PHYSICAL LABORATORY II

Exercise No. 3

Determination of gamma-ray absorption curve

THE PURPOSE OF THE EXERCISE

The aim of this exercise is to determine the linear and mass absorption coefficients of gamma-rays for various materials. The absorption coefficients will be determined from the experimental absorption curve, measured by using an universal radiometer (URL-2). The gamma-ray beam, emitted from the gamma radiation source Co-60 (Cobalt isotope), is collimated in the source and further absorbed in the studied material.

This exercise shows the legitimacy of using shielding in radiological protection. Some materials reduce the intensity of radiation to a level safe for humans.

THE COURSE OF THE EXERCISE

For a fixed distance from the gamma-ray source to the detector, the students measure the dependence of the number of counts per second (intensity of γ-rays) on the thickness of the absorbent. As an absorbent material we can use: lead, iron, aluminum, plexi and concrete.

1. In a first step, measure the number of counts coming from the background, the so-called background intensity I_{BG}. The measurement should be done by closing the $\gamma-$ray source hole with the maximum thickness of lead absorbent (15 cm).

2. Measure the initial intensity of γ-rays ($I_{0,exp}$). Note, only the air should be present between the source and the detector.
3. Measure the thickness of the plate for the given type of absorbent material.
4. Put the absorbent plate on the source (precisely on the hole). Be careful! Do not put your hand in the gamma-ray beam.
5. Write the number of counts per second I_{exp} (the γ-ray intensity) given by the counter display.
6. Repeat the measurement of γ-ray intensity I_{exp} for all possible thicknesses of the absorbent.
7. Experimental data: thickness of the absorbent (x) and number of counts per second (I_{exp}).
8. Repeat the steps 3-6 for each material.

ANALYSIS OF THE RESULTS

From each value of intensity (I_{exp} and $I_{0,exp}$) substract the background intensity ($I = I_{exp} - I_{BG}$ and $I_0 = I_{0,exp} - I_{BG}$, respectively).

1st method

1. Plot the dependence of the number of counts (I) on the thickness of the absorbent (x) for each type of material, separately.
2. Perform a fit to the experimentally measured points using the function: $y = A \cdot e^{-bx}$ ($I = I_0 e^{-\mu x}, b \equiv \mu, A \equiv I_0$).
3. Based on the obtained curve equation, determine the value of half-absorption thickness ($x_{1/2}$), i.e. such thickness of the absorbent for which the intensity is equal to half of the initial intensity value $I_{1/2} = \frac{1}{2} I_0$.
4. Calculate the linear absorption coefficient μ, according to the relation:

$$\mu = \frac{ln2}{x_{1/2}}. \tag{1}$$

5. Calculate the error $\Delta\mu$ by using the standard error propagation.

2nd method

1. For each measurement, calculate the linear absorption coefficient μ by using the relation

$$\mu = \frac{1}{x} \cdot ln\frac{I_0}{I}. \tag{2}$$

2. Determine the mass absorption coefficient $\mu_m = \frac{\mu}{\rho}$, where ρ is the density of the absorbent. Use the following values for densities: $\rho_{Fe} = 7.8\frac{g}{cm^3}$, $\rho_{Pb} = 11.3\frac{g}{cm^3}$, $\rho_{Al} = 2.7\frac{g}{cm^3}$. For plexi as well as for concrete determine the value of density out of its mass and volume.

3. Calculate the average value of μ and μ_m for each absorbent.

4. Calculate the errors $\Delta\mu$ and $\Delta\mu_m$ by using the standard linear error propagation and the standard deviation method.

3rd method

1. Plot the dependence $lnI(x)$ for each type of absorbent separately.

2. Perform a fit to the measured points using the linear function $y = ax + b$ $(lnI = -\mu x + lnI_0)$.

3. Extract the numerical value of linear absorption coefficient μ out of the equation of the fitted function ($\mu = -a$, where a is the slope of the linear function).

4. Draw the plots of the functions $y = (a \pm S_a)x + (b \pm S_b)$. Are all the experimental points within the upper and the lower curves?

$$S_a = \sqrt{\frac{\sum_{i=1}^{n} \varepsilon_i^2 \cdot n}{(n-2) \cdot (n \cdot \sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2)}}, \tag{3}$$

$$S_b = \sqrt{\frac{\sum_{i=1}^{n} \varepsilon_i^2 \cdot \sum_{i=1}^{n} x_i^2}{(n-2) \cdot (n \cdot \sum_{i=1}^{n} x_i^2 - (\sum_{i=1}^{n} x_i)^2)}}, \tag{4}$$

$$\sum_{i=1}^{n} \varepsilon_i^2 = \sum_{i=1}^{n} y_i^2 - \bar{a} \cdot \sum_{i=1}^{n} x_i y_i - \bar{b} \cdot \sum_{i=1}^{n} y_i. \tag{5}$$

 Translated by D. Sobota and M. Piotrowska.