# Geiger Counter Dead Time Determination

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**Abstract:**

## I. Introduction

### GM Counter Operation and Dead Time

The GM counter operates when a voltage is applied to the tube and a radioactive source is present, forming a potential difference between the anode and the interior of the casing, establishing an electric field. Then, when a source is present, the radiation from the source enters the tube and ionizes the gas. As a result, a scattered electron and a positively charged gas particle scatter neighboring neutral gas particles, causing more scattering. This is referred to as the Townsend Avalanche. As a result of the presence of an electric field, the positively charged gas particles collect on the inside of the casing and the electrons accumulate at the anode, sending a pulse to the counter as an output.

Other important components of GM counter operation is the voltage range and the dead time. Various radiation detectors have different operating voltage ranges. The GM counter operates best in the Geiger range, shown in Figure 1, when the rate of change of ions collected with respect to change in voltage is low (the plateau region). This is due to the fact that at a given voltage within the plateau region, the number of counts detected will not drastically change, providing consistent outputs[1]. Further, this allows for a complete discharge at the anode. At this voltage, the gas inside the GM tube completely ionizes in the presence of ionizing radiation. At voltages outside of the the optimum range, undesired effects occur; at voltages higher than the plateau region, continuous discharges occur, disallowing for the GM counter to detect radiation, potentially damaging the device.

The dead time of the GM counter is the time during which an output pulse is not detected by the counter; a pulse is not be generated until the ionized gas returns to its neutral state. The importance of knowing the dead time of a GM counter is understanding how this is a limiting factor in the operation of a GM counter. The presence of the dead time suggests that there is uncertainty in the number of counts measured. So, the dead time of the GM counter is a form of systematic error, suggesting that the dead time is independent of the identity of the source. However, the dead time of a GM counter will vary if one source is measured at different heights. Thus, in order to accurately determine the dead time, a source that is being measured should remain at the same distance from the GM tube.

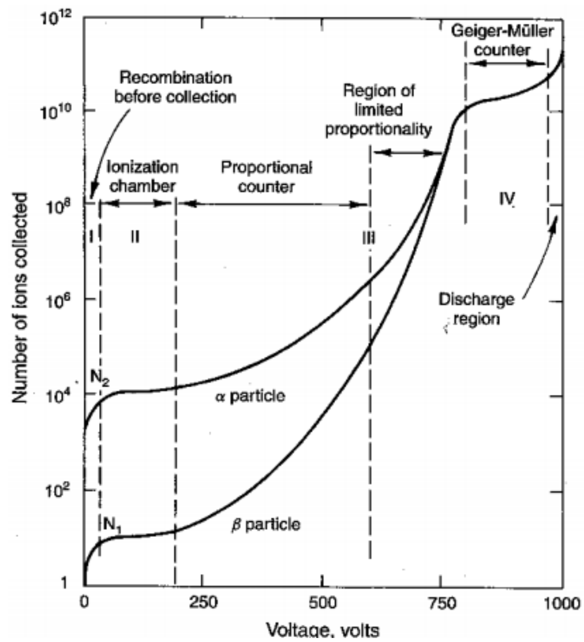


FIG. 1. Various operating ranges for different radiation detectors.

[1] Toloba, Elisa. (2018) *Geiger Counter, Part I.* [Class PDF]. Department of Physics, University of the Pacific. Stockton, CA.

