detector for beta and gamma source.

- **Apparatus required:** - Radioactive source, Geiger-Muller Counting system, GM detector/source holder stand, Computer with STX software, Power supply and necessary connection cable etc.

- **Theory and Formula used:** - Geiger-Muller (GM) counters were invented by H. Geiger and E.W. Müller in 1928, and are used to detect radioactive particles like Alpha, Gamma and Beta radiations.GM counter consists of a metallic chamber with a thin central tungsten wire insulated from the outer chamber. The central wire is at positive with respect to the outer chamber and hence the central wire acts as anode while the outer serves as cathode. If the outer chamber is made out of glass, then its inner surface is wanted with some conducting material to serve as cathode. Geiger-Muller Counter is usually filled with noble gases such as argon, neon etc. When ionizing radiation such as an alpha, beta or gamma particle enters the tube, it can ionize some of the gas molecules in the tube. From these ionized atoms, an electron is knocked out of the atom, and the remaining atom is positively charged. The high voltage in the tube produces an electric field inside the tube. The electrons that were knocked out of the atom are attracted to the positive electrode, and the positively charged ions are attracted to the negative electrode. This produces a pulse of current in the wires connecting the electrodes, and this pulse is counted. After the pulse is counted, the charged ions become neutralized, and the Geiger counter is ready to record another pulse. In order for the Geiger counter tube to restore itself quickly to its original state after radiation has entered, a gas is added to the tube. For

proper use of the Geiger counter, one must have the appropriate voltage across the electrodes.
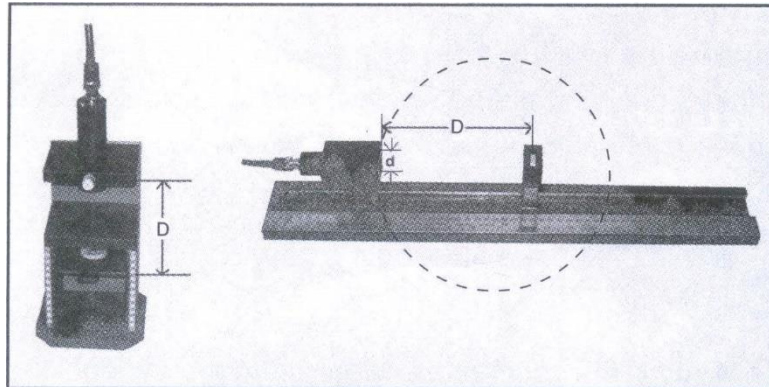

Figure: Detector source arrangement for efficiency calculation for a gamma source

Let D be the distance from source to the end window.
Let d is the diameter of the end window
Let N_S = Counts recorded with source
N_b= Counts recorded due to background
Now make the following measurements
Background counts in 100 sec N_b =……
Distance from source holder to end window   D =…….. cm
Diameter of end window   d = ……cm
No. of counts recorded in 100 sec with the source   NS = ……
From the above data, the net count rate recorded $N = (N_S - N_b/100)$ = cps
This gamma source is radiating isotopically in all directions. A fraction of this only is entering the G.M. Tube, which is given by,

$$R = (A \times d^2)/16D^2$$

This is the fractional radiation entering the detector.
Where A is present activity of the gamma source/ beta source
Hence efficiency of the detector for the gamma source at a distance D
Efficiency (E) = CPS/ DPS = N/R
CPS = Counts per Second
DPS= Disintegrations per Second falling on the window of the detector.

- **Procedure: -**

1 Make interconnection such as mains power cord to G.M. counting system and connection between G.M. detector holder mount to rear panel of GM counting system through HV cable.

2 Place a gamma source in the source holder facing the end window detector. Typically, the distance between the source to end window of GM tube can be 10 cm for gamma source and 2 cm for beta source.

3 Now record counts for about 100 sec both the background and count with the source and make the following calculation and analysis.

- **OBSERVATION TABLE:**

S. No.	Voltage	Count due to background (N_b)	Count with source (N_s)	$N = N_s - N_b$

- **Calculation:**

- **Results:**

- **Precautions:**

1. Do not let anything touch the window. It is very fragile.

2. Do not ever apply a high voltage beyond the plateau region, as the tube will be damaged.

3. Count rates of more than 100000/min will likely be subject to some coincidence error.

EXPERIMENT NO. – 04

- **AIM: -** To perform energy calibration of NAI detector and determine the energy resolution of known decay transition.

