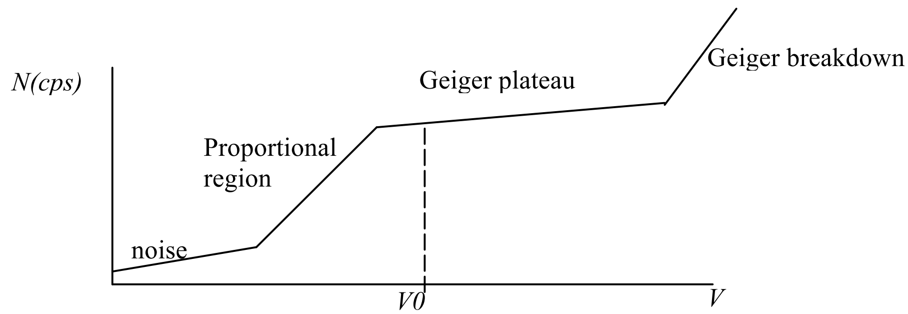
GEIGER LAB - 1

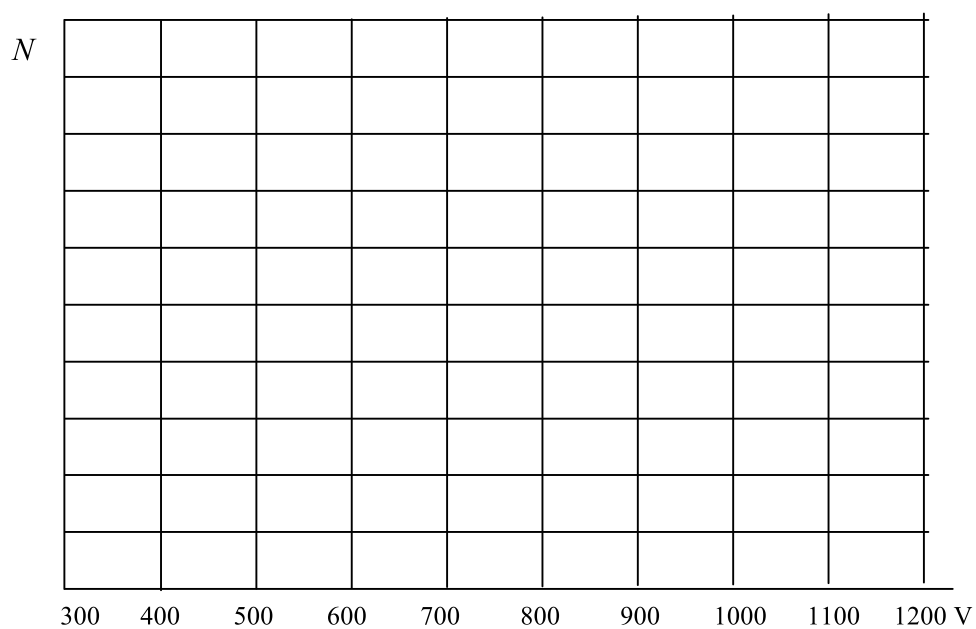
I. Geiger Plateau

A Geiger Muller (GM) tube counts the ionizing radiation entering its chamber. The optimum operating condition is achieved when each particle entering the GM chamber is counted with high efficiency. If the applied voltage *V0* to the tube is too low the tube will operate poorly. We will perform a voltage "plateau" the GM tube to set the voltage operating point.



With a Cs-137 or Th-204 βeta source Record *N* counts for 30s each at voltages 300-1200 V.

V	*N/60s*
300	
350	
400	
450	
500	
550	
600	
650	
700	
750	
800	
850	
900	
950	
1000	
1050	
1100	
1150	
1200	



1) Record the *N vs V* curve in the table and fill in the graph.

2) Record the onset of the Geiger plateau *V1*. ______________

Record the onset of the Geiger breakdown *V2*. ______________

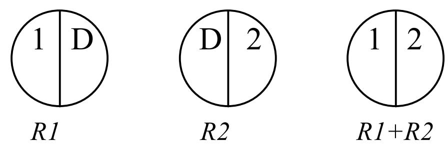
3) Determine the best operating voltage *Vapp* of the GM tube by calculating

$Vapp = V1 + 0.25\ (V2-V1) =$ ____________

This operating point is be 25% beyond the onset of the plateau.

II. Resolving GM Tube.

The GM tube will loose counting capability at higher rates because a finite time for the GM avalanche to develop and charge collection to take place. We can determine this "resolving time" by split source technique. With a split source (and dummy D) take *N1* counts for60s or enough time to accumulate >1000 counts. Similarly take *N2* counts. Then *N1* + *N2* together. Determine the rates *R1, R2, R12.*



	N	Time	R(cps)
N1			
N2			
N1+2			

1) Determine and record the the resolving time $T_R =$ _______________ s

$$T_R = \frac{R1 + R2 - R12}{2R1\ R2}$$

The corrected counting rate R' which includes the particle counts that you have missed due to the resolving T_R of the GM is

$$R' = \frac{R}{1 - R\ T_R}$$

where R is the recorded count rate, 1- $R\ T_R$ is the correction factor.

III. Linear Absorption Coefficient.

A gamma ray source's intensity I_O can be attenuated by introducing various absorbers of thickness $\boldsymbol{x}$ in the gamma flight path. The attenuation follows an exponential law

$$I(x) = Io\ e^{-\mu x}$$

where μ is called the linear attenuation coefficient. It is not constant, but varies with gamma ray energy and absorber type. Often the **mass attenuation coefficient** μ / ρ is used.

