PHYS 3650L - Modern Physics Laboratory

Laboratory Advanced Sheet

Photon Attenuation

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1. Objectives. The objectives of this laboratory exercise are:

a. To measure the mass attenuation coefficient at a gamma ray energy of 661.7 keV.

b. To verify the exponential dependence of gamma rays absorption by an attenuating medium.

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2. Theory.

a. High energy photons interact with matter primarily through three processes: the photoelectric effect, Compton scattering and pair production. Associated with each of these interaction processes are linear interaction coefficients which provide the probability per unit path length that a photon of a specific energy in a specific material will interact. The sum of the three linear interaction coefficients is the linear attenuation coefficient. The linear attenuation coefficient represents the probability per unit path length that a photon of a specific energy in a specific material interacts by any of the three interaction processes.

b. For a parallel beam of monoenergetic photons falling at perpendicular incidence on a slab of homogeneous material, the intensity of the beam that passes through the slab without interacting by any of the interaction processes is given by:

$$I = I_0 e^{-\mu x} \qquad \textbf{1}$$

where I is the intensity of the beam surviving without interaction,
I_0 is the intensity of the beam incident on the slab,
μ is the linear attenuation coefficient, and
x is the thickness of the slab.

c. Gamma ray photons interacting in the attenuating material by the photoelectric effect are absorbed. A low energy, characteristic x ray may be produced after the photoelectric interaction when the inner shell electron hole is filled. Gamma ray photons interacting by the Compton scattering interaction in the attenuator create a new, lower energy scattered photon. Gamma ray photons interacting by the pair production interaction are absorbed. When the positron produced in pair production annihilates, two photons of 0.511 MeV are created. Since the minimum energy required for the pair production interaction to occur is 1.022 MeV, secondary photons produced by all three interaction processes are lower in energy than the original photon.

d. A detector that is unable to distinguish between photons that have and have not interacted before reaching it will count some secondary photons produced in interactions in the attenuating material. Figure 1 shows an example of four photons emitted from the source that reach the detector.

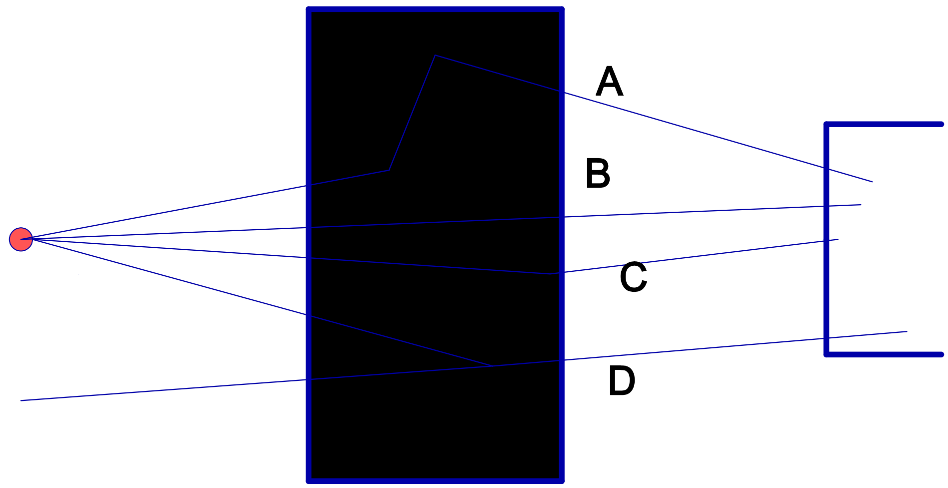

Figure 1. Photon attenuation example. Four photons from the source that reach the detector are shown in this example.

Photon A has undergone two Compton scattering events. Photon B has passed through the slab without interaction. Photon C has undergone a photoelectric effect interaction which led to the creation of a characteristic x ray (characteristic of the slab material). Photon D has undergone a pair production event. Two 511 keV photons result when the positron annihilates. One of these 511 keV photons reaches the detector. Only Photon B is accounted for by equation 1. Equation 1 accounts for only those photons that do not interact and would disagree with measurements made by the detector. Because all secondary photons are lower in energy than the source photons, a detector capable of measuring the energies of gamma rays can discriminate between photons that have and have not interacted in the attenuating material.

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3. <u>Apparatus and experimental procedures</u>.

a. Equipment.

1) Geiger-Müller tube with sample holder.

2) Radiation counter.

3) Radioactive sources.

4) Absorber set.

b. Experimental setup. To be provided by the student.

c. Capabilities. To be provided by the student.

d. Procedures. Detailed instructions are provided in paragraph 4 below.

4. Requirements.

a. In the laboratory.

1) Your instructor will introduce you to the experiment.

2) Perform the background count measurement.

4) Perform the count measurements for different absorption thickness for two materials.

b. After the laboratory. The items listed below will be turned in at the beginning of the next laboratory period. A complete laboratory report is **not** required for this experiment.

Para 3. Apparatus and experimental procedures.

1) Provide a figure of the experimental apparatus (para 3b).

2) Provide descriptions of the capabilities of equipment used in the experiment (para 3c).

Para 4. Data. Data tables are included at Annex A for recording measurements taken in the laboratory. A copy of these tables must be included with the lab report. Provide the items listed below in your report in the form a Microsoft Excel™ spreadsheet showing data, calculations and graphs. The spreadsheet will include:

1) Operating potential, resolving time, and counting time for the absorption measurements.

2) Background count measurement (per 400 s).

3) A table with columns for absorber code(s), absorber thickness, corresponding uncorrected count, and corrected count.

4) A graph of the counts vs. absorber thickness for each absorbing material.

5) A graph of the natural logarithm of counts vs. absorber thickness with linear regression plotted for each absorbing materials.

6) Mass attenuation coefficient for two absorbing materials.

Para. 5. Results and Conclusions.

a. Results.

1) A statement of the mass attenuation coefficient for two absorbing materials. How do your experimental values compare to the theoretical predictions?

2) A statement of the functional dependence of gamma attenuation in absorbing material.

b. Conclusions.

1) What are the possible sources of error in the experiment?

Annex A
Data

Counting time: 50 s.

Operating potential: ______________________________ V

Resolving time:______________________________ s

Background count/ 400 s:______________________________

1. Absorption measurements in aluminum.

Absorber code	Absorber thickness (mg/cm^2)	counts/50 s	Absorber code	Absorber (mg

2. Absorption measurements in lead.

Absorber code	Absorber thickness (mg/cm^2)	counts/50 s	Absorber code	Absorber (mg