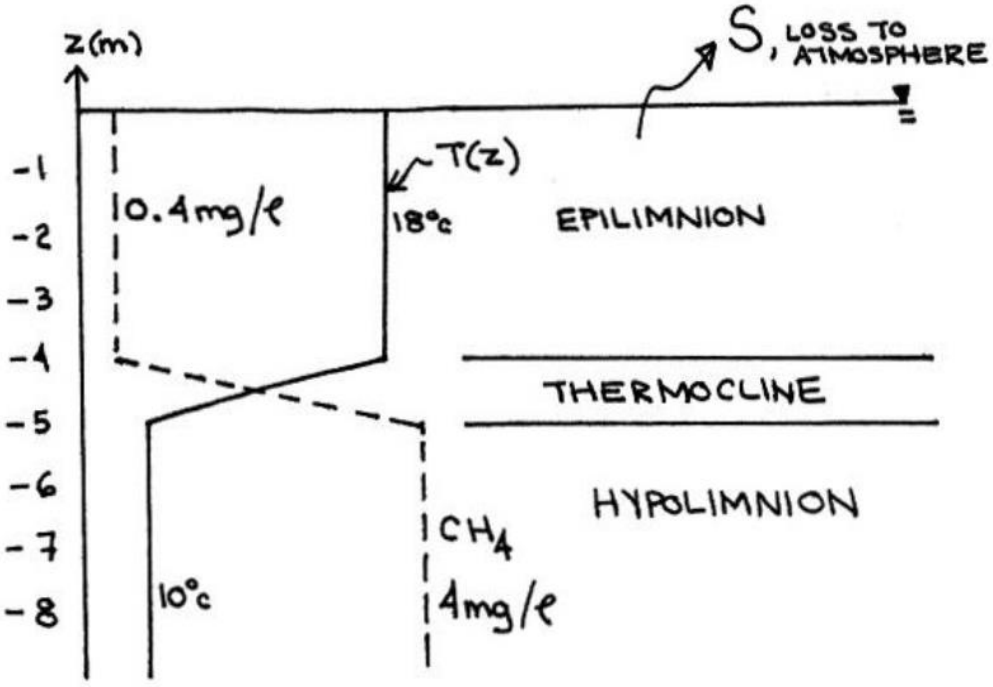
FINAL EXAMINATION

INSTRUCTION: ATTEMPT ALL QUESTIONS

TIME: 3 HOURS

Question 1.

The lower waters of a stratified lake are high in methane (CH_4) concentration. The gradient of density across the thermocline inhibits turbulence in this region, such that the vertical turbulent diffusion is greatly reduced in this region ($D_2 = 2 \times 10^{-6}\, m^2 s^{-1}$). Above the thermocline the waters are well mixed. The lake has one inflow, and one outflow, with $Q = 1\, m^2/s$. The inflow has no methane. Assuming that the conditions shown below represent steady state, estimate the flux of methane into the atmosphere (a sink). The surface area of the lake is $10^6\, m^2$.

