

**DEPARTMENT OF PHYSICS
INDIAN INSTITUTE OF TECHNOLOGY, MADRAS**

PH2140 Mathematics on the Computer

Assignment 1

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Fitting data to a curve: half-life of $^{137\text{m}}\text{Ba}$

The data file Cs137.dat has data from a radioactive decay experiment involving Cesium-137 and its metastable decay product Barium-137m. ^{137}Cs has a half-life of 30.17 years. $^{137\text{m}}\text{Ba}$ on the other hand is short-lived and decays to its stable ground state by emitting a gamma ray. In the experiment, these gamma rays are detected by a Geiger counter, as a function of time.

The goal of this exercise is to fit the radioactive decay data to a curve and estimate the half-life of $^{137\text{m}}\text{Ba}$. The number of counts ΔN detected in an interval Δt defines the decay rate $R = -\frac{\Delta N}{\Delta t} \approx -\frac{dN}{dt}$. We know from quantum mechanics that R is proportional to N , the number of radioactive nuclei present at time t . Therefore, we have,

$$\frac{dN}{dt} = -\lambda N \Rightarrow N = N_0 e^{-\lambda t},$$

where N_0 is the number of radioactive nuclei present at time $t = 0$, and $\lambda = 1/\tau$, where τ is called the *mean life* of the radioactive particle.

Equivalently, we can describe the exponential decay process in terms of the *half-life* $\tau_{1/2}$ which is defined as the time taken for N_0 to decay to half its value, so that

$$N = N_0 (2)^{-t/\tau_{1/2}}.$$

The file Cs137.dat has two columns : the first is time in 20-second intervals and the second column indicates the number of decays detected during that time.

- (i) Import the data into your notebook from Cs137.dat.
- (ii) Define the appropriate fit function and fit the data to it. Hence estimate the half-life of $^{137\text{m}}\text{Ba}$.
- (iii) Plot the data as a function of time, with the fit function superimposed on it.
- (iv) Plot the difference between your fit function and the data as a function of time.

Hint: Remember to account for the constant background level that persists in the data even after the $^{137\text{m}}\text{Ba}$ has decayed away.