E.5 THE CHARACTERISTICS OF A GEIGER-MULLER TUBE.

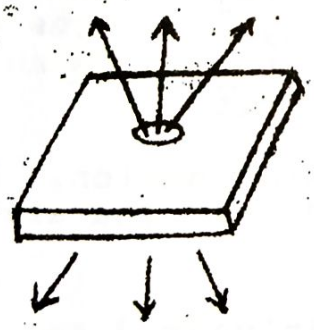
WARNING: READ CAREFULLY.

In this experiment you will be using radioactive materials. The radiations given off by the materials you will use are not detectable without special apparatus. DO NOT LET THIS GIVE YOU A FALSE SENSE OF SECURITY: you will not feel or see anything, but the radiation is still there. All radioactive materials are potentially dangerous - the results of misuse may not be spectacular or even immediately obvious, but long term, and in particular genetic, effects may develop unoticed until too late for treatment.

Do not be too alarmed by this warning! The sources you will use are very weak and have been passed as safe by the authorities for use in schools and universities. But remember, electrical appliances have also been passed as safe and are available for your use, but with mishandling, these can kill! The same rules apply to both: electrical appliances and radioactive sources are perfectly safe, IF CORRECTLY USED. So, for your own safety, observe the following general precautions:

1) Keep as far away from the source as possible (within reason, that is - say at arms length: there is no need to sit at the next bench!). Handle the source only by the extreme edge of the plastic base.

2)



The radiations from the sources you will use are emitted perpendicular to the plane of the base. Therefore as far as possible, always hold the source "edge on" towards you. Avoid pointing the flat surface of either side of the base towards you.

3) Above all, NEVER EVER bring a source up close to your eyes.

When you are ready to start the experiment detailed below, ask the tutor for a radioactive sample. The tutor will give you a lead plate with the sample. Lead is extremely effective at absorbing all types of radiation. When the source is not in the use, place it flat on the bench and cover it with the lead plate.

The theory of the Geiger-Muller tube will be dealt with in lectures. The purpose of this experiment is to make you familiar with its operation. The apparatus consists of two parts: (1) the tube itself, and (2) an electronic counter or 'scalar'.

First of all inspect the tube. This is delicate and expensive, so handle it very carefully. On the front of the tube is a blue plastic cap. This is there mainly for protective purposes: underneath is an extremely thin "window" made from a material called mica. The purpose of the window is to hold the inside of the tube at a low pressure yet at the same time allow radiation to pass through it. The cap also has the effect of reducing the sensitivity of the tube, and for some experiments it may have to be removed. Take it off carefully and inspect the window:- do not touch it, it is extremely fragile. Replace the cap and leave it in place for the rest of this experiment.

Now inspect the scalar.

Follow the procedure below:

1. Switch on the unit at the mains.

2. Press the reset button: all figures on both the mechanical and the electronic display should then read zero.

3. Switch the G.M./1 kHz switch to 1kHz.

4. Press the start button under the mechanical display. The scalar will immediately start to operate as a clock. The second figure from the right on the mechanical counter registers seconds. Figures to the right of this register tenths, hundredths and thousandths of a second respectively. Figures to the left thus register tens, hundreds, thousands and tens of thousands of seconds respectively.

5. Stop the counter by pressing the stop button. How many seconds does the display read? If you are in doubt consult the demonstrator.

You will use a scalar in this manner in year 3 and so you should be familier with its operation. In this experiment, however, you will use the scalar in conjunction with a Geiger-Muller (G.M.) tube to register counts from a radioactive source. Switch off the unit and then proceed as follows.

1. Plug the lead from the G.M. tube into the socket marked GM on the front panel of the scalar.

2. Turn the E.H.T. knob (extra-high-tension) to its minimum of 250 volts.

3. Set the G.M./1 kHz switch to GM.

4. Switch on at the mains.

5. Reset the display (this must be done every time you want to take a reading).

You are now ready to start the experiment. Place the radioactive $^{90}Sr/^{90}Y$ into the holder on the adjustable upright stand and adjust the holder until the source is about 6 cm away from the end of the G.M. tube. Make sure the source is the correct way up i.e. with the small hole in the perspex plate facing the tube.

