FARLab Radioactivity Lab Notes

Warning! **Warning!**

Avoiding radiation

In the FAR Labs Turntables section you deal with different types of radiation and that for each of these different types, there are different barriers that can shield you from some or all of the radiation being emitted. But a little bit always gets through. And what if there is no barrier at all?

Want to know the best way to avoid radiation poisoning? RUN AWAY!

Radiation can travel a very very long way. Think of the radiation from the sun, which is a long way away, but still bombards the earth. And the light from very distant stars, including Gamma rays, can still reach us.

However, the distance you are away from the source of the radiation is still very important.

Two examples of putting distance between people and radiation are the Chernobyl and Fukushima Daiichi nuclear accidents. After the nuclear accidents at each power plant, “exclusion zones” were set up so that people wouldn’t live, or go too close, to these radioactively contaminated areas.

Chernobyl

The Chernobyl nuclear accident occurred on the 26th of April 1986 at the Chernobyl Nuclear Power Plant in Ukraine. During an experiment being run to test a safety emergency core cooling feature (which are very important in stopping the reactor from overheating and causing a meltdown) the core exploded and released huge quantities of radioactive particles into the atmosphere that spread over most of Europe. Below, there are pictures of the reactor after the accident and a picture showing the increase in radiation levels in Europe after the explosion.

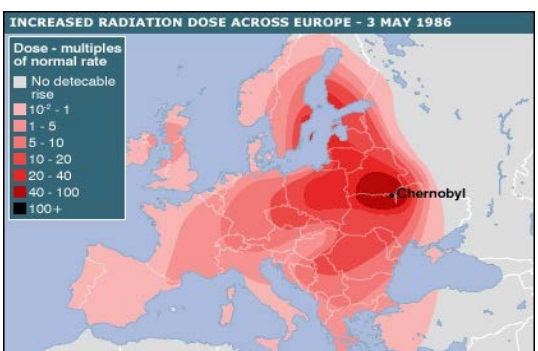


Figure 1: Level of background radiation increase across Europe one week after the Chernobyl disaster. Notice how the dose level decreases quickly from 100 times the normal dose rate near Chernobyl, back to the normal background rate as you move further away.

Figure 2: The Chernobyl nudear reactor after the disaster.

Did you know?

- The Ukrainian government set up an "exclusion zone", 30km in all directions from the wreckage of the nuclear power plant to restrict access to "hazardous areas".
- However, there are still a few hundred people living in the Chernobyl exclusion zone. These are elderly people who are not afraid of the radiation and have chosen to live on in the village they grew up in rather than move to the city.

The Louis Slotin Incident in 1946

Before the age of nuclear power plant accidents there was Louis Slotin. He was a Canadian physicist who on the 21st of May 1946, performed an experiment to show the how first steps of a nuclear reaction would be created (although he didn't intend on actually doing it!) by placing two half spheres of Beryllium around a Plutonium core. As long as the spheres were separated, nothing would happen and Slotin kept them apart using a screwdriver. As with most accidents involving radiation, human error and carelessness resulted in his hand holding the screwdriver slipping and letting the two half spheres come into contact. This started an immediate nuclear reaction releasing an intense burst of radiation.

Figure 3: Louis Slotin

Scientists in the room said they saw a blue glow and felt a heat wave. Slotin said he experienced a sour taste in his mouth and burning in his left hand.

Several people in the room that day, including Slotin, would eventually die of conditions related to radiation exposure. The amount of radiation they received and the severity of their illnesses can be directly related to where they were in the room at the time!

Did you know?

- Louis Slotin and Alvin Graves (standing closest to Slotin at the time of the accident) both tended to ignore any safety procedures and exposed many people they worked with to high levels of radiation. Graves was even quoted as saying the risks from nuclear fallout were "concocted in the minds of weak malingerers". He died of a heart attack 20 years later that was likely caused by his exposure to radiation.

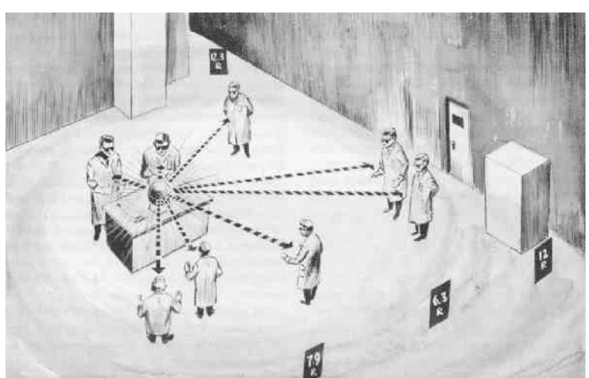


Figure 4: Drawing of the positions of everyone in the room when Slotin accidentally set off the reaction that killed him.

