

Surname .....

Name .....

Date .....

Degree program name.....

## Exercise B\_59\_BIOPHYSICS

### Study of types of natural radiation sources

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**Table 1:** Counts through different materials

Background count = \_\_\_\_\_ counts/30s

Natural radiation source (name)	Through air (no absorber) (counts/30s)	Through aluminum foil Code: n.....shields (counts/30s)	Through a plastic sheet Code: n.....shields (counts/30s)	Through plastic Code: n.....shields (counts/30s)	Through aluminum Code: n.....shields (counts/30s)	Identified/predicted type of radiation ( $\alpha$ , $\beta$ lub $\gamma$ )	Type of LET: (low or high)

**Table 2:** The measurement of the counts according to the distance of the selected source with the highest count rate

Distance (cm)	8	7	6	5	4	3
Count Rate (counts/30 s)						

## Exercise B\_59\_BIOPHYSICS

### Study of types of natural radiation sources

#### *Materials and equipment*

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- data collection system
  - wireless Geiger counter
  - Geiger counter sample holder
  - the set of 16 calibrated absorbers
  - natural radiation sources: different rocks, coffee grains, KCl, etc.
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**Figure 1.**

Wireless Geiger Counter with a sample holder (on the left). The set of 16 calibrated absorbers (on the right) includes 2 plastic sheets, 10 aluminum, 2 plastic (polyethylene), and 2 aluminum foil absorbers. /source: <https://www.pasco.com>

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#### **Safety**

**Follow these important safety precautions in addition to your regular classroom procedures:**

- **The natural radiation source should be kept in its case.**
- **The natural radiation samples are safe.**
- **Due to the low activity and natural origin, and with regard to radiation protection regulations, do not require notification to the relevant institutions, in accordance with the Decree of the Council of Ministers of March 10, 2021, on cases in which activities involving exposure to ionizing radiation do not require authorization, notification or notification, and cases in which they may be performed on the basis of notification or notification.**

#### **Objectives**

- Use a Geiger counter to measure radiation counts.
- Measure how radiation passes through different materials.
- Draw conclusions about the penetrating power of radiation.
- Compare counts of different materials and absorbers.
- Determining the relationship between distance and radiation count.

## THEORY

### *Sources of ionizing radiation*

Radiations are broadly categorized into natural and man-made sources. More than 90 % of radiation exposure to man occurs from natural sources e.g. cosmic rays, and terrestrial sources that comes from radionuclides in the earth's crust, air, food and water and the human body itself. Man-made radiation exposure to populations occurs mainly from medical uses of radiation and radioisotopes in health care, occupational sources in the generation of electricity from nuclear power reactors, industrial uses of nuclear techniques, and in the past from nuclear weapons testing. Use of ionizing radiation in medical diagnosis and therapy is widespread and constantly increasing due to useful newer health care applications. It is widely accepted that diagnostic radiation exposures can be significantly reduced by adequate safety measures and optimization of nuclear-based procedures and practices.

### *Types of ionizing radiation*

We distinguish between three types of radiation, denoted by the letters of the Greek alphabet:  $\alpha$ ,  $\beta$  and  $\gamma$ . Ionizing radiation may be divided into directly and indirectly ionizing for the understanding of biological effects. Most of the particulate types of radiation are directly ionizing i.e. individual particles with adequate kinetic energy can directly disrupt the atomic structure of the absorbing medium through which they pass producing chemical and biological damage to molecules. In contrast, electromagnetic radiations, namely, X and  $\gamma$  rays, are indirectly ionizing because they do not produce chemical and biological damage themselves but produce secondary electrons (charged particles) after energy absorption in the material. Different types of radiation have differing abilities to pass through material (Figure 2). A very thin barrier, such as a sheet or two of paper, or the top layer of skin cells, usually stops alpha particles. Because of this, alpha particle sources are usually not dangerous if outside the body, but are quite hazardous if ingested or inhaled. Beta particles will pass through a hand, or a thin layer of material like paper or wood, but are stopped by a thin layer of metal. Gamma radiation is very penetrating and can pass through a thick layer of most materials. Some high-energy gamma radiation is able to pass through a few feet of concrete. Certain dense, high atomic number elements (such as lead) can effectively attenuate gamma radiation with thinner material and are used for shielding. The ability of various kinds of emissions to cause ionization varies greatly, and some particles have almost no tendency to produce ionization.

