Name: PHY401 (Spring 2013), 01/15/13

Homework Assignment #1

(*Due Date*: Thursday, January 24, 05:30 pm, in class)

1.1 *Nuclear Waste* *(6+4+1 pts.)*

The $^{137}_{55}Cs$ isotope is one of the main medium long-lived radioactive waste of spent nuclear fuel, decaying through energetic β radiation with a half-life of $T_{1/2} = 30.2$ *years* (recall that the "lifetime" $\tau = 1/\Gamma$ as introduced in class is related to the half-life by $\tau = T_{1/2}/\ln 2$; why?). Suppose you want to dispose of $45kg$ of $^{137}_{55}Cs$ (recall that 1 *mol* of a substance, which has a mass corresponding to the atomic mass-number in *grams*, contains N_A=6.022 $\cdot$ 10^{23} particles).

(a) Write a FORTRAN code to numerically calculate the activity of the sample, defined as $R_{Cs}(t) = -dN_{Cs}/dt$, over the first 100 *years*. Use a time-step width of 0.5 *years*. Plot the result in units of $Ci = Curie$ ($1Ci = 37GBq$ with $1Bq = 1$ decay per second) together with the exact (analytical) solution in the same graph (use, e.g., GNUPLOT). Attach both the plot and your fortran source code.

(b) Investigate the accuracy of your result as function of the time-step width by increasing (and decreasing) it to 5(0.05) *years* and replot. Evaluate the percentage deviation from the exact result after 150 years. Does the deviation show the expected scaling with the three time scales in the problem (i.e., Δt, τ and t_f)?

(c) Suppose you irradiate the radioactive Cs waste (e.g., by putting it back into a reactor) so that its decay rate increases by a time-dependent factor $f(t) = [1 + 2/(1 + t/5y)]$. By which factor does this reduce the activity of the waste after 100 *years*?