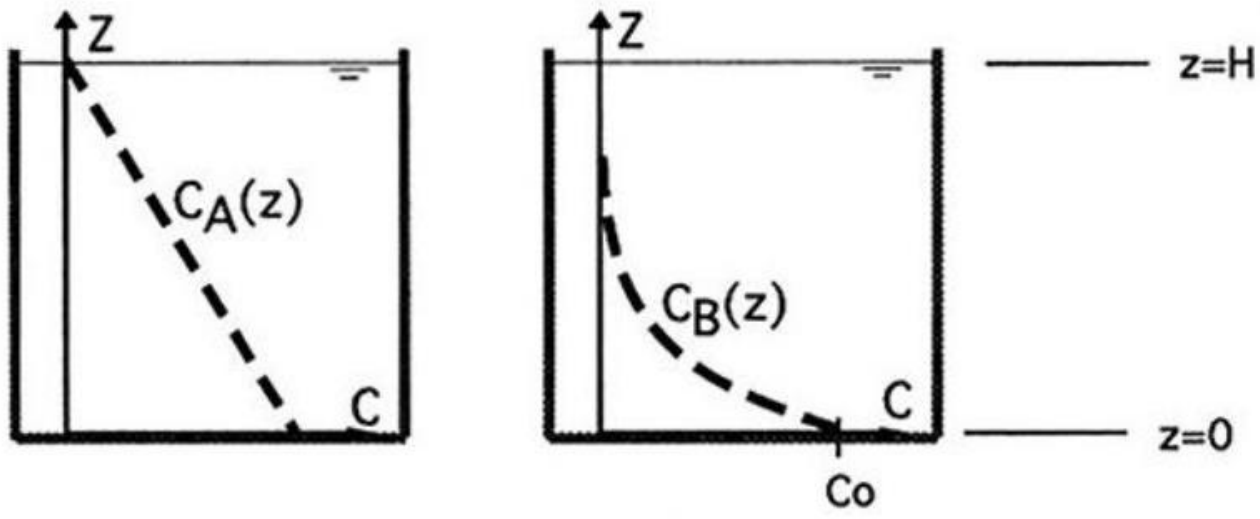


Question 2.

Chemical concentrations were measured in two beakers filled with water. The profiles of concentration are shown below. There are no sources or sinks for either chemical within the water column. Chemical A is volatile, but chemical B is not. Based on the profile shape...

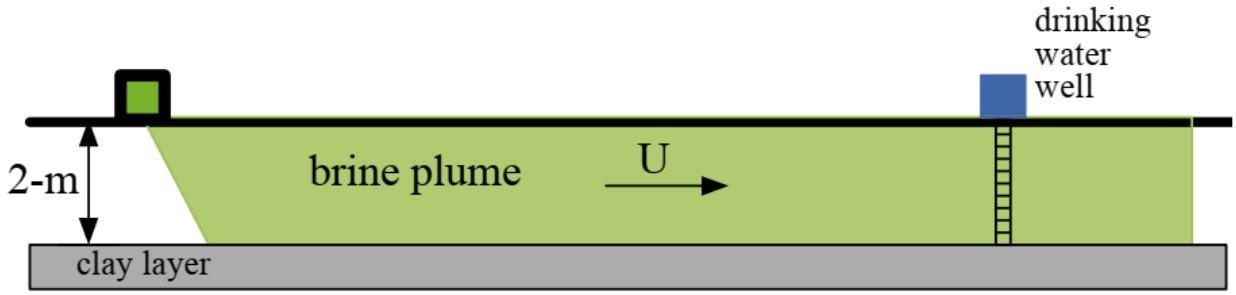
1) Indicate the direction of flux at $z = 0$ and $z = H$.

2) Is the system in steady state? If not, sketch how the chemical profile might evolve.



Question 3.