- **APPARATUS REQUIRED: -** NaI based gamma ray spectrometer, Radioactive Source (e.g., Cs-137, Co-60)

- **THEORY: -** NaI detector consists of a single crystal of thallium activated sodium iodide optically coupled to the photocathode of a photomultiplier tube. When a gamma ray enters the detector, it interacts by causing ionization of the sodium iodide. This creates excited states in the crystal that decay by emitting visible light photons. This emission is called a scintillation, which is why this type of sensor is known as a scintillation detector. The thallium doping of the crystal is critical for shifting the wavelength of the light photons into the sensitive range of the photocathode. Fortunately, the number of visible-light photons is proportional to the energy deposited in the crystal by the gamma ray. After the onset of the flash of light, the intensity of the scintillation decays approximately exponentially in time, with a decay time constant of 250 ns. Surrounding the scintillation crystal is a thin aluminum enclosure, with a glass window at the interface with the photocathode, to provide a hermetic seal that protects the hygroscopic NaI against moisture absorption. The inside of the aluminum is lined with a coating that reflects light to improve the fraction of the light that reaches the photocathode. At the photocathode, the scintillation photons release electrons via the photoelectric effect. The number of photoelectrons produced is proportional to the number of scintillation photons, which, in turn, is proportional to the energy deposited in the crystal by the gamma ray. The remainder of the photomultiplier tube consists of a series of dynodes enclosed in the evacuated glass tube. Each dynode is biased to a higher voltage than the preceding dynode by a high voltage supply and resistive biasing ladder in the photomultiplier tube base. Because the first dynode is biased at a considerably more positive voltage than the photocathode, the photoelectrons are accelerated to the first dynode. As each electron strikes the first dynode the electron has acquired sufficient kinetic energy to knock

out 2 to 5 secondary electrons. Thus, the dynode multiplies the number of electrons in the pulse of charge. The secondary electrons from each dynode are attracted to the next dynode by the more positive voltage on the next dynode. This multiplication process is repeated at each dynode, until the output of the last dynode is collected at the anode. By the time the avalanche of charge arrives at the anode, the number of electrons has been multiplied by a factor ranging from 104 to 106, with higher applied voltages yielding larger multiplication factors. For the selected bias voltage, the charge arriving at the anode is proportional to the energy deposited by the gamma ray in the scintillator. The preamplifier collects the charge from the anode on a capacitor, turning the charge into a voltage pulse. Subsequently, it transmits the voltage pulse over the long distance to the supporting amplifier. At the output of the preamplifier and at the output of the linear amplifier, the pulse height is proportional to the energy deposited in the scintillator by the detected gamma ray. The Multichannel Analyzer (MCA) measures the pulse heights delivered by the amplifier, and sorts them into a histogram to record the energy spectrum produced by the NaI(Tl) detector. See Figure 1 for the modular electronics used with the NaI(Tl) detector. For an ideal detector and supporting pulse processing electronics, the spectrum of 662-keV gamma rays from a 137Cs radioactive source would exhibit a peak in the spectrum whose width is determined only by the natural variation in the gamma-ray energy. The NaI(Tl) detector is far from ideal, and the width of the peak it generates is typically 7% to 10% of the 662-keV gammaray energy. The major source of this peak broadening is the number of photoelectrons emitted from the photocathode for a 662-keV gamma-ray. For a high-quality detector this is on the order of 1,000 photoelectrons. Applying Poisson statistics 1,000 photoelectrons limit the full width of the peak at half its maximum height (FWHM) to no less than 7.4%. Statistical fluctuations in the secondary electron yield at the first dynode and fluctuations in the light collected from the scintillator also make a small contribution to broadening the width of the peak in the energy spectrum. Because the broadening is dominated by the number of photoelectrons, and that number is proportional to the gamma-ray energy, the FWHM of a peak at energy E is approximately described by

$$\text{\% Resolution (FWHM)} = \frac{\delta E}{E} \times 100\% \approx \frac{k \times 100\%}{\sqrt{E}}$$

Where E is the energy of the peak, δE is the FWHM of the peak in energy units, and k is a proportionality constant characteristic of the particular detector.