In order to obtain a measure of the intensity of the source, readings must be taken of the number of counts (or pulses) recorded by the scalar per minute. To do this you must measure the number of counts recorded in a certain time, using a stopwatch or stopclock.

Have a practice as follows:

1. Set the E.H.T. knob to about 400 V.

2. Simultaneously depress the start button and start the stopwatch.

3. Stop the scalar by depressing the stop button when the stopclock reaches a time of 1 minute.

4. Read the display. This will thus give you directly the number of counts per minute (c.p.m.).

When you are sure you have mastered this technique (try it several times if necessary) then continue as follows:

Set the scalar to count and turn down the E.H.T. until you reach a point at which the counting stops. Set the E.H.T. to the nearest division below this point (you will probably find that it is 330 or 340 volts). Reset the scalar to zero.

Now take readings of c.p.m. against E.H.T. voltage. Gradually increase the voltage for each reading. At first, as you reach the "threshold" voltage at which the tube starts to operate, the count rate will increase dramatically. At the start therefore, increase the E.H.T. voltage by only 1/2 a division at the most (equivalent to 5 volts), even less if possible, for each reading. When you reach higher voltages (about 400 V) the count rate will level off in this region it is only necessary to take readings every 2 divisions (20 V). Continue taking readings until you reach the maximum of 500 V.

Plot a graph of c.p.m. against E.H.T. voltage. Find the threshold voltage (the voltage at which the tube starts to operate) from your graph.

Find also the voltage at which the count rate starts to level off. This is called the "Geiger-Threshold". Above this voltage is the "plateau" region of the curve, where the c.p.m. changes much less rapidly with voltage. A Geiger-Muller tube should always be operated in the centre of this plateau region.

Background Count.

Set the E.H.T. to a suitable voltage near the centre of the plateau region. Maintain this setting for the rest of the work in this Unit.

Remove the radioactive source from the stand and place it safely to one side, with the top face covered with a sheet of lead.

Start the stopclock and counter simultaneously. You will notice that a small count is registered. This is due to "background radiation" which is always present in the enviroment. Stop the counter after 10 minutes and record the value of this background count. Convert your figure into an average c.p.m.

If you are measuring the intensity of radiation from a radioactive source which is very weak (i.e. small c.p.m.) then the presence of background radiation can introduce a serious error into your results. It is thus always necessary to measure the background count. If this count is significant compared with any measurements you are making with a radioactive sample, then the background count must be subtracted from your readings to obtain the correct results.

Absorption of Radiation

All radiation is absorbed to some extent by matter. In the case of β-rays and γ-rays this absorption is approximately exponential which means that the intensity I (no. counts per second) after passing through a thickness x of matter is related to the incident intensity I_o by the equation:

$$I = I_o e^{-\mu x}$$

where μ is a constant for a given material and is called the ABSORPTION COEFFICIENT of the material.

The source $^{90}Sr/^{90}Y$ which you have used so far is a β-source. The radiation emitted from it should thus approximately obey the above equation.

You are provided with a box of absorbers, mostly lead and aluminium. With the β-source still 6 cm from the tube, and with the counter in operation, place the thickest piece of lead available between the source and the tube. Notice how effectively it absorbs the β-rays.

In this part of the unit you are to investigate the absorption of the β-particles by the aluminium absorbers (7 of these are available; and to obtain data to check the intensity relationship given above. Notice from this relationship that a graph of $\ln I$ versus x should be a straight line of slope $-\mu$.

The actual average thickness of the aluminium absorbers can be calculated from the data stamped upon each absorber: this gives their mass per unit area (in mg/cm^2). Given that the density of aluminium is 2.7×10^3 kg/m^3, the mean thickness of each plate can be found.

Measure the count rate with the source at 6 cm from the tube over the minute intervals with each aluminium absorber in turn placed between the source and the tube. Finally, measure the count rate with no absorber present. This gives you a total of 8 readings. Correct each of these for background count and then plot a graph to obtain a value of μ. Since the exponential law is only approximately obeyed, you may find that a ln graph of your data gives a slight curve. If this is the case, draw the best straight line possible.