Homework 2: Radioactive Decay

To simulate how a **small** number of radioactive particles decay. In particular, to determine when radioactive decay looks exponential and when it looks stochastic (determined by chance).

Because the exponential decay law is only a large number approximation to the natural process, our simulation is closer to nature than the exponential decay law.

Radioactive Decay

Theory: Spontaneous Decay

Spontaneous decay is a natural process in which a particle, with no external stimulation, and at one instant in time, decays into other particles.

Because the exact moment when any one particle decays is random, it does not matter how long the particle has been around or what is happening to the other particles.

Radioactive Decay

In other words, the probability P of any one particle decaying per unit time is constant, and when one particle decays it is gone forever. So as the number of particles decrease with time, so will the number of decays.

The number of decay events -dN over an interval dT is proportional to the number of atoms N

$$-\frac{dN}{dt} \propto N$$

The probability of decay -dN/N is proportional to dT

$$-\frac{dN}{N} = \lambda \cdot dt$$

Each radionuclide has its own decay constant, λ, describing its decay. λ has units of 1/time.

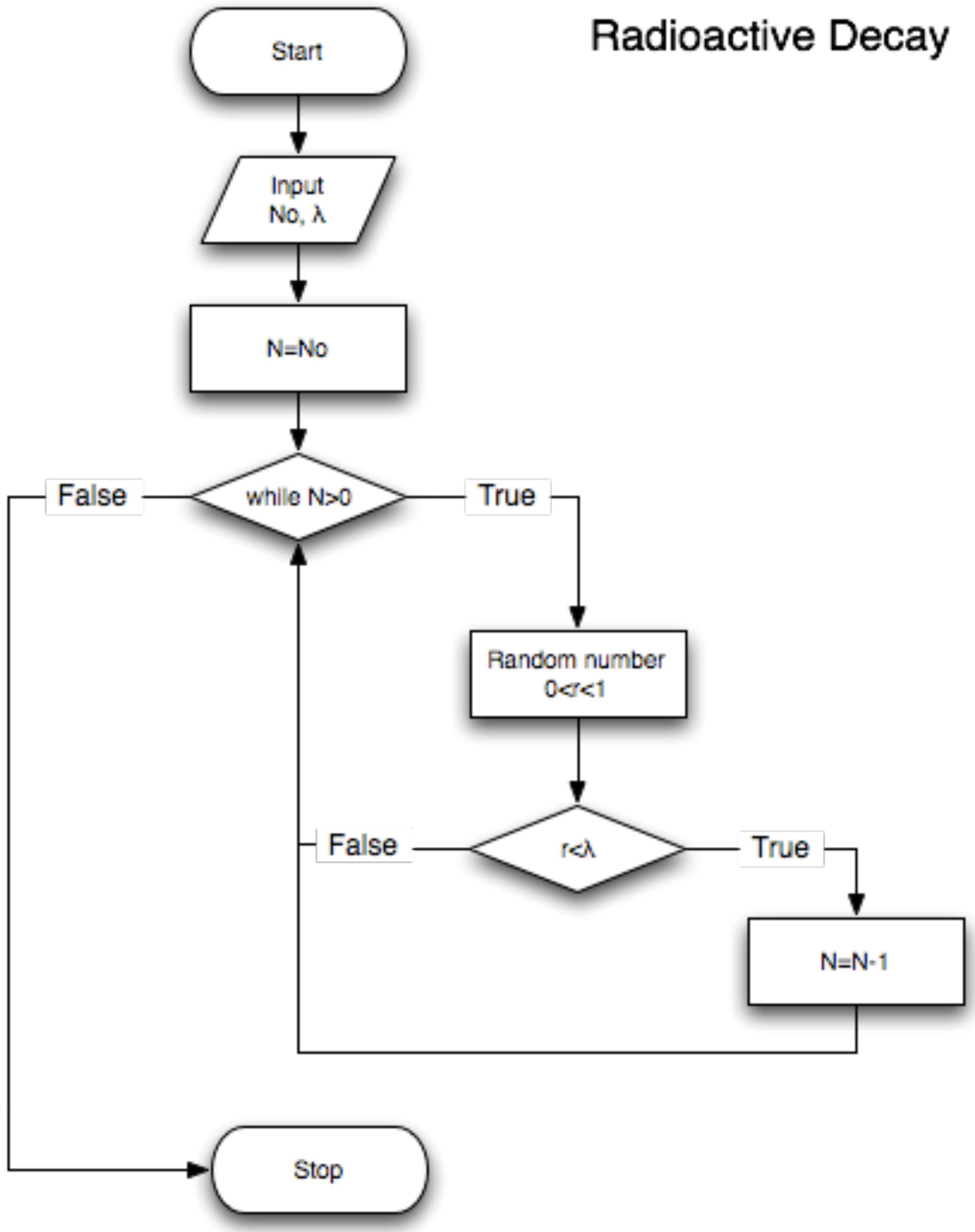
$$N(t)=N_0 e^{-\lambda t}=N_0 e^{-\frac{t}{\tau}}$$

