My name is ______________________________

Midterm II

Please be sure to put your name on each sheet; use the back or attach another sheet if you need more room. Once again, you are free to use Vogel, but not your notes.

1. In one particular setting, a suspension feeder encounters only particles without excess density. That is, in this environment, for all particles, $\rho_s = \rho$. The size range of particles is broad, from 0.01 μm to 1 mm. You know that there are four potential mechanisms of encounter by its appendages, *i.e.,* direct interception, inertial impaction, gravitational deposition and Brownian diffusion. Consider the encounters to occur with a cylindrical appendage in cross flow, so that the axis of the cylinder is perpendicular to both the gravity vector and the dominant flow direction. Given this flow orientation and these particle characteristics, (2)where on the cylinder would you expect encounters to occur and by which one or more of the four mechanisms? (1)Please start with a brief sketch of the flow geometry and (2)indicate on which face(s) of the cylinder encounters will occur by the mechanism(s) that you suggest. (3)Be sure to explain your reasoning.

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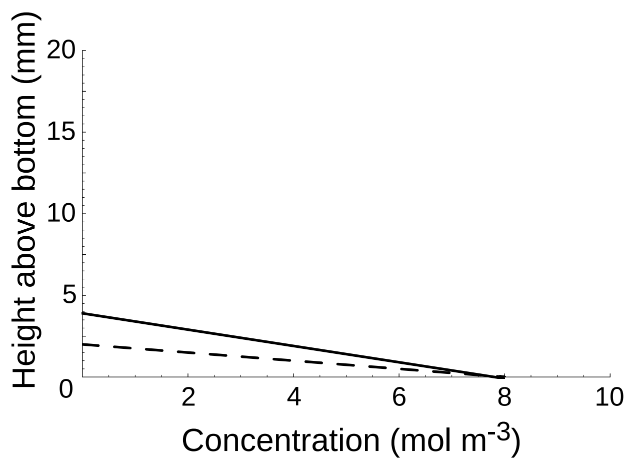
2. A gradient in dissolved concentration of substance X is observed under smooth-turbulent flow over the seabed (dashed line). Outer flow velocity then is changed abruptly, but remains within the smooth-turbulent regime. That is, a diffusive sublayer is still present (solid line). The two equations that you have gotten for total flux of material are as follows:

$$\boldsymbol{Q} = CuS \text{, and} \tag{1}$$

$$\boldsymbol{Q} = -D\frac{\partial C}{\partial z}S \text{,} \tag{2}$$

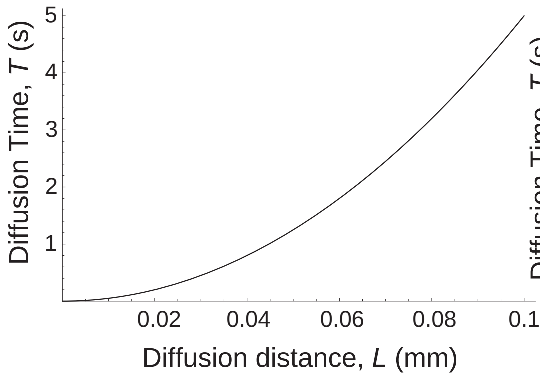
where C is concentration (mol m^{-3}), S is the relevant cross-sectional area (m^2), D is the molecular diffusion coefficient, and z is one of the three Eulerian coordinates. Use one or both equations and anything else you know to explain (1)the direction of diffusional flux and whether and (2)how much the direction and magnitude of the flux of solute will change from one flow velocity to the other. Also explain (3)whether the initial flow velocity was higher or lower and (4)how you know. (5)Justify your choice of equation(s) and (6)explain to which direction u and z refer (by showing them on the graph below) if you choose to use Eq. 1-2. (6)Specify whether the sediment is a source of or sink for the solute and (7)explain how you know.

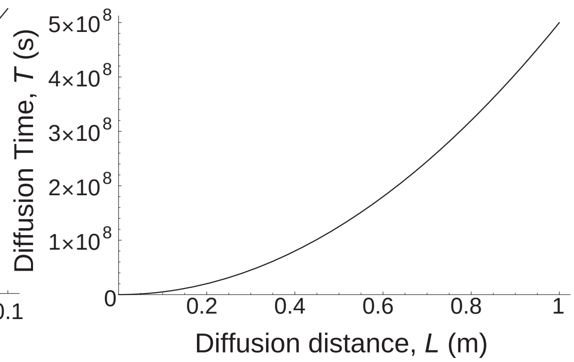


3. As you learned from the review sheet if not sooner:

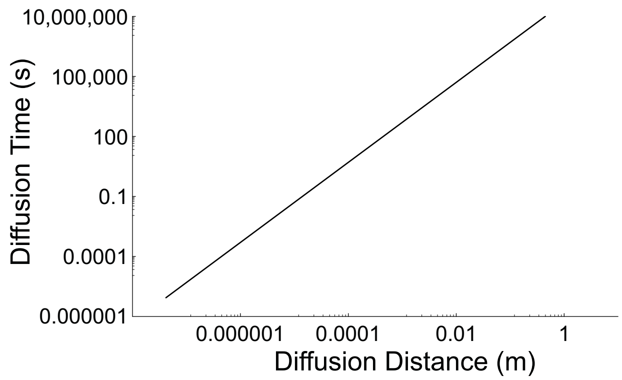
$$D = \frac{L^2}{2T}, 2DT = L^2, T = \frac{L^2}{2D}, L = \sqrt{2DT}. \quad (3)$$

All three graphs below plot the results of the third equation in this list, with D, the molecular diffusion coefficient set at its typical value for small molecules in water of 10^{-9} m^2 s^{-1}.



