Radiation

Purpose

Radioactive isotopes are atoms with unstable nuclei that emit energetic particles and transmute into their daughter nuclei through random decay process. The emitted particles include alpha (α) particles, beta (β) particles and high energy photons (i.e. gamma (γ) rays). These sources of radiation have found many important applications in medicine and industry, and one important consideration is its penetrating power or absorption of the radiation in materials. The knowledge of the absorption coefficients in different materials is essential to the calculation of dosage as well as the design of protective shielding systems.

In the case of γ radiation, these high energy photons can be regarded as electromagnetic wave. The intensity over distance of the waves obeys the inverse square law if emitted from a point source. In practice, with the limitations imposed by the finite size of the radioactive source and relatively large dimensions of the detector, the Geiger-Muller tube (GM tube), it is still possible to verify the inverse square law, relating intensity and distance of γ-rays.

The objectives of the experiment, therefore, are:

- to study the absorption of radiation in different materials;
- to investigate the inverse square law for -radiation.

Theory

A. Absorption of radiation in materials

- For narrow beams of β and γ radiation the intensity transmitted through an absorbing medium varies according to an exponential law

$$l_z = l_0 \exp(-\mu x) \qquad \text{(A1)}$$

where
l_0 = incident intensity
l_z = transmitted intensity
x = thickness of the absorber, and
μ = linear attenuation coefficient of the particular radiation

- The use of μ is sometimes inconvenient because of its dependence on the density of the absorbing material ρ. μ varies with temperature and pressure, particularly when the medium is a gas. Hence the mass absorption coefficient is often used, which is defined as

$$\mu_m = \mu/\rho \qquad \text{(A2)}$$

- Radium ($^{226}_{88}R_a$) decays into lead ($^{206}_{82}P_b$) via a complex process. During the decay process, a number of radioactive by-products are generated. These intermediate by-products will decay and emit either α, β particles and γ-rays. As a result, the radiation from a $^{226}_{88}R_a$ source consists of α and β particles as well as γ-rays. Alpha particles have a short range in air, and are stopped by a thin sheet of aluminium.

- The intensity of beta particles can be measured with a Geiger Muller tube (GM counter) as shown in the following figure. This instrument is a halogen gas-filled tube with two electrodes maintained at a potential difference of several hundred volts, and registers a "count" when an avalanche breakdown occurs in the gas, by the ionization effect of a beta particle passing through.

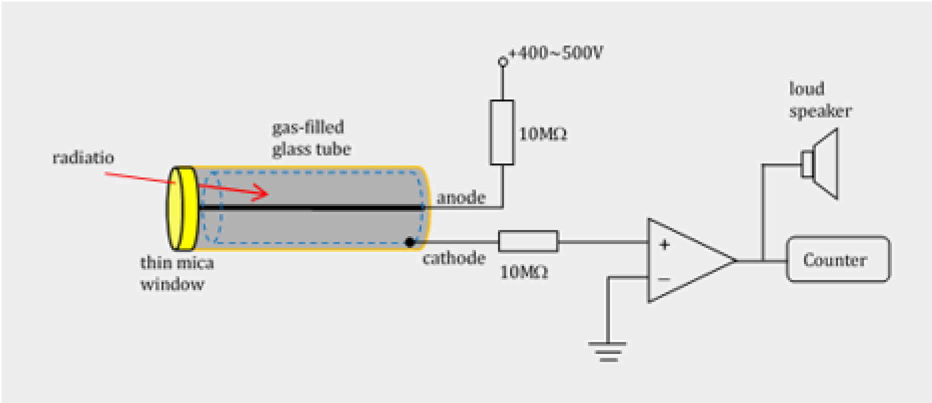


Figure 1

- The GM counter is not an appropriate detector for γ-rays because some γ-rays penetrate the counter without causing an avalanche; as a result, only a fraction of the beam is registered. Therefore, the number of count per unit time (count-rate) is only proportional to the radiation intensity. In this experiment however, only the relative intensities (i.e. the ratio I_z/I_0) are needed. GM counter can therefore be used in the study of absorption of both types of radiation.

