Experiment 9 Simulated Radiation Using Virtual Dice

William Wagner

Alex Yeoh

We chose an online die rolling website of our choice, in my case it was rolladie.net, and simulated what would happen with the situations we were given. We used the data we collected to calculate expected averages, radioactive decay, and radiation penetration.

**Experiment 9: Simulated Radiation Using Virtual Dice**

In many areas of physics, the statistical mechanics of gases, the radioactive decay of nuclei, and even the quantum mechanical description of electrons in an atom, individual events are governed by chance. We will use dice to simulate these random events, and see how they result in averages that describe a much more predictable behavior.

In this experiment you will use a dice rolling simulator to roll virtual 6-sided dice.

Enter “dice rolling simulator” into a search engine and you should have several sites that would work for this experiment. Make sure that the site uses 6-sided dice and that you can “throw” multiple dice.

**Part 1: Single Events and Their Averages**

When rolling a 6-sided die there is a 1 in 6 chance that a particular number will result. What is of interest is when you repeat an event (rolling the die) several times and average the results over the number of times it was repeated you would expect a particular average value to come about.

**Question 1:** Before throwing any dice, what would you expect the overall average value to be when rolling a 6-sided die several times? Record your answer on the Excel worksheet.

Throw a single die ten times, recording the numbers that come up into table 1 on the worksheet. Determine the average of these ten throws and write this in the box at the bottom of the column.

Some websites will have you “reset” before “throwing” a new roll

Next, “throw” ten dice at a time. Adjust the number of dice to be thrown on the simulator so that it will “throw” 10 dice. If the online simulator only throws one die at a time you will either have to do multiple throws, or choose a different online simulator. Determine the average for each throw by dividing the sum of the numbers by ten. Write these values in the column marked “Average of 10 Throws” in table 1. When finished, determine the average of these averages (which is also the average for 100 throws), and record it at the bottom of this column. For the Average of 100 column just repeat the same technique you used for the Average of 10 column except now you will click on the 100 roll dice button. Some websites might not be able to “throw” 100 dice, so you may have to either do multiple rolls to achieve 100, or find another website that does throw 100 dice.

In the following questions you will compare: (a) the average of your 10 throws; (b) the average of your 100 throws; and (c) the average of the class’s 1000 throws with this expected average (or expectation value). Also, compare the range of values for: (a) single throws; (b) averages of 10 throws; and (c) averages of 100 throws.

As can be seen from the data, as more dice are thrown the average value approaches a particular value.

**Answer the following questions, using complete sentences, in your written report. Make sure to number your answers to correspond with the number of the question.**

**Question 2:** What expected average value is being approached?

An average of 3.8 was being approached.

**Question 3:** Does this value equal your expected average that you answered in question 1? If not, how far off were you?

This value is larger than the expected average from question 1 by 0.3.

**Question 4:** How did the average of the 10 single throws compare to the expected average?

The average of the average of 10 throws approached 3.65 which is closer to the expected average, only exceeding it by 0.15.

**Question 5:** How did the average of a 100 throws compare to the expected average?

The average of the average of 100 throws was equal to the expected average.

**Question 6:** How did the average of 1000 throws compare to the expected average?

The average of 1000 throws approached 3.49 which is 0.01 smaller than the expected average.

**Part 2: Radioactive Decay**

The time it takes for a single radioactive atom to decay to a more stable state could be a few seconds, or could be thousands of years. We cannot know when a particular radioactive atom will decay. However, if we look at a huge number of the same kind of radioactive atoms grouped together we will see that half of these atoms will decay in a certain amount of time. This time is known as the half-life, and is usually denoted as . Different radioactive atoms, such as Cesium-137, and Radium-226 take years for half their initial number to decay (Cesium takes approximately 30 years, while Radium takes 1600 years). They are different because they have different rates of decay. This decay rate, or decay constant, is denoted by the Greek letter λ. The equation for the number of radioactive atoms at a given time is:

Where

N = number of unstable atoms remaining

No = the original number of unstable atoms

λ = decay constant

t = time that has elapsed

If we were to take the natural log of both sides of the equation we would get the following equation:

This takes on the equation of a straight line (y = mx + b). By allowing N to equal to No/2 we can determine that the half-life is equal to:

However, there is an easier way to determine the half-life. By plotting the number N versus the time t on a **semi-log graph** and adding a linear trend line to the data, the half-life can be determined by choosing a particular value for N and noting the time that it occurs and then find the value for N/2 (half the original N) and seeing at what time this occurs. The difference in the two times on the graph is equal to the amount of time it takes for the radioactive atoms to decay to half its original number, or, the half-life.