## II. Data Acquisition

### Materials

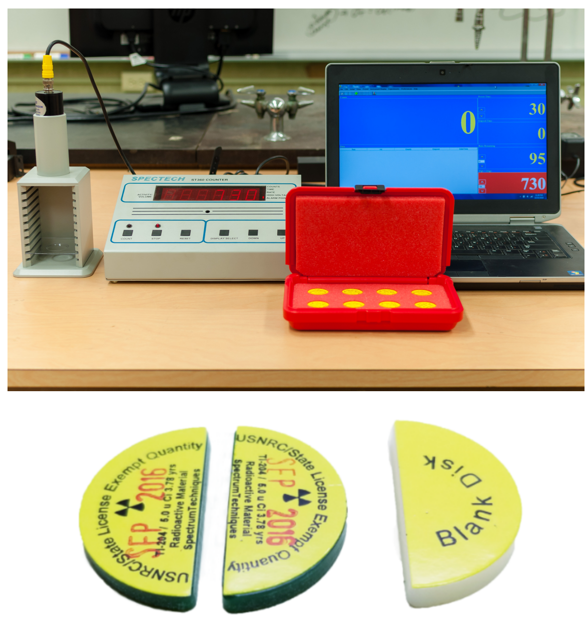


FIG. 2. Image (1): The setup of the apparatus. Image (2): The types of sources used in this experimentation.

The materials used to perform this experimentation, from left to right according to Figure 2, are: the GM 35 Probe, the GMS 35 Stand, the source tray, the BNC cable, the ST360 Counter, the USB connector, the laptop with the appropriate Spectrum Techniques software, and two semi-circle sources with a blank disk.

### Procedure and Methods

To measure the dead time of the GM counter, the number of counts for each semi-circle source, accompanied by the blank disk, was measured in the first slot at the top of the GMS 35 Stand. Then, instead of using the blank disk, both halves were placed together, at the same height, and the number of counts was again measured. This was accomplished at the optimum voltage of the GM counter ($950 \pm 20$ V) for 20 runs at 60 seconds per run. Then, to measure the effect of the height on the dead time of the GM counter, the above procedure was repeated where the number of counts from the sources was measured from the fifth slot from the top.

## III. Analysis

The approximate dead time of the GM counter was calculated using the following equation

$$\tau \approx \frac{R_1 + R_2 - R_{12}}{2R_1R_2}, \tag{1}$$

where $R_1$ and $R_2$ are the counts from each individual source and $R_{12}$ is the number of counts from both sources[2]. Further, to determine the margin of error, $\delta\tau$, equation (1) was used so as to properly account for the uncertainty, i.e.,

$$\delta\tau = \sqrt{\left(\frac{\partial\tau}{\partial R_1}\delta R_1\right)^2 + \left(\frac{\partial\tau}{\partial R_2}\delta R_2\right)^2 + \left(\frac{\partial\tau}{\partial R_{12}}\delta R_{12}\right)^2}, \tag{2}$$

where the arguments inside the square root are the partial derivatives of $\tau$ with respect to each variable, given by

$$\frac{\partial\tau}{\partial R_1} = -\frac{1}{2R_1^2} + \frac{R_{12}}{2R_1^2R_2}$$
$$\frac{\partial\tau}{\partial R_2} = -\frac{1}{2R_2^2} + \frac{R_{12}}{2R_1R_2^2}$$
$$\frac{\partial\tau}{\partial R_2} = -\frac{1}{2R_1R_2},$$

and each partial derivative is multiplied by the uncertainty of the variable of differentiation. The uncertainty in the counts is the square root of the counts.

Because there were 20 runs for each measurement, a vector was made whose components were $R_1$, $R_2$, and $R_{12}$. Then, to obtain the uncertainty in the number of counts for each source, the square root of the vector was taken. Afterwards, the vectors of the number of counts and the uncertainties in the number of counts were taken and substituted into equations (1) and (2) to obtain dead times and their respective uncertainties. Then, plots were made of the dead time versus the trial number, including the arithmetic mean of the dead time and error bars for each dead time calculation, so as to compare the data with the mean, as shown in Figure 3. This process was repeated for the data collected for the sources in slot five, as shown in Figure 4. The dead

[2] See footnote 1.

times obtained for the GM counter with the sources in slots one and 5 were 10 $\pm 4$ $\mu$s and 31 $\pm$ 14 $\mu$s, respectively.