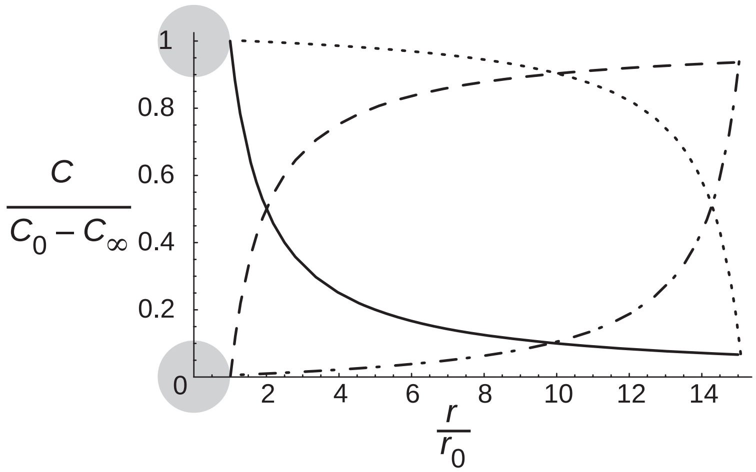


Period	Seconds
Hour	3,600
Day	86,400
Month (30 d)	2,592,000
Year	31,536,000



(1)Explain some of the consequences for biota of this relationship between diffusion times and distances, as described by Eq. 3. The answer requires some creativity and is open ended, so that you may wish to leave it until last. One or more of the other questions should also stimulate your thinking on this issue.

4. You are bored with Cartesian coordinate systems and ready to go spherical to better match the diffusional geometry of a single spherical diatom cell that is leaking small carbohydrate molecules. So you (correctly) solve for the radial distribution (with distance r from the center of the cell) of this carbohydrate that is being constantly lost by the cell at the same rate. At this constant rate of loss from the cell surface, the concentration at the cell surface, C_0, also stays constant. You plot it up as follows, getting a little cutesy by putting an image of the cell (grey region) on the graph itself:



The infinity subscript refers to the concentration at a large distance from the cell, whereas the subscript zero refers to the cell surface, with C_0 indicating the concentration there; r_0 is the cell radius or radial distance from the origin to the cell surface. All transport is occurring by molecular diffusion. Unfortunately, you run several variants of your model and you get four different results, summarized by the solid (—), dashed (– – –), dotted (· · ·) and dash-dotted (— · — ·) lines. (1)Specify which one is correct, and (2)justify your reasoning. It may or may not help you to know that the correct magnitude of the total flux, Q, to or from the cell is given below as Eq. 4. The magnitude is correct, but it is your job to (3)identify the direction of this flux. I have intentionally omitted putting a leading sign on the right side of the equation to keep from confusing you about the direction:

$$\boldsymbol{Q} = 4\pi D r_0 (C_0 - C_\infty). \quad (4)$$

(4)Which one or more of the curves could not be correct no matter whether the cell is a source or sink for solute? (5)Explain your reasoning.

5. It is your job, Mr. or Ms. Sherwood, to increase the flux of a solute that is uniformly distributed in seawater at C_∞ to a very wide, long, flat, perfectly absorptive organism ($C_0 = 0$) lying on the seabed (*Platybenthos steamrolleri*). Assume that it is effectively infinite in length and width, so that edge effects are not important, and only its upper surface is absorptive. Flow cannot go through the seabed or the organism. You are given the ability to deliver a constant flow volume of (m^3 $time^{-1}$) arranged in any geometry that you like. The flow that you produce at a point above the seabed can be either toward or way from the bed at any angle, or it can be perfectly parallel. You can divide your flow into as many separate streams as you like, but your total flow volume per time is constant. (1a)How would you arrange the flow to maximize the flux of solute to the organism? (2a)Explain why. This question cannot be solved exactly, without specification of more details, but I am eager to see your reasoning. If you are stumped, I will give the majority of credit for answering the alternative question of (1b)how the flux might differ with the flow in the ordinary boundary-layer orientation (*u* parallel to the seabed) versus as a single oncoming jet hitting the center of the organism from directly above and spreading outward along the organism and bottom in all directions. Whether you answer the original question or this more specific one, I am of course most interested in (2a or b)your reasoning and not just the answer. Please provide a sketch to supplement the written answer to part (1), and (3)label any relevant layers, sublayers, streamlines and detachment or attachment points, as you (4)explain their relevance to the issue of the total flux, $\boldsymbol{Q}$, that you are trying to maximize, where S is the surface area of your organism, and your flow as well as the water distant from the organism contains 1 mol solute m^{-3}(= C_∞):

$$\boldsymbol{Q} = -D\frac{\partial C}{\partial z}S \qquad (5)$$

Note that this equation is identical to Eq. 2 in question 2.