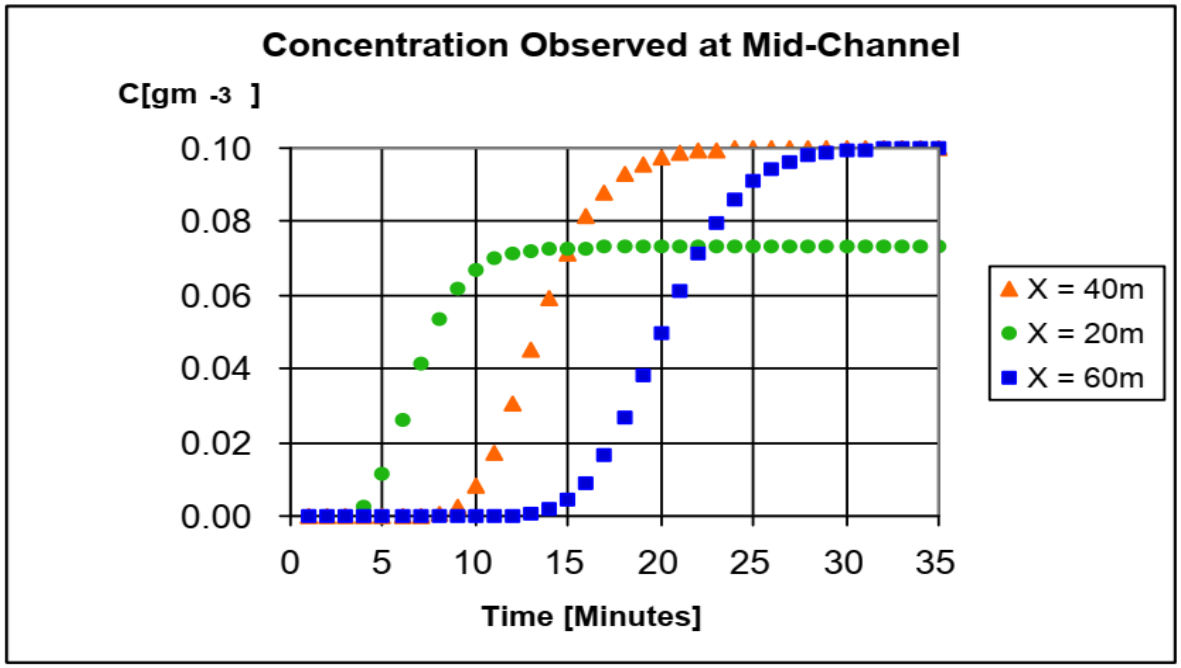
Pickles are made in large wooden vats filled with brine of 10 g L^{-1} salt concentration. The base of each vat is square, 5-m to a side. At the Dill Pickle factory one of the vats begins leaking brine directly into a shallow aquifer at a rate of 0.1 m^3 $week^{-1}$. The leaking is distributed evenly over the vat's base area. The aquifer is 2-m deep and sits atop an impermeable clay layer. The density of the brine allows it to quickly disperse over the depth of the aquifer. The Pickle Company is not concerned about losing this small amount of brine, but the community using the aquifer for drinking water is concerned. The community well is located 500-m from the vats in the direction of groundwater flow. Assess the possible impact on drinking water quality by estimating the maximum salt concentration at the well. How long after the leak begins will this concentration be reached? The transport velocity (pore velocity) in the aquifer is 10^{-6} m/s. The molecular diffusion of brine is 10^{-9} m^2s^{-1}. The longitudinal dispersion coefficient is 10^{-5} m^2s^{-1}. The lateral dispersion coefficient is 10^{-6} m^2s^{-1}.



Side View of Plume - Not to scale

Question 4.

Tracer is released at 10mgs^{-1} at the sidewall of a rectangular irrigation channel. The concentration is measured mid-channel at three downstream locations, x = 20m, 40m, and 60m. The injection starts at t = 0. Estimate the flow in the channel, the mean cross-sectional area, and the coefficient of longitudinal dispersion.



Question 5.

Between midnight and 2 am, illegal dumpers empty two five-gallon drums containing 2 kg of Toluene into a shallow abandoned well. Within 24 hours the Toluene is distributed vertically over the shallow (5 m thick), sandy aquifer. Evidence of the dumping is discovered two days later, and you are asked to assess the risk to a drinking well located 1 km directly downstream, if no remediation is done. Previous tests on this aquifer indicate the following:

