Experiment 5
Attenuation of Radiation in Matter

Gamma particle intensity decreases exponentially with distance into a material medium according to the formula:

$$I(x) = I_0 e^{-\alpha x} \tag{1}$$

where x is in units of length, and α is the linear absorption coefficient. See Chapter 6 for a more complete discussion of attenuation of radiation. This expression can also be written as

$$I(x) = I_0 e^{-\mu z} \tag{2}$$

where z is in units of grams/cm^3, and μ is called the mass attenuation coefficient. Both of the above equations are referred to as Lambert's Law. As explained in Chapter 6,

$$\alpha = \mu\rho \tag{3}$$

where ρ is the density of the material.

Your task for this experiment is to measure the mass attenuation coefficient for beta particles in Aluminum and one of the gamma rays below in Lead:

662 KeV gamma particles in lead (Pb)
1275 KeV gamma particles in lead (Pb)

Although you should be able to do the experiment with no help, here are some tips:

Take a number of spectrum readings using ^{137}Cs or ^{22}Na as a source. Keep the source the same distance from the detector while you place the absorbers of various thicknesses between the source and the detector. Be sure you record data for a long enough time to obtain good statistics. Determine the area under each of the photopeaks for the gamma rays. The area is what we will consider as $I(x)$. For the β particles (electrons), we will use the Geiger Counter in lecture to record the counts. Then plot your data using Excel and see if it is well described by an exponential trendline. Express your attenuation coefficients in units of cm^2/gm. For the β particles you will have to subtract off the counts due to the gamma and x-rays. **Include**

all data, calculations, and graphs in your writeup.

<u>Recommended thicknesses:</u>
a) For the gamma rays in lead, use the 5 lead absorbers (A, B, C, D, E).
b) For the beta particles we will use the Geiger counter and the 12 thinnest aluminum absorbers.

Note: Lambert's law assumed that the beam is well collimated. However, very often in the laboratory these "good geometry" conditions are not satisfied. A photon may be scattered and yet still be recorded by the detector. Photon's may also be scattered off shielding and still be recorded under the photopeak. Thus, absorption may not follow Lambert's law exactly. Particularly with the β particles, since β decay does not emit the electron with the same energy every time, Lambert's law might not follow exactly.

Writeup for Experiment 4

1. (8 points) Turn in all data, calculations, and graphs for your measurements of the attenuation coefficients for the two different cases. Be sure to include the correct units on all quantities.

2. (Question): (1 points) Discuss how well Lambert's law is satisfied for the two cases: a) 662 KeV or 1275 KeV gamma's through lead, b) β particles through aluminum.

3. (Question): (1 point) Which of these particles travels the furthest distance though matter? travels the shortest distance through matter?

4. (2 points) How do your values for μ for the 662 KeV or 1275 KeV gamma compare to the values listed in the literature shown below?

Photon Energy (KeV)	Lead (cm^2/g	Aluminum (cm^2/g
20	85.7	3.41
30	29.7	1.12
40	14.0	0.567
50	7.81	0.369
60	4.87	0.280
80	2.33	0.203
100	5.4	0.171
150	1.97	0.138
200	.99	0.122
300	0.404	0.104
400	0.231	0.0927
500	0.161	0.0844
600	0.125	0.0780
800	0.0885	0.0684
1000	0.071	0.0615
1250	0.0588	0.0550
1500	0.0522	0.0501

Table I. Linear mass attenuation coefficients μ for photons passing through Lead and Aluminum. The units of μ are cm^2/g.