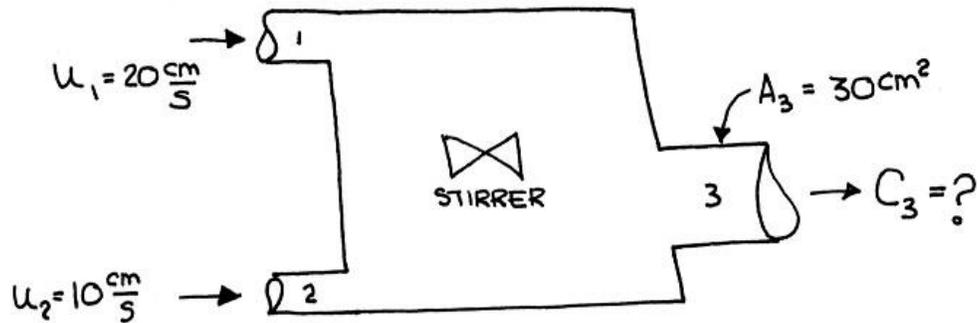


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1.061 / 1.61 Transport Processes in the Environment
Fall 2008

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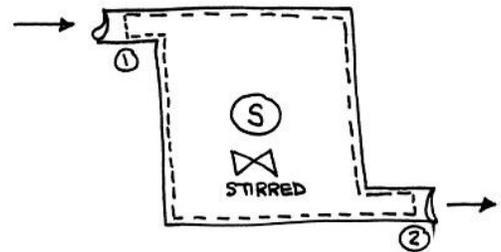
Problem 1



Two pipes, each of 10 cm^2 cross-section, carry water into a mixing chamber. The upper pipe carries water saturated in oxygen ($C_1 = 9 \text{ mg/l}$), and the lower pipe carries deoxygenated water ($C_2 = 0 \text{ mg/l}$). A stirrer within the chamber rapidly mixes the two streams, such that the concentration in the tank is spatially uniform. Assuming the system is at steady state, what is C_3 ?

Problem 2

A well-stirred tank is fed by an inlet pipe with cross-section, $A_1 = 10 \text{ cm}^2$. The inlet velocity is $U_1 = 10 \text{ cm/s}$. Inside the tank a plaster ball slowly dissolves supplying a steady source of calcium carbonate to the water, $S = +5 \text{ g/s}$. The outlet pipe area is the same as the inlet. There is no calcium carbonate in the inflow. At steady state, what is the outlet concentration?



Problem 3

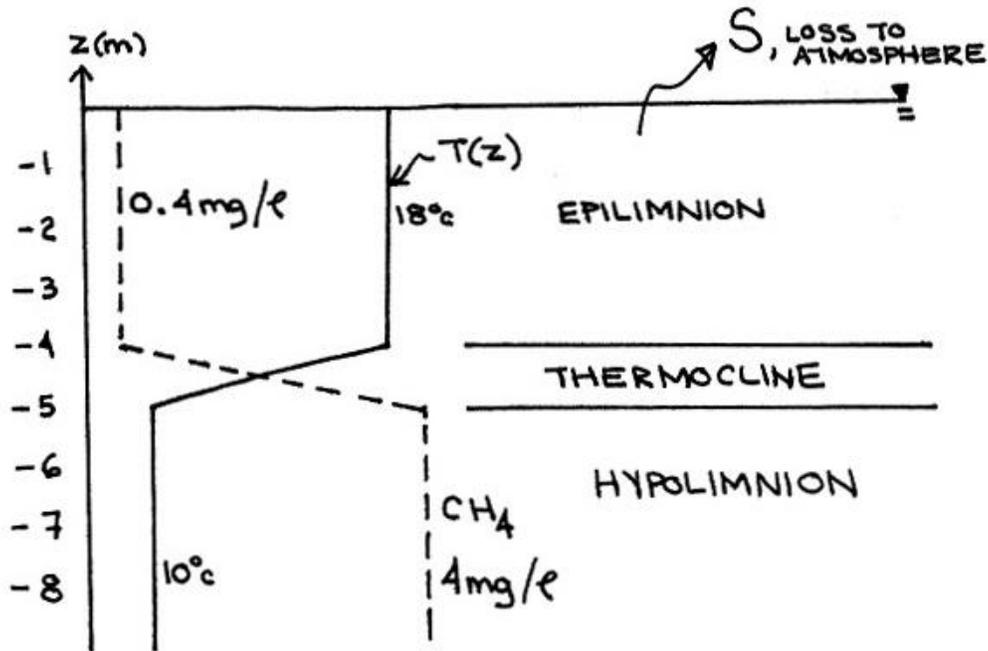
Two water pipes of equal cross-section, $A = 20 \text{ cm}^2$, join to form a single pipe of cross-section, $A_3 = 40 \text{ cm}^2$. The two incoming pipes carry water of different temperature, $T_1 = 10^\circ\text{C}$ and $T_2 = 20^\circ\text{C}$, respectively. If the velocity in the two upstream pipes is the same, what is the temperature in the pipe downstream of the junction? Assume that all pipes are perfectly insulated.