  The observed count-rate n (after correction for background count-rate) is the sum of the radiation due to β particles and γ-rays.

- For either type of radiation,

$$n = Aexp(-\mu_x) = Aexp(-u_m x\rho) \qquad \text{(A3)}$$

where A is a constant and u_m is mass absorption coefficient for the radiation. The product $x\rho$, which is the mass per unit area of the absorber, is referred to as the "optical thickness" of the absorber.

- The absorption of β particles by materials is very much larger than that of the γ-rays. Hence the count-rate of β particles is reduced to a negligible amount by a few millimeters of aluminium. When small thicknesses of aluminium are used, the decrease in count-rate may, as an approximation, be considered as arising from the absorption of β particles; the contribution of γ-rays may be neglected. From the slope of the logarithmic plot, the mass absorption coefficient of β particles in aluminium can be estimated.

- On the other hand, when lead absorbers are used, the decrease in count-rate arises from the absorption of γ-rays. From the slope of the logarithmic plot, the mass absorption coefficient of γ-rays in lead can be found.

  By plotting $\ln(n)$ against $(x\rho)$, a graph consists of two nearly straight line segments are obtained whose slopes are the u_m of the radiation in the respective materials.

  In this experiment, only the absorption of β radiation in Al will be measured.

B. Inverse Square Law for γ Radiation

In this part of the experiment, the GM tube is moved relative to a fixed radioactive source. Since both of the radiation source and the GM tube are not point-like objects, then the distance between the two is conveniently expressed as $d + x$, where d is the measured separation between the source and the counter, and x is an unknown fixed distance depending on the dimensions of the GM tube and the source.

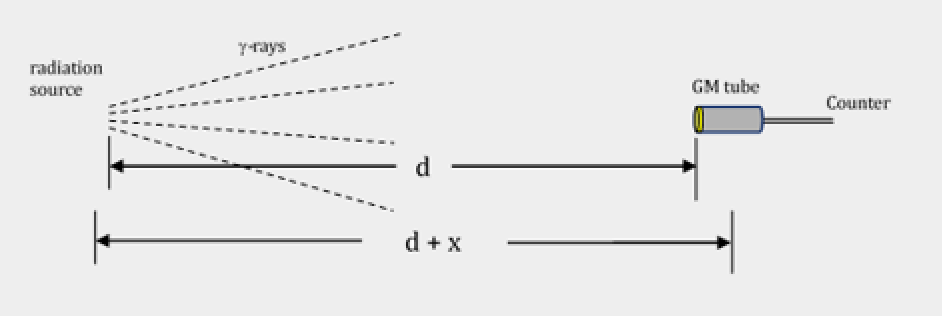
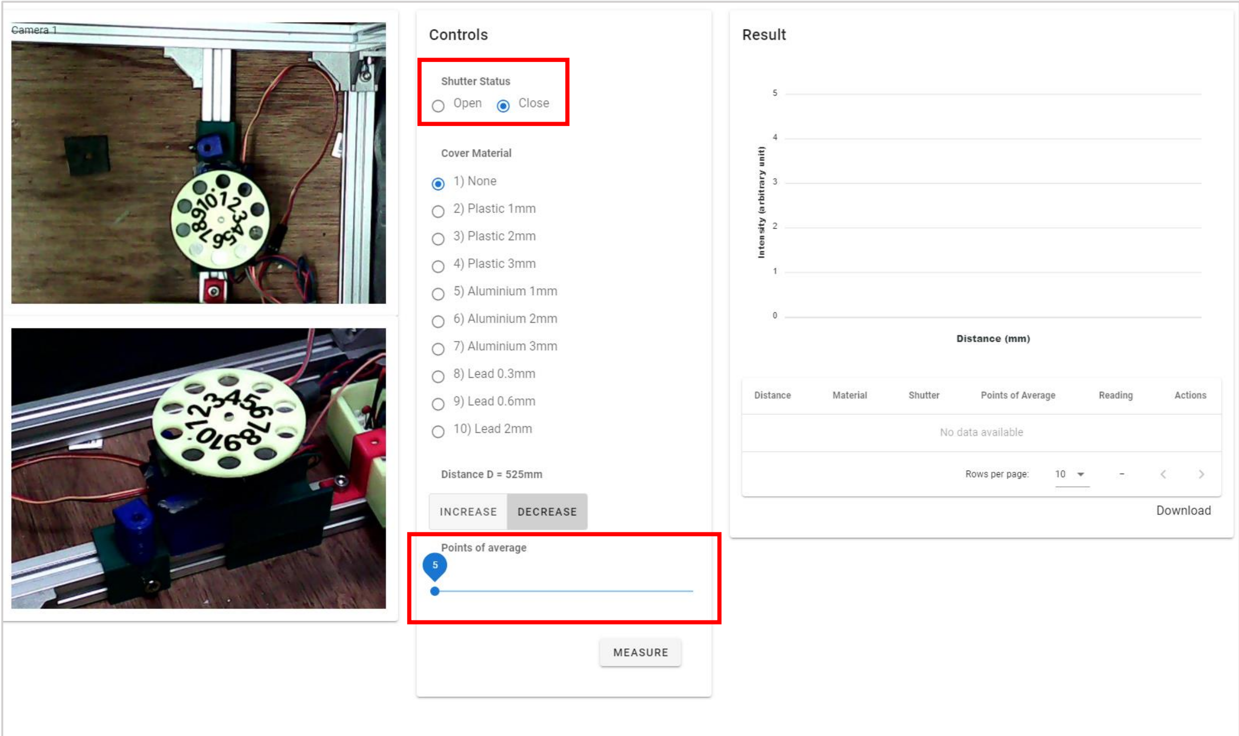