**Radiation  $\alpha$**  are nuclei of helium atoms. These are particles made up of two protons and two neutrons. Particles  $\alpha$  are formed by the transformation of the parent nucleus into a daughter nucleus with a reduced atomic number relative to the parent nucleus by two units and a mass number of four. Particles  $\alpha$  passing through matter strongly ionize it and lose kinetic energy in the process - thus they are not very penetrable. **Radiation  $\beta^+$** , or positron emission ( $e^+$ ), accompanies nuclear decays, in which, at an unchanging mass number, the charge number of the nucleus decreases by one. More frequently emitted are electrons ( $e^-$ ) - then we are dealing with decay  $\beta^-$ . With **emission  $\beta^-$**  the mass number also does not change, but the charge number of the final nucleus increases by unity. In transformation,  $\beta^-$  the energy distribution of emitted particles (their energy spectrum) is continuous. This means that we are dealing with particles from zero energy to maximum energy, determined by the difference in masses of the nuclei participating in the decay. Beta particles on their way, are weaker ionizing matter and thus are more penetrating. Only **gamma quanta ( $\gamma$ )**, as electromagnetic radiation, fully justify their name. The spectrum of radiation  $\gamma$  is monoenergetic, since the energy of its quanta closely corresponds to the difference in energy states of the nucleus before and after emission. The  $\gamma$  quanta react weakly with matter, as a result of which they are very permeable - the gas hardly ionizes at all.

Type of radiation	source	half-life ( $t_{1/2}$ )
$\alpha$	Po-210	138 days
$\beta$	Sr-90/Co-60	28.6 / 5.27 years
$\gamma$	Co-60/Cs-137	5.27 / 30 years

The diagram illustrates the penetration of four types of radiation through a vertical column of materials. From left to right, the materials are Paper, Metal, Water, Concrete, and Lead. Alpha particles (represented by a cluster of two protons and two neutrons) are stopped by Paper. Beta particles (represented by a single electron) are stopped by Metal. Neutrons (represented by a single neutron) are stopped by Water. Gamma rays (represented by a wavy line) are stopped by Concrete and Lead.

**Figure 2.** Different types of radiation, sources and half-time (left panel). The ability of different types of radiation to pass through material is shown (right panel). From least to most penetrating, they are alpha < beta < neutron < gamma. A diagram shows four particles in a vertical column on the left, followed by an upright sheet of paper, a person's hand, an upright sheet of metal, a glass of water, a thick block of concrete, and an upright, thick piece of lead (source: *Openstax:chem.libretexts.org/Bookshelves*).

### **Linear energy transfer**

When ionizing radiations traverse through matter, they lose energy gradually through various interaction processes along the length of their path. For a particular absorber, the rate of loss of energy depends on the energy and type of radiation, as well as the density of the material. The density of energy deposition in a material such as tissue is called the **Linear Energy Transfer (LET)** of the radiation. It is defined as the average energy deposited per unit length of track of radiation, and the unit is keV/ $\mu\text{m}$ . Note that the LET varies along the length of the track of charged particles because, as the charged particle deposits energy in tissue, it slows down. Charged particles generally have higher LET than X and  $\gamma$  rays because of their greater energy deposition along the track. Radiations are categorized into low and high LET radiations, with particulate radiations usually being high LET radiations, whereas X and  $\gamma$  rays are low LET radiations due to their sparse ionizations. Energy loss events are essentially randomly distributed along the track of the photon or charged particle. For low LET radiations, the energy deposition events along the track of the photon are sparse relative to the dimensions of biomolecules such as DNA, with the result that photons may pass through such a molecule without depositing any energy.