- **PROCEDURE: -** Return the 137Cs source to the counting position, and implement an acquisition for a time period long enough to form a well-defined spectrum with minimal random scatter in the vertical direction. The amount of scatter is controlled by counting statistics. If the ith channel contains Ni counts, the standard deviation in those counts is expected to be And the percent standard deviation in the Ni counts is Note that 100 counts in a channel corresponds to a 10% standard deviation, 10,000 c ounts yield a 1% standard deviation, and 1 million counts are needed to achieve a 0.1% standard deviation. Consequently, the vertical scatter in the spectrum will begin to appear acceptable when the rather flat continuum at energies below the Compton edge has more than a few hundred counts per channel. 2. Plot the spectrum accumulated in step 1 with a linear vertical scale. Mark the photopeak, the Compton edge and the backscatter peak (if discernable) on the spectrum as indicated in Figure 3. Determine the channel number for the 662-keV peak position. 4. After the 137Cs spectrum has been read from the MCA, save it in a file that you designate for possible later recall. Erase the spectrum, and replace the 137Cs source with a 60Co source from the gamma source kit. 5. Accumulate the 60Co spectrum for a period of time long enough for the spectrum 6. Save the 60Co spectrum for possible later recall and plot the spectrum.

- **OBSERVATIONS: -**

Table:

SOURCE	ITEM	ENERGY (MeV)	CHANNEL NO
137Cs	Photo Peak	0.662	
	Compton Edge		
	Back Scatterd Peak		
	Area under the Photo Peak		
60Co	Photo Peak	1.33	
	Compton Edge		
	Back Scatterd Peak		
	Area under the Photo Peak		

- **RESULT: -** The Calibration graph has been drawn.

Calibration Graph:
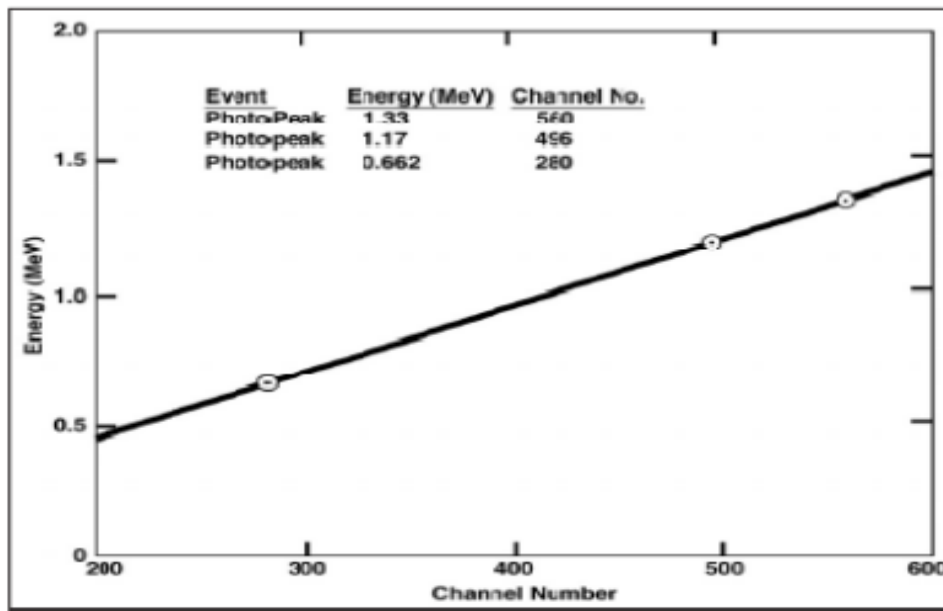
Event	Energy (MeV)	Channel No.
PhotoPeak	1.33	560
Photopeak	1.17	496
Photopeak	0.662	280

- **Precautions: -**

1. While performing an experiment with one radioactive source other sources should not be present nearby. They should be put behind the lead shield.