.

1) With the Pb (11.34 g/cc) absorbers insert absorbers 1,2,3,4 in to the GM 2nd tray with Cs-137 (662 KeV) source in the 3rd position. Record the counting rates for a time *T* seconds such that the thickest absorber gives > 500 counts. Also record an empty tray.

T(s) =	*Empty-0*	*Abs-1*	*Abs-2*	*Abs-3*	*Abs-4*
x (cm)					
N					
R(cps) =N/T					
R' (corrected)					

2) Graph and fit the *R' vs x* distribution to an exponential form $f(x) = Ae^{mx}$ to determine μ. Or Graph $\ln(R'/R'_0)$ vs x and fit to a linear function $f(x) = A + m\ x$ o determine μ. Attach the fitted graph to the back of the report. Find μ/ρ and compare with the accepted value of $0.113\ \text{cm}^2/\text{g}$

$\mu/\rho\ (cm^2/g) =$______________ *% difference =* _________________

3) Comment on the % difference comparison.

IV. Mean Decay Constant and Lifetime of a Radioactive Source

Radioactive sources are not stable and nuclei will follow the exponential decay law decay with mean lifetime τ. The decay constant $\mu=1/\tau$

$$N(t) = N_0\ e^{-t/\tau} = N_0\ e^{-\mu t}$$

The half-life $T_{1/2}$ of a radioactive nucleus is the time it takes for half the original sample to decay, where $T_{1/2} = 0.693\ \tau$. Consider the decay

$$Cs_{55}^{137} \rightarrow Ba_{56}^{137} * + \beta_{-1} + \overline{\upsilon}_e$$
$$\rightarrow Ba_{56}^{137} + \gamma(662)$$

where daughter $Ba_{56}^{137}*$ is in secular equilibrium with parent Cs_{55}^{137} (the half-life of the daughter radionuclide is much shorter than the half-life of the parent radionuclide). We will leach out *Ba* nuclei in a *Cs* source with a weak *HCl* solution forming $BaCl + H_2O$ and measure the decay constant of the excited *Ba**.

1) With your instructors help extract a few milliters of BaCl in to a planchette. Insert the BaCl in to the GM counter tray-3. Begin the data acquisition (10 s intervals for 10 minutes).

2) Fit the data to an exponential form $f(t) = Ae^{mt}$ and determine the half-life $T_{1/2}$ of this decay. Compare with the accepted value of the decay $T_{1/2} = 2.6\,\text{m}$. Attach the fit to this report.

$T_{1/2}$ =______________ *% difference =* _________________

3) Comment on the % difference comparison.

V. Efficiency of a GM tube to Beta and Gamma radiation

We will investigate the efficiency of a GM tube in response to gamma radiation. Beta particles are very effective at ionizing argon gas in the GM tube. A GM tube is practically 100% efficient for detecting entering betas. Gamma radiation is less likely to ionize the gas in the GM tube and thus the GM tube is not nearly as efficient for detecting gamma radiation. We will investigate the efficiency of the GM tube to gamma radiation.

In each Cs-137 decay a beta and gamma are emitted simultaneously. First we count $N_{\gamma+\beta}$, the total # of pulses registering in a 100s time interval. Then we place a 1/32" Cu sheet in front of the source to absorb the betas and count again to determine.

	N/100s	**R (cps)**
$N_{\gamma+\beta}$		
N_γ (with Cu foil absorber)		

Define $\varepsilon_\gamma \simeq \dfrac{N_\gamma}{N_{\gamma+\beta}}$ *and* $\varepsilon_\beta \simeq 1-\varepsilon_\gamma$ be the efficiency for detecting gammas and betas in the GM tube.

From geometrical (G) considerations the fraction f_G of particles from a radioactive source placed at distance *R* and enter a cylindrical detector of radius *r* is $f_G = \pi a^2/4\pi R^2 = a^2/4R^2$

The rate *R* in counts per second (cps) entering the GM tube from a source of activity *A* is predicted to be

$$R = A \; x \; f_G \, .$$

For a 1 inch GM tube $f_G = \pi a^2/4\pi R^2 = (1.27\text{cm})^2/4(3.0\text{cm})^2 = 0.045$

From your measurement of the $R_{\gamma+\beta}$ in $tray-3$ estimate the activity of the Cs137 source.

$A = R_{\gamma+\beta} / f_G$ = ____________________ cps

Further Discussion of Resolving Time ΔT

A particles enter the GM counter the tube/wire floods with charge and may become inactive for a period, ΔT, the resolving time. ΔT is the smallest time that two particles can be subsequently resolved or counted. The resolving time will be proportional to the count rate

Let T be the total time the detector is on and T_L = time the detector is on. Then $T_L = T - N\Delta T$
By definition R is the experimental counting rate and R' the true or corrected counting rate.

$$R/R' = (N/T) / N/T_L) = T_L/T$$

We assume that the live time T_L will be the real time T minus some time proportional to N. As N increases T_L becomes smaller.

$$T_L = T - N\Delta T$$

$T_L/T = 1 - (N/T)\,\Delta T = 1 - R'\Delta T$
$R/R' = 1 - R\Delta T$
$R' = R/1 - R\Delta T$