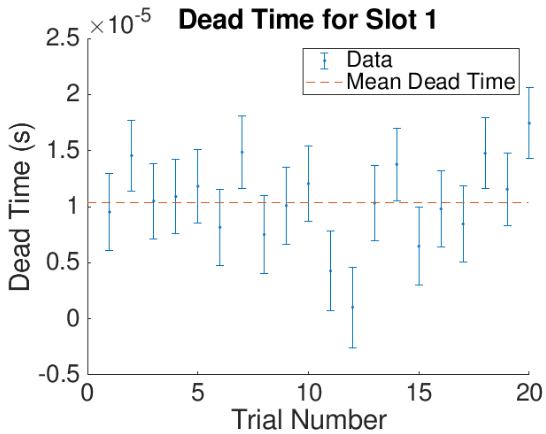


FIG. 3. Dead time for the sources in slot one.

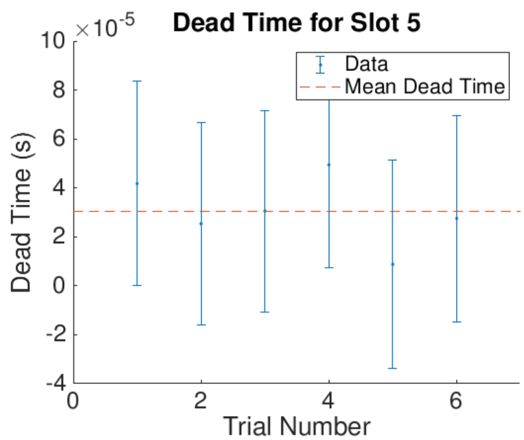


FIG. 4. Dead time data for the sources in slot five.

**Error Analysis**

In this experimentation, the primary sources of uncertainty are the same as those that were present in Lab 2: the potential presence of other radioactive sources, potential background radiation, and the natural uncertainty in the activity of the radioisotopes. These uncertainties directly affect the counts observed. The dead time causes uncertainty when the GM counter is quenched, disallowing the detection of an electric pulse. This is an instrumental limitation, which cannot be minimized. The presence of other radioactive sources and background radiation could influence the number of counts by producing a higher reading of counts than the source emitted. Errors of this nature can be reduced by moving radioactive materials away from the GM counter and by subtracting potential background radiation from the data. Because activities can not be measured precisely, there will always be a natural uncertainty with the activity of a radioisotope, which too cannot be minimized. For the number of counts, the uncertainty is given by the square root of the number of counts.

## IV. Discussion

The graphs obtained in Figures 3 and 4 convey that the dead time calculated for each individual run are consistent with the mean values of the dead time for slots one and five, 10 $\pm 4$ $\mu$s and 31 $\pm$ 14 $\mu$s, respectively. This is a direct result of the mean lying within the error bars of most of the data points from slot one and all of the data points from slot five. It is important to mention that some of the dead times obtained from slot five were discarded. This is primarily due to the fact that negative times for the dead time do not hold physical significance. Further, the short values for the dead times that were obtained suggest that it does not take the ionized gas very long to return to its neutral state, allowing for better estimates of the number of counts read by the GM counter. For slots one and five, the dead times are different. This can be reconciled from the fact that at different heights, the amount of particles emitted from the source would be different due to the inverse square law.

## V. Conclusion

The dead time for the GM counter at slots one and five were determined to be 10 $\pm 4$ $\mu$s and 31 $\pm$ 14 $\mu$s, respectively. The graphs from Figure 3 and Figure 4 suggest that the values obtained for the dead time are consistent. Lastly, the identity of the radioactive source should not affect the dead time that is measured, but at greater distances from the GM counter tube, the dead time will be greater due to the decrease in the particles emitted.

## VI. References


1. Toloba, Elisa. (2018) *Geiger Counter, Part I.* [Class PDF]. Department of Physics, University of the Pacific. Stockton, CA.