2. Handle the radioactive sources with care. Don't touch in bare hand to the center of samples.

3. While handling the liquid radioactive samples please use hand gloves.

4. Don't put your mobile near to the detector. It may add some counts to the signal.
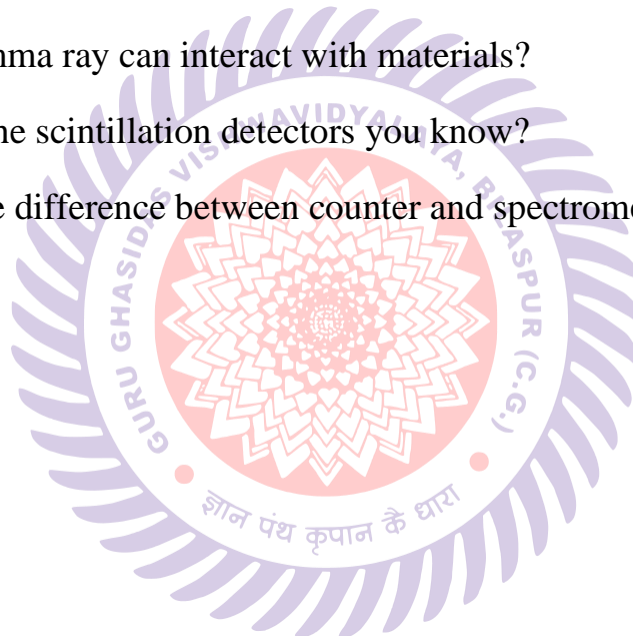
5. Amplifier and detector are always running at high voltage. So please don't switches off any part during the data acquisition, it may damage the amplifier and detector.

- **VIVA-VOCE QUESTIONS: -**

  1. How a gamma ray can interact with materials?

  2. What are the scintillation detectors you know?

  3. What is the difference between counter and spectrometer?

- **AIM: -** To perform spectrum analysis of ^{60}Co and ^{137}Cs with NaI detector using single channel analyzer

- **APPARATUS REQUIRED: -** NaI based gamma ray spectrometer, Radioactive Source (e.g., Cs-137, Co-60)

- **THEORY: -**

Gamma ray spectroscopy is one of the most developed and important techniques used in experimental nuclear physics because gamma ray detection and its energy measurement form an essential part of experimental nuclear physics research. The purpose of this experiment is to acquaint one with this field using a gamma ray spectrometer comprising of thallium activated sodium iodide (NaI(Tl)) scintillator, photo multiplier tube, associated electronics and multi channel analyzer. The scintillation spectrometers with their high detection efficiency and moderately good energy resolution have made tremendous contribution to our present knowledge of nuclear properties. The detection of gamma rays occurs through its interaction with the detecting medium, (NaI (Tl) in the present case). There are three important processes by which gamma ray photons interact with matter enabling us to detect them and measure their energies. These processes are the following.

(i) Photoelectric Absorption

Photoelectric absorption is an interaction in which the incident gamma ray photon disappears. In its place, a photoelectron is released from one of the electron shells of the absorber atom with a kinetic energy given by the incident photon energy h minus the binding energy of the electron in its original shell (EB). The interaction is with the atom as a whole and cannot take place with free electrons. For typical gamma ray energies, the photoelectron is most likely to emerge from the K shell of the atoms for

which typical binding energies range from a few keV for low-Z materials to tens of keV for materials with higher atomic number. After the ejection of an electron by this process, the vacancy in that shell of the atom is filled up by another electron from outer shells. This is followed by emission of X-rays or Auger electrons consuming the binding energy EB. The configuration of the atomic shells recovers within a very short time after the photoelectric emission. The atomic X-rays produced as a follow-up of the photoelectric effect are almost completely absorbed by the matter surrounding the point of emission, giving rise to further photo-electrons. Thus the total energy of the incident gamma ray is completely converted into the kinetic energy of the electrons and thus one gets an output which is proportional to the energy of ejected electrons. (Here the energy of the ejected electrons (E-28) KeV, E = hυ is the energy of the incident gamma ray and 28 KeV is the binding energy of K shell of an electron in the iodine atom). Therefore in general, one expects two peaks in photoelectric absorption corresponding to E and (E-28) KeV but they are not often resolved due to limit on resolution. (ii) Compton Effect.

a). Compton Scattering: -

In this process an incident photon interacts with a free electron, gets scattered and leaves the detector. Compton scattering also includes scattering of the photon by electrons bound to an atom because in comparison to the energy of the photon, the electron binding energy is quite small. Thus an incident photon of energy h can be considered to collide with a free electron of rest mass m0. The photon is scattered through an angle with an energy h/(<h) while the electron recoils with a kinetic energy K eV at an angle .

