CBE 5790 Modeling and Simulation (Autumn 2018)

Homework P0

Deadline for uploading program to Carmen: Thu, Sep 13 at 2:20 PM
Deadline for completing Carmen quiz: Thus, Sep 13 at 11:59 PM

Problem P0 – Radioactive decay chains

A portion of the radioactive decay chain for the radon $^{222}_{86}\mathrm{Rn}$ isotope is tabulated below.

isotope	$^{222}_{86}\mathrm{Rn}$	$\longrightarrow$ $^{218}_{84}\mathrm{Po}$	$\longrightarrow$ $^{214}_{82}\mathrm{Pb}$	$\longrightarrow$ $^{214}_{83}\mathrm{Bi}$	$\longrightarrow$ $^{214}_{84}\mathrm{Po}$	$\longrightarrow$ $^{210}_{82}\mathrm{Pb}$
$t_{1/2}$	3.8235 days	3.10 min	26.8 min	19.9 min	164.3 μs	22.2 yr
type of decay	α	α	β^-	β^-	α	β^-

Background: Read the "*Radioactive decay*" handout in the Supplemental Material page on Carmen. This handout describes two approaches for modeling radioactive decay: a continuous-variable deterministic approach, and a discrete-variable stochastic approach.

Assignment: Professor Rathman has written a Python program to simulate a discrete stochastic model of radioactive decay in which n_0 atoms of pure $^{222}_{86}\mathrm{Rn}$ at time zero decay over a period of several days. Given the relatively long half-life of $^{210}_{82}\mathrm{Pb}$ we do not need to consider the further decay of this isotope, which ultimately results in the formation of the stable element $^{206}_{82}\mathrm{Pb}$. His program is shown on the next page. It's a pretty nice program. It works. It gives correct results. Unfortunately, Professor R did a lousy job commenting his code and so he may well fail this assignment unless you can help.

Your job is to carefully study this program and then rewrite it, adding comments to properly document the program and explain what's going on at each step. Remember that you can use the dreaded octothorpe (#) to create comments on a single line and you can also use triple single- or double-quotes (''' or """) to start and end comment blocks.

In the lecture notes (slides 107 and 108), we discussed two possible algorithms for this problem. Determine which algorithm Professor R used and be sure to mention this in your comments.

How to submit: Upload your script py-file on the Assignments page in Carmen. Also complete the Carmen quiz for problem P1.

```python
# -*- coding: utf-8 -*-
"""
CBE 5790 Homework P0
James F. Rathman
Created: 2015-07-27
Revised: 2018-09-06
"""

import numpy as np
import matplotlib.pyplot as plt

n0 = (20, 0, 0, 0, 0, 0)
thalf = np.array((3.8235*24, 3.10/60, 26.8/60, 19.9/60,
    (164.3e-6)/3600, 22.2*365*24))
tau = thalf / np.log(2)
dt = 0.1
tmax = 500.

t = np.arange(0., tmax, dt)
p = np.exp(-dt / tau)
n = np.zeros((t.size, 6), dtype = np.int)
n[0, :] = n0

for i in range(1, t.size):
    n[i, :] = np.random.binomial(n[i-1, :], p)
    d = n[i-1, :] - n[i, :]
    n[i, 1:] = n[i, 1:] + d[:-1]

lines = plt.step(t, n)
plt.title('CBE 5790, Homework P0')
plt.xlabel('time (hr)')
plt.ylabel('number')
plt.legend(('$^{222}$Rn', '$^{218}$Po', '$^{214}$Pb', '$^{214}$Bi',
            '$^{214}$Po', '$^{210}$Pb'), loc = 'best')
```