### **The construction and operation of a Geiger-Müller counter**

The Geiger-Müller counter is a gaseous radiation detector - it belongs to the group of ionization detectors. The G-M counter usually has the shape of a cylindrical metal tube, inside which, along its axis of symmetry, is placed a thin tungsten wire, axially fixed inside the cylinder. The cylindrical tube is called a cathode because it always operates at a potential lower than that of the tungsten wire, which is called the anode. Fig. 3 shows a diagram of the electronic apparatus operating the G-M counter. In simple terms, the operation of the counter can be described as follows: Radiation passing through the window ionizes the gas between the electrodes. The electrons released as a result of ionization, the electrons are accelerated by an electric field. At sufficiently strong intensity of the field, the electrons reach such high energy that they induce another ionization. The process proceeds in an avalanche. It is sustained by ultraviolet radiation from excited gas molecules and positive ions, which can knock more electrons out of the cathode. In order to stop the continuous discharge, small amounts of gas with multi-atomic molecules are added to the working gas (methane, alcohol vapors), which absorb ultraviolet radiation and block the knockout of electrons from the cathode. After the avalanche expires, the counter is ready to register the next particle. The pulse of discharge current in the counter corresponds to a change in voltage across the resistance R incorporated in the counter circuit.

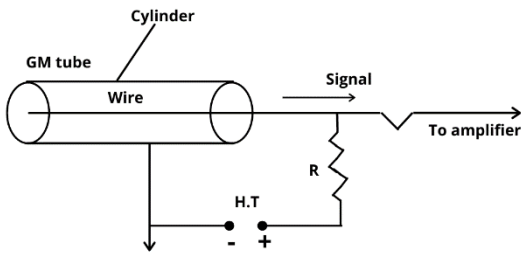
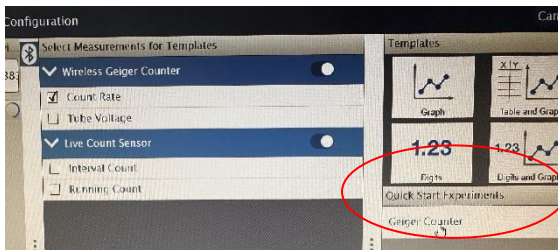


Figure 3. Schematic of the Geiger-Müller counter circuit (source: *physicswave.com*)

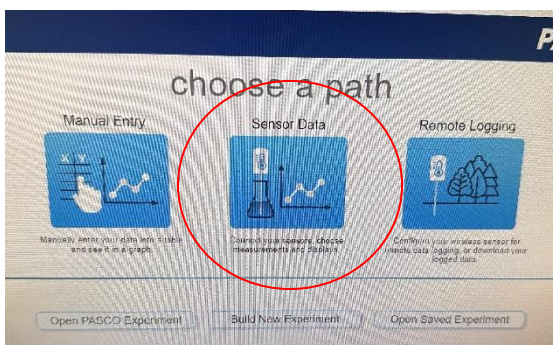
## Procedure:

### PART I:

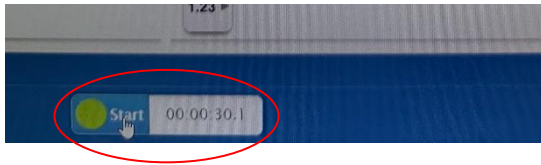
1. Turn on the power of the table (see the dashboard of the table - by your right leg, when you sit in front of the computer) - turn the red "knob" in the direction of the arrows (it should pop out), turn the key as in a car, and let go.
2. Turn on the computer.
3. Turn on the **Geiger counter**, place a sample holder in slot no 4. This slot is marked with no 4 on the side. This indicates the distance of 4 cm from the Geiger counter.
4. Choose a **SPARKvue** icon.
5. Connect it to the data collection system (**Geiger-counter 030-830**).



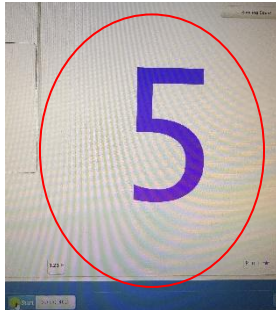
6. Choose a path: **Sensor Data** (in the middle).



7. The beeps can be silenced by pressing the on button for about a half second or by unchecking the Enable Beeps box in the software.
8. Make sure the natural radiation sources are far from the Geiger counter.
9. Set the sample interval to **30 s** and check the **Record only one interval** box in the software.



