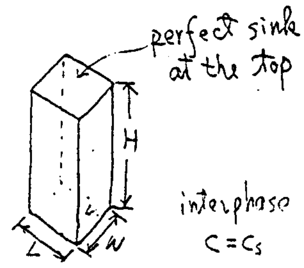
Note: In the following computations, you need to use the convective diffusion equation which, in Cartesian coordinate, is

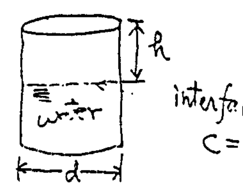
$$\frac{\partial C}{\partial t}+u\frac{\partial C}{\partial x}+v\frac{\partial C}{\partial y}+w\frac{\partial C}{\partial z}=D\left(\frac{\partial^2 C}{\partial x^2}+\frac{\partial^2 C}{\partial y^2}+\frac{\partial^2 C}{\partial z^2}\right)+r$$

1. Mr. Chan wants to compute the concentration profiles of HNO_3 vapor in a close rectanglar column as shown on the right. The container is made of Teflon so that the wall of the container is impermeable to the vapor. The change of position of the gas-liquid interphase is negligible and the concentration at the interface is Cs. The surface at the top is a perfect sink for HNO_3 vapor. Please compute the steady state concentration profile. (20%)

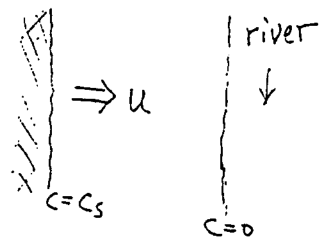


2. Please derive the computation schemes for the first derivative f_i' with equival-spaced points (a) f_{i-1}, f_i, and f_{i+1}; (b) f_i, f_{i+1}, f_{i+2}. Also show the orders of accuracies for the two computation schemes. (20%)

3. $NH_{3(g)}$ is diffusing into the bottle, as shown on the right, at a constant rate of N g/sec. If the concentation of NH_3 at the gas-water interface is zero and the concentration profile may be simplified to be an one-dimensional problem, please compute the NH_3 concentration as a function of time and space. The diffusivity of HN_3 is D cm^2/sec. (15%)



4. Groundwater flows through a landfill toward a river at an uniform velocity u, as show on the right. On leaving the landfill, groundwater is saturated with pollutant at concentration Cs. While transported toward the river, the pollutant decay as a first-order chemical reaction with rate constant k. Compute the steady state concentration profile between landfill and river if the problem is assumed to be one-dimensional and the concentration at the river is zero. Assume the diffusivity of pollutant is D cm^2/sec. (15%)



5. A particle is attracted toward the origin by a force whose magnitude is proportional to the distance r of the particle from the origin and the coefficient is k. How much work is done when the particle is moved from the point (0,1) to the point (1,2) along the path $y=1+x^2$, assuming a coefficient of friction μ between the particle and the path ? (15%)

6. In the mathematical analysis of the organic waste and oxygen contents in a natural stream as shown below, Streeter and Phelps (1925) had made the following assumptions: plug flow, first-order reaction of organic waste with respect to its own concentration, unit stoichiometric ratio of oxygen consumption with respect to organic waste, and the interfacial transfer flux of oxygen as k(Ca*-Ca). Please compute the concentrations of organic waste and oxygen as functions of distance if their concentrations are Cbo and Cao, respectively, at x=0. (15%)