DEAD TIME OF GM COUNTER

1 OBJECTIVE

To determine the dead time of a Geiger-Müller counter by the double-source method.

2 REQUIREMENTS

Setup for ST-350 Geiger-Müller counter, GM tube and stand, shelf stand, serial cable and a source holder, two radioactive sources: ^{137}Cs & ^{132}Ba.

3 INTRODUCTION

Energetic nuclear particles (ionizing radiation) passing through the cylinder and entering the GM tube ionize the gas molecules. The freed electrons are attracted toward the wire and the positive ions toward the cylinder. If the voltage between the wire and cylinder is high enough, the accelerated electrons acquire enough energy to ionize other gas molecules on their way to the positive wire. The electrons from the secondary ionizations produce additional ionizations. This process is called **cumulative ionization**.

As a result, an *avalanche* discharge sets in, and a current is produced in the resistor. This reduces the potential difference between wire and cylinder to the point where cumulative ionization does not occur. After the momentary current pulse, which lasts on the order of microseconds, the potential difference between the wire and the cylinder resumes its original value.

A finite time is required for the discharge to be cleared from the tube. During this time, the voltage of the tube is less than that required to detect other radiation that might arrive. This recovery time is referred to as the **dead time** of the tube. If a large amount of radiation arrives at the tube, the counting rate (counts per minute, or cpm) as indicated on the counting equipment will be less than the true value.

Let us define the following variables:

T : The dead time of the detector

t_r : The real time the detector is operating. This is the actual time the detector is on. *(It is our counting time and does not depend on the dead time.)*

t_R : The live time the detector is operating. *(It is the time the detector is able to record count and depends on the dead time.)*

c : Total number of counts that we record.

n : The measured counting rate; $\left[n = \dfrac{c}{t_r}\right]$

N : The true counting rate; $\left[N = \dfrac{c}{t_R}\right]$

Note that

$$\frac{n}{N} = \frac{c/t_r}{c/t_R} = \frac{t_R}{t_r} \tag{1}$$

Since cT is the total time the detector is unable to read counts during the time t_r,

$$t_R = t_r - cT \tag{2}$$

On solving (1) & (2),

$$\begin{aligned} \frac{t_R}{t_r} &= \frac{t_r - cT}{t_r} \\ &= 1 - \left(\frac{c}{t_r}\right) T \\ &= 1 - nT \end{aligned}$$

$$\therefore \frac{t_R}{t_r} = 1 - nT$$

Now, from (1),

$$\frac{t_R}{t_r} = \frac{n}{N}$$

$$\implies \frac{n}{N} = 1 - nT$$

$$\therefore N = \frac{n}{1 - nT} \tag{3}$$

Let
n_1 : measured counting rate with source 1.
n_2 : measured counting rate with source 2.
n_{12} : measured counting rate with both sources 1 & 2.

Then, the true counting rate is given by:

$$N_{12} = N_1 + N_2 \tag{4}$$

Using (3),

$$\frac{n_{12}}{1 - n_{12}T} = \frac{n_1}{1 - n_1 T} + \frac{n_2}{1 - n_2 T}$$

The solutions to these equations is given by:

$$\boxed{T = \frac{n_1 + n_2 - n_{12}}{2n_1 n_2}} \tag{5}$$

The above equation can be used to determine the dead time T of the GM counter.

4 PROCEDURE

1. Set up the GM counter
2. Introduce a γ-source (^{132}Ba) in the double source holder.
3. Record the count rate n_1 by measuring counts in a given time.
4. Fix the second γ-source (^{137}Cs) by the side of the first source.
5. Determine the count rate n_{12}.
6. Now remove the first source and determine the count rate due to the second source alone, n_2.
7. Repeat this sequence of counting and calculate the dead time by the equation (5).

5 OBSERVATIONS

First source			Second source			Both sources		
No. of counts	Time taken (s)	Counting rate (n_1)	No. of counts	Time taken (s)	Counting rate (n_2)	No. of counts	Time taken (s)	Counting rate (n_{12})

Mean n_1 = ____________________

Mean n_2 = ____________________

Mean n_{12} = ____________________

6 CALCULATIONS

$$T = \frac{n_1 + n_2 - n_{12}}{2n_1 n_2} = \underline{\hspace{4cm}}$$

7 RESULT

The dead time of the GM counter by the double source method is determined to be ____________________ms.