Problem 4

A shallow river flows out of a shaded, wooded region into an open plain at $x = 0$. Once in the open region ($x > 0$) the river begins to receive solar radiation at $H_3 = 800 \text{ watts m}^{-2}$. If the river emerges from the forest at a constant temperature, T_0 , find the gradient of temperature along the river, $\partial T / \partial x$, for $x > 0$. The river is $h = 1 \text{ m}$ deep, $b = 10 \text{ m}$ wide and flows at $U = 1 \text{ m s}^{-1}$. The diffusion coefficient is homogeneous and isotropic, $D = 0.1 \text{ m}^2 \text{ s}^{-1}$.

Problem 5

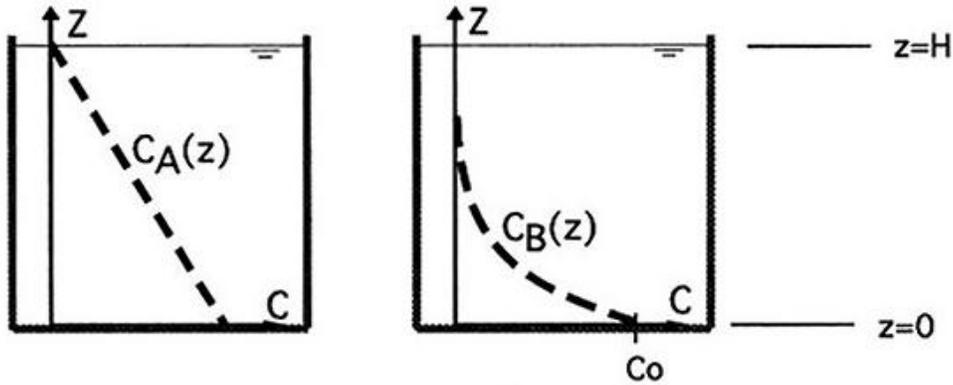
The lower waters of a stratified lake are high in methane (CH_4) concentration. The gradient of density across the thermocline inhibits turbulence in this region, such that the vertical turbulent diffusion is greatly reduced in this region ($D_2 = 2 \times 10^{-6} m^2 s^{-1}$). Above the thermocline 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 $10^6 m^2$.



Problem 6

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.



Problem 7

Many water bodies have problems with anoxia, low levels of dissolved oxygen (DO) in the water column due to phytoplankton respiration. Lake Monger in Western Australia is one such water body. A colleague asks you to predict DO profiles in the lake to determine whether anoxia will occur. Preliminary investigations reveal that there are negligible horizontal gradients of DO across the lake. However, the competing effects of oxygen consumption by phytoplankton and reaeration from the surface cause significant vertical gradients of DO.

- Assuming steady-state conditions, derive the governing equation for the vertical (z) profile of dissolved oxygen from equation 14b in the theory. Also assume that the phytoplankton represent a first-order oxygen sink (i.e. the rate of consumption of dissolved oxygen is proportional to its concentration in the water, with constant of proportionality = k). Vertical flows in the lake can also be assumed to be insignificant.
- Find the solution to this equation, subject to the following boundary conditions:
 - reaeration at the surface ($z = 0$) keeps the water at the surface saturated with dissolved oxygen at a concentration of 8 mg/L.
 - the sediments ($z = -10\text{ m}$) are sufficiently impermeable and abiotic to represent a no-flux boundary for dissolved oxygen.

Use typical values of $D = 0.1\text{ cm}^2/\text{s}$ and $k = 0.05\text{ day}^{-1}$ (which corresponds to high phytoplankton levels).

- Where in the water column would you expect the lowest concentration of DO?
- Your colleague tells you that DO concentrations below 1 mg/L are considered dangerous. Determine whether Lake Monger will have dangerously low levels of dissolved oxygen. What if eutrophication increase the phytoplankton population, such that $k = 0.1\text{ day}^{-1}$?