In this remote laboratory experiment you will investigate exactly how distance is related to the intensity of radiation absorbed and what relationship they have.

Exploring the Intensity of Radiation

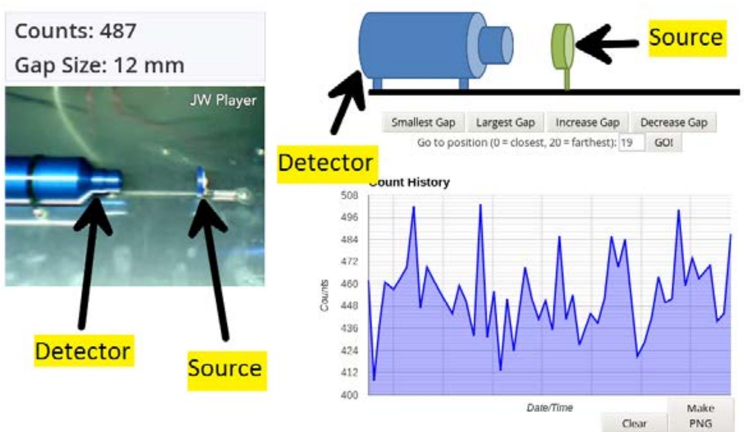
Changing the distance from the radioactive source

In this FAR Lab experiment you will monitor and plot the number of counts recorded by a Geiger counter as you *increase the distance* from the source.

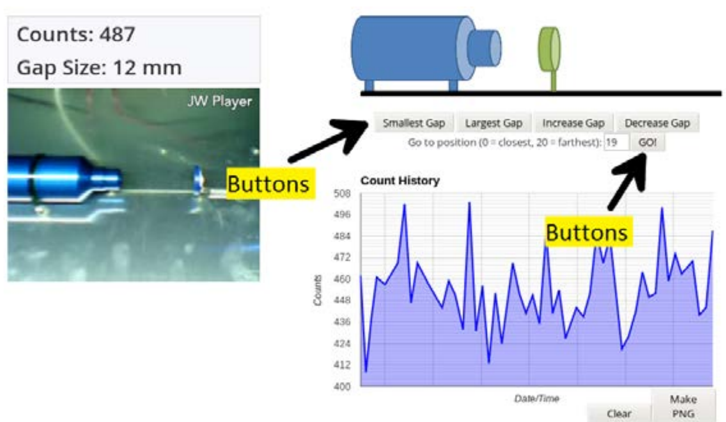
In this experiment it doesn't matter what kind of radiation it is. All that matters is how the number of counts changes as you get further away from the detector.

We know that radioactive emissions are potentially very harmful to humans. If there is no barrier between us and a radioactive source, how far away do we need to be to be safe?

- In the middle of the screen there is a diagram showing the radioactive source (Green) and detector (Blue). The detector and source can also be seen in the video feed to the left . Underneath the diagram, there are buttons labelled "Smallest Gap", "Largest Gap", "Increase Gap" and "Decrease Gap".



- The buttons help you move the source to 11 different positions ranging from 5 mm to 75 mm from the detector. If you want to move a large distance in a short amount of time, you can type in a number from 0 to 10 in the text box and click the "GO!" button. Clicking the "Increase Gap" and "Decrease Gap" buttons moves the source by a small amount.



What we're most interested in is the effect distance has on the "Counts" at the detector. We are going to **plot a graph** of Counts versus distance. What do you think your graph will look like? A curve? A straight line?

Plotting your graph

Method:

1. Make sure that your source is as close to the detector as possible. You can do this by clicking the "Smallest Gap" button underneath the diagram (Check that the source is right up against the detector in the video feed on the left). The "Gap Size" should say 20 mm.
2. Wait for a few seconds and then take at least five recordings of the "Counts" and make a note in your lab books OR
3. Use the "Count History" graph next to the video screen to record the counts. Wait for your Count History graph to record at least 15 seconds of data then click the "Make PNG" button under the graph. A snapshot of the graph at that point will open in a new window.
4. Find the average by adding up your recordings and dividing by 5 (if you did step 2 and wrote down 5 numbers) OR by ruling a straight line horizontally across your Count History graph where you think the middle value is (if you did step 3).
5. Once you find the average you can start filling in the table below the video feed. The number for the "Gap Size" is above the video feed while the "Average Counts" is the average you just found.
6. Repeat this process for several different distances and keep filling in the table. Ask your teacher how many distances you need to do.
7. When you have enough values, you can see what your graph looks like by clicking the "Plot" button. Before you click Plot ask your partner what they think the graph will look like! What do you think?