$$\tau = \frac{1}{\lambda}, \text{ and } \lambda = \frac{1}{\tau}$$

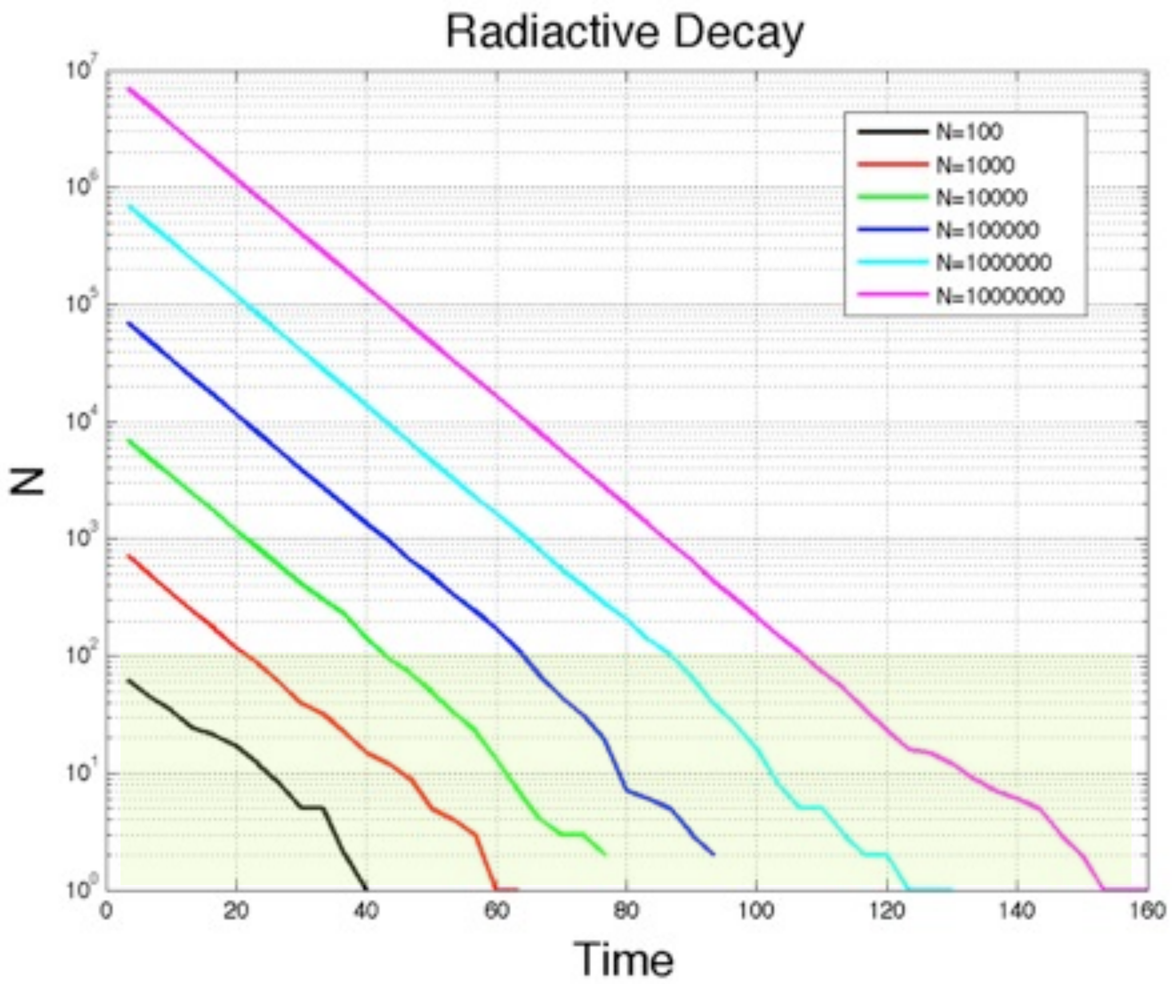
$$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \tau \ln 2$$

