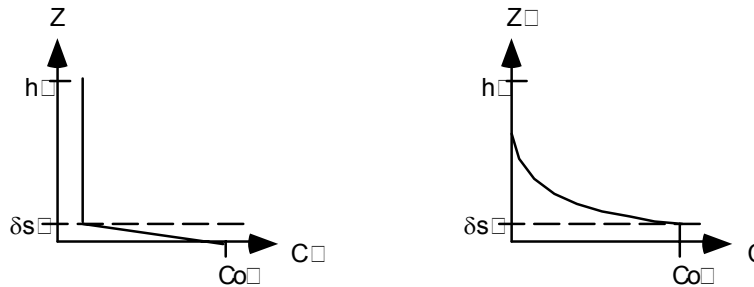


**Problem 1 [4pts]:** Consider a river channel of depth  $h = 1$  m and mean flow speed  $U = 1$  m/s. The bed is a source chemical through dissolution. The equilibrium concentration is  $C_0$ . Which concentration profile would you expect to see in the channel. Defend your answer with clearly stated scaling arguments. The kinematic viscosity is  $\nu = 10^{-6} \text{m}^2 \text{s}^{-1}$ , and a typical molecular diffusion would be  $10^{-9} \text{m}^2 \text{s}^{-1}$ .



**Problem 2 [6 pts]:** A container filled with water is  $h = 40$ -cm high and has a base area of  $100 \text{ cm}^2$ . At  $t = 0$  a lid is placed on the container. The lid is filled with solid  $\text{CaSO}_4$  and fits snugly to the water surface. The water in the container is stirred gently, such that the laminar sub-layer is  $\delta_s = 0.1$  cm at every surface. Outside the laminar sub-layer the diffusivity of all substances is  $D_t = 0.01 \text{ cm}^2 \text{ s}^{-1}$ . Estimate the total of calcium [in grams] in the water column at  $t = 6$  hours. The molecular diffusivity of  $\text{Ca}^{++}$  in water is  $D_m = 8 \times 10^{-10} \text{ m}^2 \text{ s}^{-1}$ . The solubility product for  $\text{CaSO}_4$  is

$$K_{\text{sp}} = \frac{[\text{Ca}^{++}][\text{SO}_4^{--}]}{[\text{CaSO}_4(\text{s})]} = 230 \frac{\text{mol}^2}{\text{m}^6}$$

a) Write an expression for the calcium concentration,  $C(z)$ , in the water at  $t = 6$  hrs. **Beware:** you must account for the no-flux boundary at the bottom of the container.

b) Find the total mass of calcium in the water at  $t = 1$  hr.