b. Back Scattering: -

Back scattering peak derives its origin from the detection of gamma rays scattered by the material of which the source is made. These gamma rays are scattered at 180° , then enter the crystal and absorbed by photoelectron emission and thus have energy, E/(1+2) as explained before. In this particular detector E=0.5 MeV and 2 MeV and we expect back scattering peaks at 0.17 and 0.22 MeV, respectively. (iii) Pair Production When a

photon having energy greater than 1.02 MeV strikes a material of high atomic number, it is found that it is completely absorbed and a pair of electron and positron is produced. This process is known as pair production and the cutoff energy of the photon is 1.02 MeV. The conservation of energy yields $h\upsilon = 2m_0c^2 + E^+ + E^- + E_{nuclear}$, where $2m_0c^2$ is the rest mass energy of the pair while E+, E- and E(nuclear) are the kinetic energies of the positron, electron and nucleus, respectively. The presence of the nucleus is essential for the conservation of linear momentum. The kinetic energy of the pair is then (E-1.02) MeV (where E=hυ) which is shared equally between the electron and the positron which are stopped in the crystal. The positron annihilates with the nearest electron available and produces two oppositely directed gamma rays of total energy 1.02 MeV. Both or one of these annihilation gamma rays (each having energy of $m_0c^2 = 511$ KeV) can either be stopped in the crystal through processes photoelectric absorption and Compton or they can escape from the crystal. In case both the photons are completely stopped in the crystal one will get a full energy peak at E, as in the case of photoelectric absorption. If one or both gamma rays escape we get a corresponding peak at energies $E - m_0c^2$ or $E - 2m_0c^2$. As an example of one extreme in gamma ray detector behavior, we first examine the expected response of detectors whose size is small compared with the mean free path of the secondary gamma radiations produced in interactions of the original gamma rays. These secondary radiations are Compton scattered gammas, together with annihilation photons formed at the end of the tracks of positrons created in pair productions. Because the mean free path of the secondary gamma rays is typically of the order of several centimeters, the condition of "smallness" is met if the detector dimensions do not exceed a
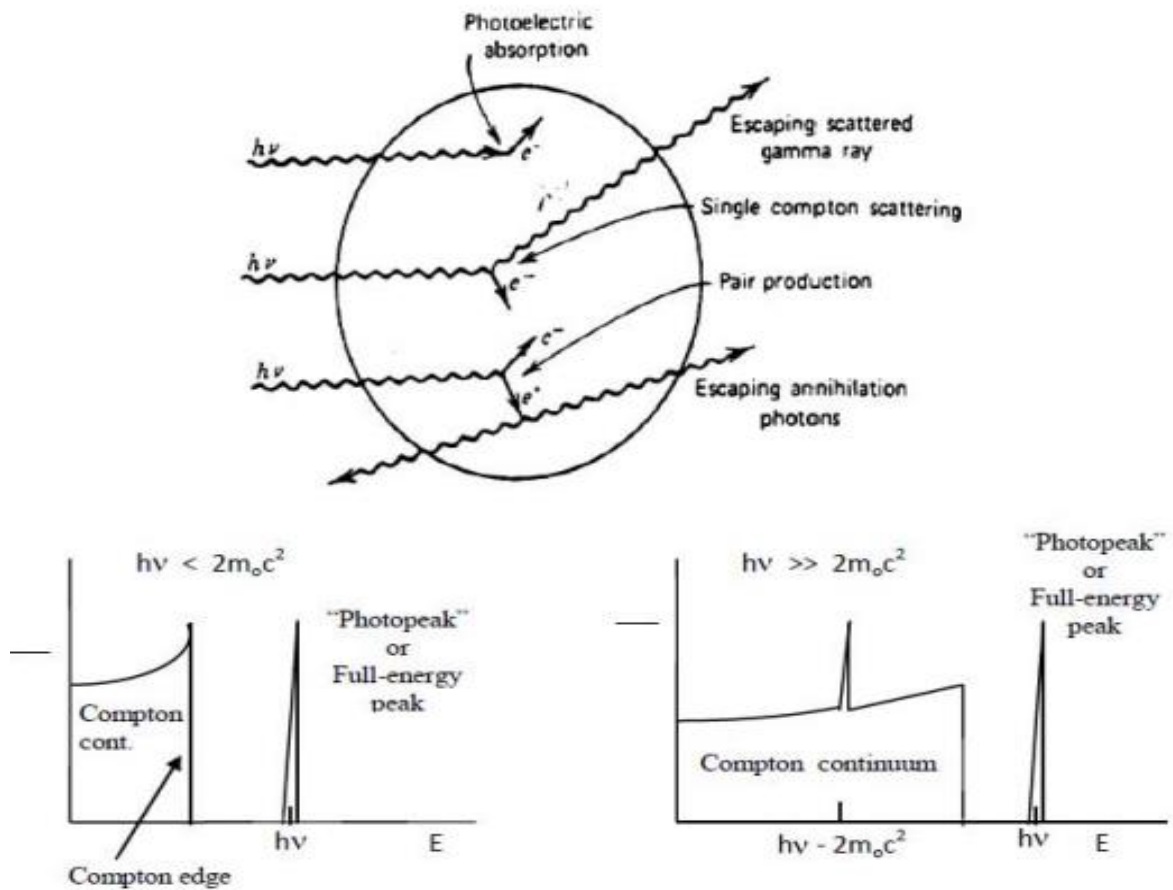
centimeter or two. At the same time, we assume that all charged particle energies (photoelectron, Compton electron, and positron) are completely absorbed within the detector volume. The predicted electron energy deposition spectra under these conditions are illustrated in Fig.1. If the incident gamma ray energy is below the value at which pair production is possible, the spectrum results only from the combined effect of Compton scattering and photoelectric absorption. The continuum of energies corresponding to Compton scattered electrons is called the Compton continuum, whereas the narrow peak corresponding to photoelectrons is designated as photopeak. For a small detector only single interactions take place, and the ratio of the area under the photopeak to the area under the Compton continuum is the same as the ratio of the photoelectric cross section to the Compton cross section in the detector material.