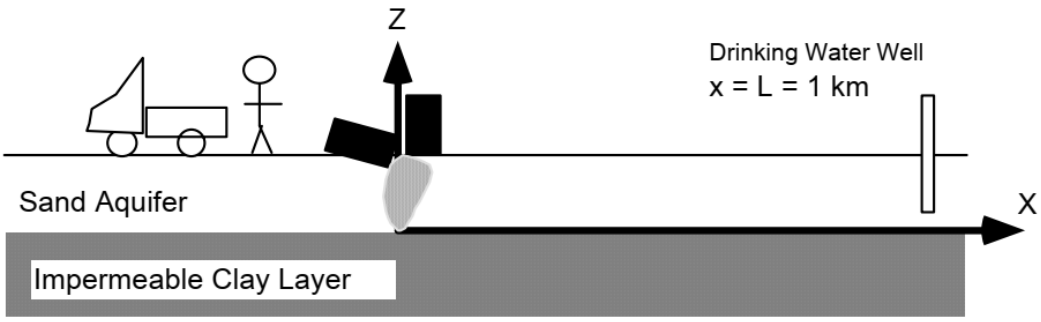
Mean pore velocity, u = 1 m /day
Isotropic, Homogeneous Dispersivity, K = 0.1 m^2/day.
Porosity, n = 0.3
Solids density, ρ_S = 2.6 g/mL.

Toluene partitions rapidly to aquifer solids and has a solid-water partitioning coefficient of

$$K_d = 0.5 \frac{g_{toluene} / kg_{solid}}{g_{toluene} / L_{water}}.$$

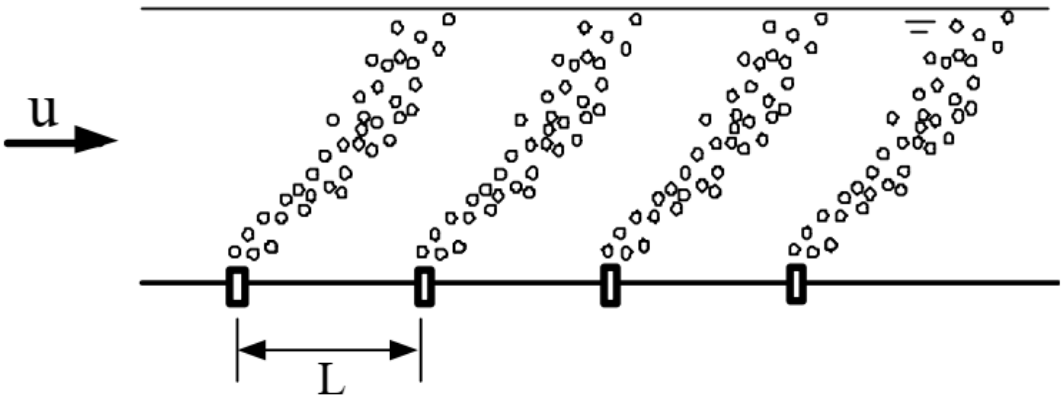
Assume that the partitioning of Toluene is everywhere in equilibrium.

a) Write an appropriate transport equation.
b) Estimate the total concentration, C(t), at the drinking well.
c) Estimate the peak concentration in the pore water at the well and the duration of exposure.



Question 6.

A processing plant wants to use bubbles to maintain high mixing conditions in a water channel. Maximum efficiency is achieved when the spacing between individual bubblers, L, is chosen such that new bubbles enter at the bed just as the bubbles from the previous upstream bubbler are exiting the surface. Determine the spacing, L, if the mean channel velocity is u = 1ms^{-1}, the water depth h = 1m and the average bubble diameter is D = 1 mm.



Question 7.

You have been monitoring the levels of particulate phosphorus in a small lake. Some of your recent measurements are given below. Predict whether the concentrations in the epilimnion will increase, decrease, or stay the the near future. The base of the epilimnion is set at the depth of the thermocline, as shown.

Particle settling velocity: $w_P = 2.0 \times 10^{-6}$ m/s

Vertical Diffusivity: $D_t = 2.0 \times 10^{-6}$ m^2/s

River Inflow: $Q_I = 0.1$ m^3/s with phosphorus concentration, $C_I = 100\mu g/L$

River Outflow: $Q_O = 0.1\ m^3/s$ with phosphorus concentration, $C_O = 50\ \mu g/L$

Surface Area of Lake: $2 \times 10^4\ m^2$