Question:

1. What shape did the graph have? Was this what you expected?
2. If you double the distance away from the source what happens to the counts?
3. Do you think that a different radiation source (alpha/beta/gamma) would produce a different graph? If so, how? Would the shape be different?

Can you explain why the Counts decrease in the way you have observed?

Radiation and the "inverse-square" law

If you have done the FARLabs Turntable experiment, you would know that radiation comes in many forms, including alpha, beta and gamma radiation. BUT did you know that regardless of the type, ALL kinds of radiation are emitted from the source in the same way?

Each little piece of radiation (alpha particle, beta particle or gamma ray) is emitted from the source in a RANDOM direction. It then travels in more or less a straight line.

Imagine two gamma-rays emitted from the same place, but in slightly different directions. As they move away from the source, they get further and further away from EACH OTHER. They are spreading out.

You might like to try this with people in your class room. Stand next to each other then all start walking in slightly different directions, but all walking in your own straight line. You will notice that you get further from each other as you walk.

The *separation* between two people (or two radiation particles) *increases* as you move from the place where you started. Increase the distance from the starting point and the separation between particles increases.

Now if we think about the Geiger detector which counts the intensity of the radiation, as we get further from the source, the particles get further and further apart. This means less of them enter the detector together. This is why the counts at the detector decrease as it gets further from the source. Each individual particle is just as "powerful" – they don't slow down much at all … but less of them enter the detector together.

Here are some examples:

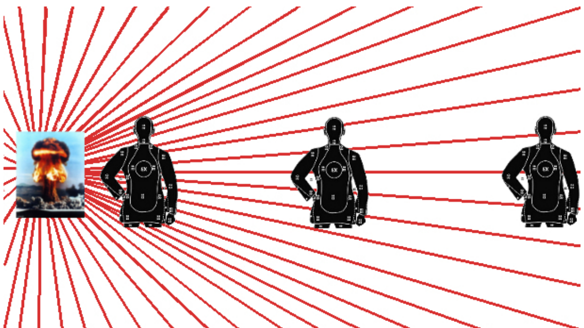


Figure 5: Here, a nuclear test sends damaging particles in all directions. A single particle will do just as much damage 20 kilometres away as it will 2 kilometres away. But if the target is closer, A LOT more particles will hit it!

Figure 6: Below is a picture of water being sprayed from a hand-held pump. Water droplets sprayed from the nozzle come out in many directions. If you are very close to the spray, you get very wet. Further away, you just get a little damp!

The "inverse-square" law

If the distance from the source *doubles*;

- the separation between particles *doubles*
- the number of particles *per metre* is *halved*.

So the number of particles per *square* metre is *quartered*.

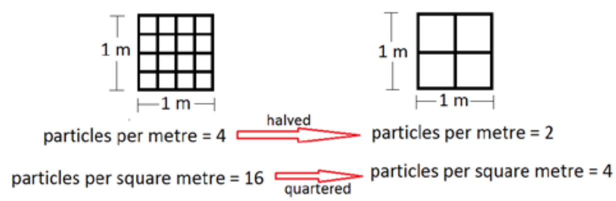


Figure 7: If the number of particles per metre is halved, the number of particles per square metre is quartered.

So the number of particles entering the detector is quartered if the detector is twice as far away! This is what you should have seen in the experiment.

What does "inverse-square" mean – a more advanced explanation

In the diagram to the left, as the distance from the source increases, the *same* number of particles (9 – count them!) are passing by. But the area covered by the 9 particles is *increasing* as they spread out, at a rate equal to the distance squared. This means double the distance and you double × double = quadruple the area (for example, going from "**r**" to "2 **r**" in the picture). So, the number of particles *per square metre* (which is actually what the detector counts!) is *decreasing* at a rate equal to the distance squared. This is what "inverse-square" means.

At distance **r** we have 9 particles spread over 1 square metre; $^{9}\!/_{1} = 9$ particles per square metre. At distance 2 × **r** we have 9 particles spread out over 4 square metres; $^{9}\!/_{4} = 2.25$ particles per square metre and at distance 3 × **r** we have 9 particles spread out over 9 square metres; $^{9}\!/_{9} = 1$ particle per square metre.

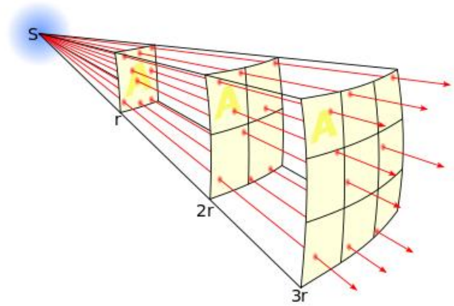


Figure 8: The inverse-square law. The same number of particles passing through an increasing area means the particles per square metre decreases with distance.