Problem 1. Taylor Dispersion

A stream is flowing down the lovely Tipperary landscape landscape in Ireland that drops 1m every 2500m. It is 75cm deep and 4 meters wide with a fine gravel bed made of pebbles, resulting in a roughness height of 1.5cm. Farmer Podge has a cattle farm and the cows regularly do their business in the stream potentially contaminating it pretty badly downstream. Jimín's farm is 450 m downstream and he has measured concentration of the toxin methoguinnessine associated with fecal matter from this particular breed of Irish cows at concentrations of 5g/liter, way above an acceptable threshold. Assuming that all this contamination came from Podge's farm, do you expect that Jimin's water sample is representative of the concentration in the stream; i.e. would he measure the same thing had he taken it anywhere else at that transect - e.g. on the other bank, a little deeper?

To understand how far downstream Podge's cows are compromising water quality, the lads at the local consulting firm *Uisce Beatha Glan* decide to run a tracer test where they dump a certain amount of rhodamine, a conservative tracer into the stream at Pat's farm. To decide what mass of rhodamine to add they need to estimate the concentration at several locations downstream locations. To be detectable with their equipment some part of the plume must have concentrations at least larger than 100 micrograms/m. How much mass must they add to be able to still measure things 5 km downstream, where the lovely village of Roscrea lies? And how wide will the plume be when its peak hits that point?

Problem 2. First Order Reactions

Methoguinnessine, the contaminant Podge' cattle are contaminating the stream with, is know to undergo pretty rapid first order degradation reactions in the benthos as those Irish microbes simply can't get enough of it. From a tracer test you estimate that the effective reaction rate for a stream with the characteristics of this stream is 0.2 hr^{-1}.

(i) You conduct the same tracer test that the local consultants performed with rhodamine, but instead using the exact same mass of methoguinnessine. Write down an expression for how the concentration evolves in the stream over time. What will the peak concentration of methoguinnessine arriving at the station 5km downstream be?

(ii) Now that you have established several of the transport parameters for the problem that you're interested in you want to know how far downstream Podge's cows are impacting water quality. Podge and his cattle have been using the stream for decades so the contamination is long lived and after taking a few measurements it seems that they are contaminating the water next to the farm at a concentration of 25 g/liter. Based on all your estimates so far what do you expect the worst case concentration in Roscrea (recall 5 km downstream) to be. State any assumptions that you are making clearly.

Problem 3. Photochemical Reactions

The river Liffey, which flows through the city of Dublin is famous for some pretty horrendous odors that emerge during the summer, particularly on those very rare sunny days in Ireland - so much so that the Dubs sometimes refer to it in endearing terms as the *Sniffey*. Given that it only happens when the sun pops out for any significant amount of time some of the locals have hypothesized that it's actually a chemical reaction driven by interaction with the sun. They go and explore and find that high amounts of hexajamesonine can be measured at the bottom of the river at a concentration of $C_0 = 10g/m$. hexajamesonine is known to react with sunlight to produce the noxious gas butojamesonile. In the city during the summer the river is typically 2.5 meters deep. It's also a pretty murky river and sun light attenuates at a rate of 10 m^{-1}.

The locals estimate that they can treat this particular system as one where reactions are zeroth order (what do they mean by this?) and that the reaction rate at the surface of the water is 0.1 $gm^{-1}min^{-1}$. Based on this information: (i) What is the amount of butojamesonile that is produced per unit area of the river over one day?; (ii) what is the concentration of hexajamesonine at the surface of the river?; (iii) what changes if the following day the sunlight is twice as intense? (don't perform extra calculations, but explain what changes) and (iv) do you think the assumption a zeroth order reaction is justified and why?

Problem 4. Lake Compartment Models

County Kerry has one of the loveliest lake networks in Ireland. Lake Mór in particular is at the heart of the national park. It is fed by two streams (each flowing in at 10 m^3min^{-1}) and drained by one river. Historically the streams have been pristine, but recently one of them has been contaminated with pixie dust (in case you did not know Kerry is famous for having a particularly large density of portals to the other realms where fairies live). While most people are not aware of it pixie dust is quite toxic to fish and at concentrations larger than 1g/liter can stunt the growth of the bottom feeding *iasc*.

The lake is approximately 2×10^4 m^3 in volume and roughly speaking has a top mixing layer of 8000 m^3, an intermediate layer of 7000 m^3 and the bottom layer where the *iasc* live makes up the rest. Uncontaminated groundwater feeds all three layers at a total volume flow rate of 6 m^3min^{-1}, split evenly across all of the layers. The top and middle layers exchange mass due to turbulent mixing at a rate of 3 m^3min^{-1} and the middle and bottom layers exchange mass at a rate of 0.5 m^3min^{-1}. What is the maximum concentration of pixie dust that the contaminated stream can carry while still ensuring that the delicious *iasc* can grow to full maturity. Assuming it is actually loaded with double this concentration, how long will it take for the bottom layer to exceed the threshold value, assuming that the whole lake starts out as pristine.

Problem 5. Creative Project

Please provide me with an update of your creative project. What have you done so far? What are you planning on doing? Set yourself a timeline and goals to achieve so that it all

comes together properly. Share your timeline with me and keep me updated frequently (At least on each homework).