If the incident gamma ray energy is sufficiently high (several MeV), the results of pair production are also evident in the electron energy spectrum. For a small detector, only the electron and positron kinetic energies are deposited, and the annihilation radiation escapes. The net effect is to add a double escape peak to the spectrum located at an energy $2m_0c^2$ (~1.02 meV) below the photopeak. The term double refers to the fact that the annihilation photons escapes.

- **PROCEDURE:-**

1. Collect a spectrum of a ^{137}Cs source. Place the source about 5 cm above the opening of the detector, to make sure that the count rate is not too high. Note the distance between the source and the detector. Measure for 5 minutes and make a sketch of the spectrum. Store the spectrum. Note that a spectrum from a source with only one gamma-ray energy consists of a peak (the photo peak or the full-energy peak) and a distribution on the low-energy side (to the left) of the photo peak. If there are several photo peaks in a spectrum, the studied radiation must contain several different energies.

2. The low-energy distribution to the left of the photo peak originates from gamma quanta, which have collided with electrons in the detector crystal or in the lead shielding. The collision takes place in such a way that only part of the original energy of the gamma quantum is absorbed in the detector. This kind of collision is called Compton scattering and the low-energy distribution is the so-called Compton distribution. The Compton distribution always forms a background to the left of the photo peak with which it is associated.

3. Note that there is always a discriminator setting, which rejects the most low-energetic gamma quanta and the electronic noise. The discriminator setting can be adjusted with the knob on the amplifier box, but should not be changed during a measurement.

4. Note in your sketch of the ^{137}Cs spectrum where the photo peak, discriminator level and Compton distribution are situated.

5. Record a spectrum of KCl or of the mineral salt. The mineral salt contains KCl, and thus 40K, which is a naturally occurring radioactive isotope.

Measure for 15 minutes and then make a sketch of the spectrum. Compare with the background spectrum. Save the spectrum.

6. Record a background spectrum, i.e. collect a spectrum without a source. The measuring time is 20 minutes. Don't forget to remove all sources close to the detector. Save the background spectrum. Compare with the 40K spectrum in b.

