MATH327: StatMech and Thermo, Spring 2026

Extra practice — Drift and diffusion

At 06:30 UTC on Monday, 28 April 1986, radiation detectors started going off at the Forsmark Nuclear Power Plant in Sweden. Within a few hours, the Swedes had confirmed that the radiation was coming from some distant source (rather than Forsmark itself). Based on the direction of the wind, the Swedish government asked the USSR what had happened. Although the Soviet authorities initially denied there had been any incident, that evening they released a 15-second news bulletin reporting an accident at the Chernobyl Nuclear Power Plant in northern Ukraine.

The lack of reliable official information made it urgent to estimate how severe this accident may have been. We can do this by modelling the motion of each radioactive particle in the atmosphere as a one-dimensional random walk along the $1100\ \mathrm{km}$ line between Chernobyl and Forsmark.

Suppose that the wind produced a steady drift velocity $v_{\mathrm{dr}} = 14\ \mathrm{km/hour}$ from Chernobyl to Forsmark, and that the radioactive particles have a diffusion constant $D = 7.3\ \mathrm{km}/\sqrt{\mathrm{hour}}$. Further suppose that measurements at 06:30 UTC indicated a billion becquerels ($1\ \mathrm{GBq}$) of radioactivity had travelled at least $1100\ \mathrm{km}$ from Chernobyl, while later measurements at 09:30 UTC indicated rapid growth in this radioactivity, to $100\ \mathrm{GBq}$. (The becquerel is the SI unit of radioactivity.)

(a) Use the central limit theorem to estimate the time of the accident.

This is easiest to do numerically (using Python, for example). If it gives you trouble, you can move on to part (b) assuming that the accident occurred around 21:30 UTC on Friday, 25 April.

(b) Similarly estimate how much radioactivity was released in the accident.

(c) The estimates above involve several simplifying assumptions and approximations. Choose at least one simplification and explain — without attempting to carry out a corrected calculation — whether it causes an underestimate or an overestimate of the amount of radioactive material released.