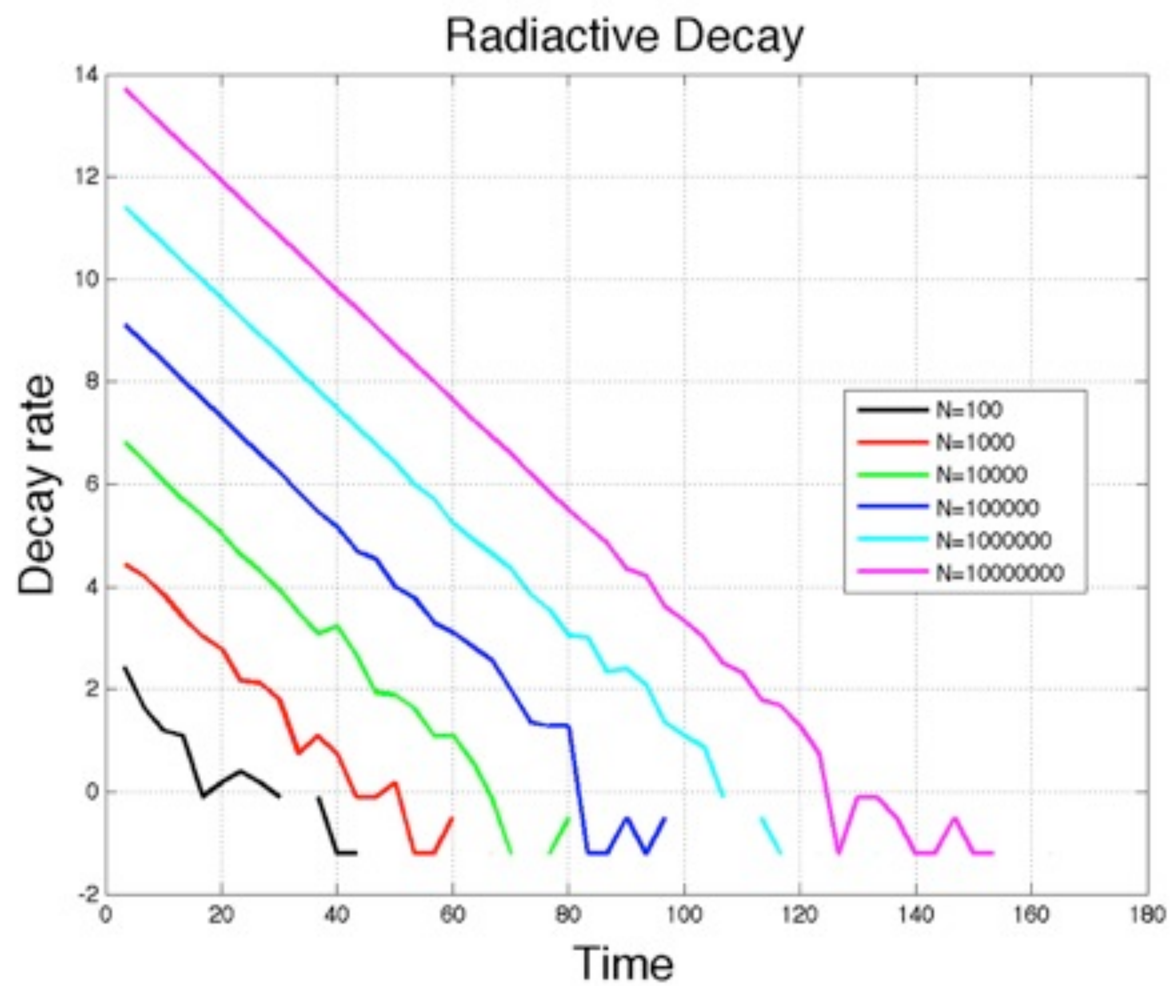
Homework 2

Radioactive Decay



- Implement and visualize a Monte Carlo Simulation of radioactive decay. Start with 10^n radioactive atoms where n is 2,3,4,5,6, and 7.
- First of all start with $\lambda=0.3$. Time for one generation is λ^{-1}.
- Determine when the decay starts to be stochastic.
- Plot the decay versus time.
- Plot the decay rate ($\lambda\Delta N$) versus time.
- Try a range of λ, and verify that the decay is still exponential and that λ determines the decay rate.


Radiactive Decay
N
Time
N=100
N=1000
N=10000
N=100000
N=1000000
N=10000000


Radiactive Decay
Decay rate
Time
N=100
N=1000
N=10000
N=100000
N=1000000
N=10000000