- **OBSERVATIONS: -**

Table: For a 137Cs spectrum

ITEM	ENERGY (MeV)	CHANNEL NO
Photo Peak	0.662	
Compton Edge	1.17	
Back Scatterd Peak	1.33	
Area under the Photo Peak		

Example Spectrum: -
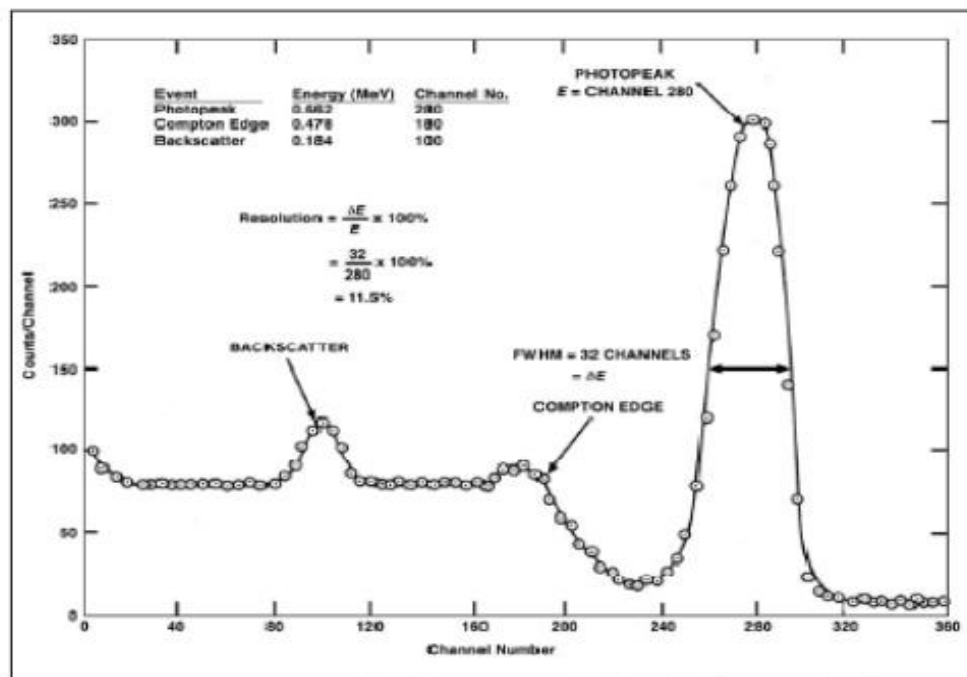
- **RESULT: -**

The Photo Peak for the ^{137}Cs is found in the Energy = ------ (MeV)

- **PRECAUTIONS: -**

1. While performing an experiment with one radioactive source other sources should not be present nearby. They should be put behind the lead shield.

2. Handle the radioactive sources with care. Don't touch in bare hand to the center of samples.

3. While handling the liquid radioactive samples please use hand gloves.

4. Don't put your mobile near to the detector. It may add some counts to the signal.

5. Amplifier and detector are always running at high voltage. So please don't switch off any part during the data acquisition, it may damage the amplifier and detector.

- **VIVA-VOCE QUESTIONS: -**

1. How a gamma ray can interact with materials?

2. What are the scintillation detectors you know?

3. What is the difference between counter and spectrometer?

EXPERIMENT NO. – 06

- **AIM: -** To determining the efficiency of a given unknown alpha emitting radio isotope

- **APPARATUS REQUIRED: -** alpha counter, Radioactive Source (e.g., Am-241)

- **THEORY: -**

Alpha detector (PNC-Alpha) is a micro controller-based scintillation detector uses ZnS (Ag) Scintillator as it is detector, which is protected by a MYLAR sheet. A scintillation detector or scintillation counter is obtained when a Scintillator is coupled to an electronic light sensor such as a photomultiplier tube (PMT) or a photodiode. PMTs absorb the light emitted by the scintillator and reemit it in the form of electrons via the photoelectric effect. The subsequent multiplication of those electrons (sometimes called photo-electrons) results in an electrical pulse which can then be analyzed and yield meaningful information about the particle that originally struck the scintillator.

There are two principal types of scintillating crystals, broadly described as organic and inorganic. In either type, the details of the physical processes by which particle kinetic energy eventually appears as light are fairly complex. No attempt will be made to discuss this matter here, but a fairly comprehensive treatment is given in Ref. 2. The commonest type of inorganic crystal is sodium iodide with thallium ions as activator. This has the advantage of high density, so that energetic particles can be brought to rest in a fairly small crystal. The major disadvantage is that NaI is very hygroscopic, so that the crystals must be carefully mounted in sealed housings. After passage of a particle, the light output from the crystal decays with a time constant of about 2.5 $10-7$ s. This is a rather long time as rates of atomic processes go, and sodium iodide, along with most inorganic crystals, is regarded as a "slow" scintillator. Incidentally, the screens of cathode ray tubes and T.V. picture tubes employ inorganic scintillators which convert the kinetic energy of 15 keV electrons to visible light.