10. Start recording data. Data recording will stop automatically after 30 seconds. Record the count below.

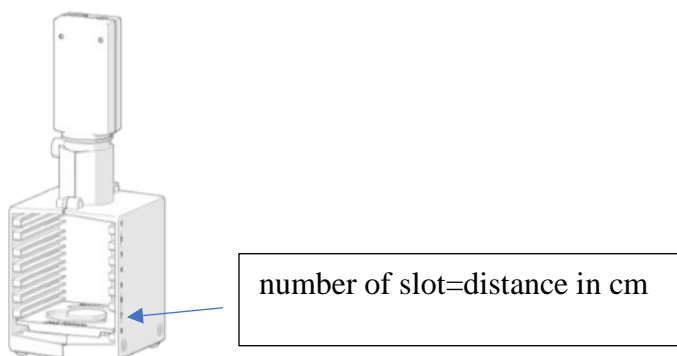


This is called **the background count** because there was no radioactive source nearby. The background radiation is produced by small amounts of radioactive elements in the environment, and radiation produced high in the Earth's atmosphere when cosmic rays collide with atoms.

11. Place a selected natural radioactive source under the Geiger counter in the sample holder in slot 3.
12. Start data collection and wait for data collection to stop after 30 seconds.
13. Subtract the background count from the measurement. Record the result as **the through-air counts and then for the selected absorbers (packed in a box)** for each source in Table 1. The background count should be subtracted from all measurements. If this results in a negative number, record the value as zero. Absorbers should be placed at slot no 1 in the sample holder or above the source, close to the Geiger counter.
14. Place the different absorbers above the different natural radiation sources according to the table. Measure and record the counts in **Table 1. Select a natural source of radiation with the highest counts for the second part of the experiment.**

## PART II:

1. Place the radiation source on the sample holder tray and place it in the lowest slot 8 (distance of 8 cm from the Geiger counter) as presented in the picture below.



2. Start recording data. When the recording stops after 30 s has elapsed, record the count rate in **Table 2**.
3. Repeat the count rate measurements for the remaining distances (slot 7, 6, 5, 4, and 3) and write your results in Table 2. Create a graph in an Excel file with count rate on the vertical axis and distance on the horizontal axis (include in your conclusions).

### Questions to answer in final report:

1. The 3 most common types of ionizing radiation are called alpha, beta, and gamma. They are called ionizing radiation because they have enough energy to knock electrons off atoms, therefore ionizing them. When radiation was first discovered, the types were distinguished by their ability to penetrate materials. Alpha radiation had the least ability to penetrate materials. Beta radiation was the next most penetrating. Gamma radiation was the highest penetrating.
  - a) Based on the collected data in Table 1 and Table 3 below, identify the type of radiation coming from each natural radioactive source and explain your reasoning.
  - b) Identify low or high LET type of radiation in your results and write in the table.

Table 3:

Radioactive sample	Through air (counts/30s)	Through paper (counts/30s)	Through an aluminum (counts/30s)	Through a plastic (counts/30s)	Through wood (counts/30s)	Type of radiation
<b>Cs-137</b>	771	98	107	157	119	$\gamma$
<b>Sr-90</b>	99	97	61	85	53	$\beta$
<b>Co-60</b>	33	31	22	28	27	$\gamma/\beta$

2. Alpha radiation consists of 2 protons and 2 neutrons. It is a fast-moving helium nucleus. Beta radiation is a fast-moving electron. Gamma radiation is a photon. The mass, charge, and average energy of each type of radiation are shown in Table 4 below. Based on the data in Table 1 and Table 4, what factor(s) are more important for predicting the ability of radiation to penetrate material? Explain your reasoning.

Table 4: Radiation types

Radiation Type	Mass (AMU)	Charge (e)	Average Energy (MeV)
Alpha	4	+2	~5
Beta	0.00055	-1	< 1
Gamma	0	0	~1

3. The natural radioactive samples used in this lab are safe for student because of their low activity. A large amount of radioactive material is used in some medical equipment. Would it be more effective to protect medical workers and patients using shielding or distance? Does the answer depend on the type of radiation being produced? Explain your reasoning based on your results collected, also in Table 2.