As stated above different radioactive atoms have different decay rates. You will simulate the different decay rates by removing dice that show a particular value per “throw”. In parts A, B, and C you will start out with 50 dice on the simulator. A particular face value on each die, as stated in each part, will represent that the atom (die) has decayed and given up its energy. “Remove” the decayed atom from the next “throw” of the dice. Say that on your first “throw” of the 50 dice you have 6 of the dice which show the numerical value chosen to represent that it has decayed. You would “remove” these six dice from the fifty so that on your second “throw” you would have 44 dice. On each throw you will remove the dice (atoms) that have decayed and continue to “throw” until either you have no more dice, or you have thrown the maximum number of throws.

**A. Relatively Stable Radioactive Atoms**

Start with 50 6-sided dice selected on the simulator. “Throw” the dice and remove only those dice that exhibit a value of “1”. Record in table 2 the number of remaining dice. “Throw” the remaining dice again and remove only the dice showing a value of “1”, again record the remaining number of dice. Repeat this for a total of 10 “throws”. Make each “throw” equivalent to 1 year of time.

**Question 7:** What is the half-life of this simulated radioactive atom? (show work)

Equation: y = -4.2545x + 44

X=0, y = -4.2545(0) + 44 = 44

Y=22, 22 = -4.2545x + 44, 22 = 4.2545x, x = 5.171

years

**B. Unstable Radioactive Atoms**

A more unstable radioactive atom would decay much faster. To simulate this start again with 50 6-sided on the simulator. With each “throw” remove all dice that exhibit a “1”, or a “2”, or a “3”. Repeat for a total of 10 “throws” and record these values in table 3 on the worksheet. Plot this set of data on a semi-log graph and determine the half-life.

**Question 8:** What is the half-life of this simulated radioactive atom? (show work)

Equation: y = -3.5636x + 28.364

X=0, y = -3.5636(0) + 28.364 = 28.364

Y=14.182, 14.182 = -3.5636x + 28.364, 14.182 = 3.5636x, x = 3.980

years

**Part 3: Radioactive Penetration**

If a gamma ray strikes a barrier, such as a layer of aluminum, it has a certain probability of being absorbed. If it is not absorbed, it passes through unaltered, and has the same probability of being absorbed in the next absorber layer. We can describe this penetration with dice, each “throw” representing a layer of aluminum. Let us choose a 2 out of 6 probability for each absorption. Start with 50 dice chosen on the simulator. “Throw” the dice and remove all dice registering a “1” or a “2” (those absorbed by the first layer) and record the number of gamma rays that are not absorbed in table 4. “Throw” again and remove all “ones” and “twos” (absorption by the second layer). Repeat for a total of 10 “throws”. This time graph your results with a regular quadrille graph and see the characteristic decay curve. Smoothly fit a curve to your data points on this graph.

**Question 9:** How many “layers” of aluminum will reduce the initial number of gamma rays to half? Determine this from your graph.

Equation: y = 54.661e-0.323x

X=0, y = 54.661e-0.323(0) = 54.661

Y=27.3305, 27.3305 = 54.661e-0.323x, 0.5 = e-0.323x, ln(0.5) = -0.323x, x = 2.146 ≈ 2 layers

**Question 10:** How many “layers” of aluminum will reduce the initial number of gamma rays to zero?

Equation: y = 54.661e-0.323x

X=0, y = 54.661e-0.323(0) = 54.661

Y=0, 0 = 54.661e-0.323x, 0 = e-0.323x, ln(0) = -0.323x, undefined so we have to go slightly over 0

Y=0.001, 0.001 = 54.661e-0.323x, 1.829\*10-5 = e-0.323x, ln(1.829\*10-5) = -0.323x, x = 33.774 ≈ 34

An infinite number of layers are required for the initial number of gamma rays to reach zero, but 34 layers would have a very high likelihood of reducing the initial number of gamma rays to zero.

**Results:**

In your Results section write about how well the data points follow the fitted trend line in each graph. If the data points don’t exactly fall on the trend line discuss why this may be so (think probability when answering this). Also, write about the correlation between using dice to simulate radioactive decay and penetration.

For the graphs of table 2 and table 3, the data points don’t follow the trendlines very well, but that is likely because a linear trendline was used to calculate the half-life of 50 dice given the situation; however, the graph for table 4, fit the trendline fairly well but the individual points were never on the trendline, this is likely because each ray (die) has a 1/3 chance of being blocked (rolling a 1 or 2) but it is likely that the number of dice rolling either of those numbers will not be exactly 1/3 of however many dice remain, but rather close to 1/3 of the dice. Using dice to simulate radioactive decay and penetration makes sense because they both rely on probability, there is no way of knowing when exactly, for example, half of a radioactive sample will decay because the chance of decay is entirely down to probability, there is always a slim chance that after the half-life of a sample has passed, none of the material has decayed, it is simply extremely unlikely.