- **Crystals:-**

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Organic crystals used at one time were mainly of the condensed benzene ring structure such as anthracene, stilbene or phenanthrene.

- **Photomultipliers (PMT):-**

These devices utilize the two phenomena of photoelectric effect and secondary electron emission. Actual examples of tubes are available in the laboratory. The whole structure is contained in an evacuated glass envelope. Light from the scintillator produces photoelectrons at the photocathode, and these electrons are then accelerated through a potential difference of a few hundred volts and directed against the first dynode. This is a metal electrode with a special surface which emits several low energy electrons (on the average) when struck by an electron or ion of a few hundred electron volts energy. The mean number of secondary electrons per primary electron is known as the secondary emission ratio. In the multiplier structure these secondary electrons are again accelerated and directed against another dynode where the secondary emission process is repeated for each electron coming from the first dynode. If the secondary emission ratio is α and the tube contains n stages of multiplication, then each photoelectron will

produce α^n electrons at the output of the multipliers. Thus, α^n is the gain of the photomultiplier.

Multipliers are commonly built with ten stages ($n = 10$), though fourteen stage tubes are not unusual. The secondary ratio depends on the accelerating voltage per stage, with values in the range of 3 to 5 for usual voltages. Thus the total gain can be quite high ($3^{10} \approx 10^5$). Because of the dependence of on accelerating voltage, the gain is a very sensitive function of total voltage applied to the multiplier, and carefully regulated power supplies must be used. The electrons from the output of the photomultiplier charge a capacitor, and the resulting voltage pulse can be observed on an oscilloscope, or amplified and used to drive a single- or multi-channel analyzer.

To find the disintegration rate, change from microCuries (μCi) to disintegrations per minute (dpm). The disintegrations per minute unit is equivalent to the counts per minute from the ERS, because each disintegration represents a particle emitted.

The conversion factor is:

1 Ci $= 2.22$ x 10^{12} dpm or 1μCi $= 2.22$ x 10^{6} dpm …………….. (1)

Multiply this by the activity of the source and you have the expected counts per minute of the source. We will use this procedure to find the efficiency of the ESM, by using a fairly simple formula. You want to find the percent of the counts you observe versus the counts you expect, so you can express this as

% Efficiency $= r (100)/CK$ ……………(2)

In this formula, r is the measured activity in cpm, C is the expected activity of the source in μCi, and K is the conversion factor.

- **PROCEDURE: -**

1. Make connections to Radiation Counting System with alpha probe.

2. Power up the Radiation Counting System unit & increase the HV to Alpha probe to operating voltage.

3. For a known preset time (say)100 seconds take background (BG) counts.

4. Now place standard Alpha source of known DPS & count for same time.

5. By subtracting the BG obtain net counts (CPM).

6. Take ratio of CPM Vs DPM to obtain efficiency of the probe.

- **OBSERVATIONS: -**

- **FORMULAE / CALCULATIONS: -**

Table

Run Duration = -----Seconds   Background counts:

SOURCE	COUNTS	CORRECTION IN COUNTS	EXPECTED COUNTS	EFFICIENCY

- **Results: -**   The Efficiency of an alpha counter is = ------ (%)

- **Precautions: -** Warning! Dangerous voltages can exist at the GM and SCINT connectors. Ensure that the high voltage is set to zero or that the instrument is OFF before connecting or disconnecting a detector.

- **Viva-Voce Questions: -**

1. What is the principle of a Scintillation detector?

2. Define Luminescence

3. How a Photo Multiplier Tube is working?

- **References: -**

1. R. Eisberg and R. Resnick, Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles (Wiley, New York, 1985), Secs 2-8 and 16-5

2. A. C. Melissinos & J. Napolitano, Experiments in Modern Physics (San Diego, CA: Academic Press, 2003)

3. Handbook of Chemistry and Physics, (CRC Press; available in the lab).

4. Enge, H., "Introduction to Nuclear Physics" (Reading, Mass.: Addison-Wesley, 1966; available in the lab)