Figure 2

Procedures

<u>IMPORTANT NOTES</u>



<u>Fig 3: The interface of the radiation remote experiment</u>

- Always CLOSE the shutter if you are not measuring for safety issue.
- Due to the randomness of radioactive decay, it is suggested to collect more points and take the average for each measurement to reduce error. It can be adjusted by sliding the bar of “Points of average”.
- The number you choose equals to the number of points that will be taken. For example, when you slide the bar to 5, the measurement will take 5 points in 5 seconds, i.e. 1 point

per second. Then, the average counts of these 5 points will be computed and obtained. Data will be displayed in counts per second.

I. Background radiation

1. Make sure that the shutter is CLOSE.
2. Move the thickest lead plate onto the source by choosing the correct slot in the Control Panel. This ensures the strongest absorption of radiation from the source and the measured value is closest to the background.
3. Press "MEASURE" to measure the result.

II. Absorption of Radiation in Materials

1. Set the GM counter to a distance of 400 mm from the source. Check the distance display on the interface.
2. Choose the slot with one slice of plastic. Check the viewports and confirm the material selected has moved over the source.
3. You can adjust the logging time by sliding the bar of "Points of average".
4. OPEN the shutter and start the measurement. Record the results in Table 1.
5. CLOSE the shutter when the measurement is finished.
6. Repeat steps 2 to 4 for different absorption materials (aluminium, lead) of the same thickness. The list of available materials and the corresponding thickness of slices are listed in the Control panel.

III. Inverse Square Law of γ radiation

1. Make sure that the shutter is CLOSE.
2. Set the GM counter to a distance of 400 mm from the source. Check the distance of the counter and confirm your selection.
3. Choose 0.3mm thick lead plate under the cover material. Check the viewports and confirm the material selected has moved over the source.
4. Perform the measurement.
5. Repeat step 1 to 3 for varying distance between the source and the GM counter (about 1cm each time). If the count rate is too low, adjust the log time in the 'Measurement' Panel and repeat the measurement (See Important Notes.)
6. CLOSE the shutter when the measurement is finished.

Results

I. Background Radiation: ______________________________

II. Absorption of Radiation in Materials

Distance (mm)	Material	Thickness (mm)	Points of Average	Reading (counts)

III. Inverse Square Law of γ radiation

Distance (mm)	Material	Thickness (mm)	Points of Average	Reading (counts)