Final Project 2: Shielding a nuclear reactor

During the World War II scientists in Los Alamos (Manhattan project) had to find how far neutrons would travel in different materials. Results were important for the calculation of critical masses as well as shielding. The physicists knew most of the basic data and their dependences on the neutron energy, namely, the average distances between collisions of a neutron with an atomic nucleus, the probabilities of neutron elastic or inelastic scattering, probability of capture by an atomic nucleus, the energy loss of the neutrons after each collision. However, it was not clear how to use all this information to find a solution. Ulam and von Neumann solved the problem by a novel numerical approach i.e. simulating a path of a neutron using random numbers. This project below is a very simplified version of the original problem solved by Ulam and von Neumann.

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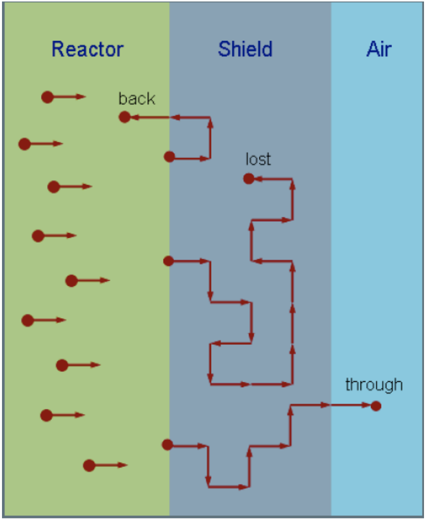
A beam of neutrons bombards a reactor's wall. Considering motion of neutrons as a random walk on (x,y) plane find probabilities for neutrons (as a function of the shield size)
a) to be back in the reactor,
b) to be captured in the shield,
c) to get through the shield.
The shield size is measured in "steps", where one step h corresponds to an average distance that neutrons move between collisions. Consider shield sizes from h to $50h$.



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Conditions:

- only four directions of motion are possible (left, right, up or down)..
- on the next step the neutron can not step back, but only forward, left or right, and
- the probability to go forward is two times more than changing a direction
- on each step the neutron looses one unit of energy
- initial neutron energy is enough for 100 steps
- initial neutron velocity is perpendicular to the shield
- a capture probability on every step is 0.01

Assume that the probability P to get through the shield has the asymptotic exponential dependence as $P \sim e^{-ax}$ with x is the size of the shield. Estimate the exponent a.

Extra credit (5 points) : obtain a by least squares method applied to $\log P$. Assume that the dispersion σ_n of probability P_n with the shield size nh is proportional to $1/\sqrt{n}$.