Biology 3820
Physical Principles in Biology
Spring Semester 2011

Quiz 2
9 February 2011

Please write your name on each page.

Be sure to show your work and include correct units in all of your answers!

25 points total.

1. (8 pts) A gentleman likes to take a walk for exercise everyday. He doesn't like to go too far from home, but he likes variety. So, each day, he steps outside of his house and flips a coin. If the coin shows heads he will turn right, and if it shows tails he will turn left. After each step, he flips the coin again. If the coin shows heads, he continues in the same direction, but if it shows tails, he turns around and steps in the opposite direction.

   The starting point for the gentleman's random walk happens to be at the middle of a city block, and there is a corner 100 meters away in each direction. Each of his steps is 1 meter long.

   (a) Suppose that the gentleman takes a total of 100 steps in his walk. What is the probability that he will end up at one or the other corner? Explain the basis of your calculation.

   (b) If he were to repeat this walk every day for a year, what would be his average displacement from the starting spot after 100 steps? Be sure to specify what kind of average you have calculated, and its definition.

(c) How many steps would he need to take so that the average displacement is 100 meters?

(d) Estimate how long the walk with an average displacement of 100 meters would take. Clearly state any assumptions you make.

2. (17 pts) Imagine a simple diffusion experiment like the one we did in class:
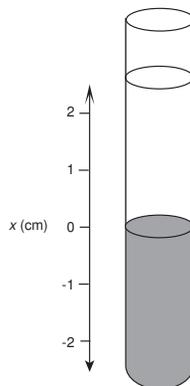

The bottom section of the tube initially contains 1 mM dye, and the top section initially contains only water. For the following, assume that the boundary between the two sections is initially 1 mm thick. Also assume that the diffusion coefficient for the dye, D, is $10^{-10}\,\mathrm{m^2s^{-1}}$, the value we estimated for our experiment.

(a) Using the coordinate axes below, sketch curves representing the following as a function of position (x):

- The dye concentration, C.
- The derivative of C with respect to x, $\partial C/\partial x$.
- the second derivative of C with respect to x, $\partial^2 C/\partial x^2$.

For each graph, draw two curves, one representing the beginning of the experiment and the other representing the state of the tube after two days. You should not need to do any calculations for this; just show the qualitative difference between the two curves, and clearly label them.
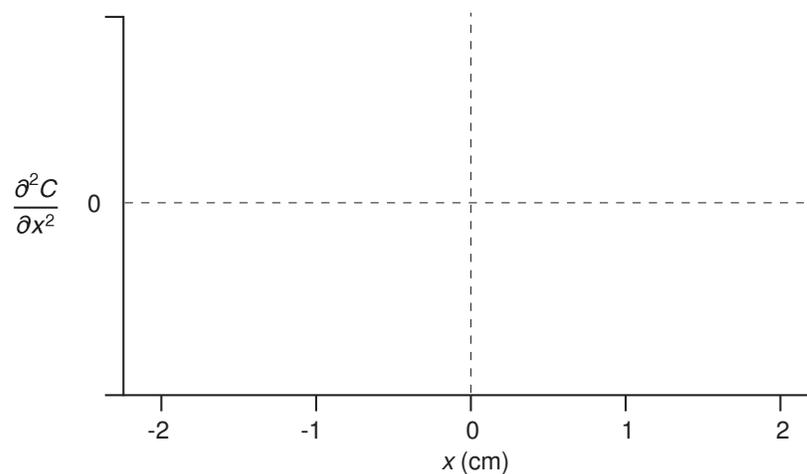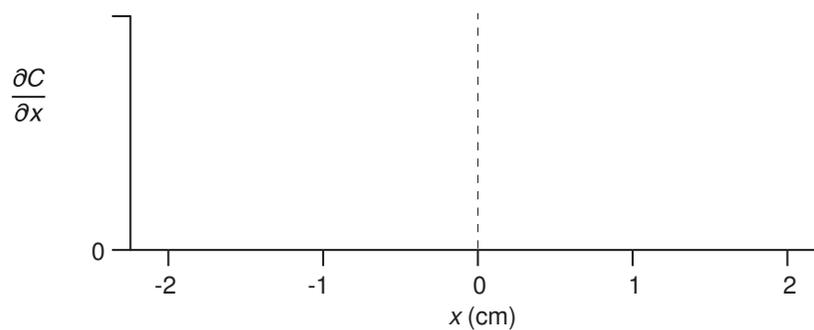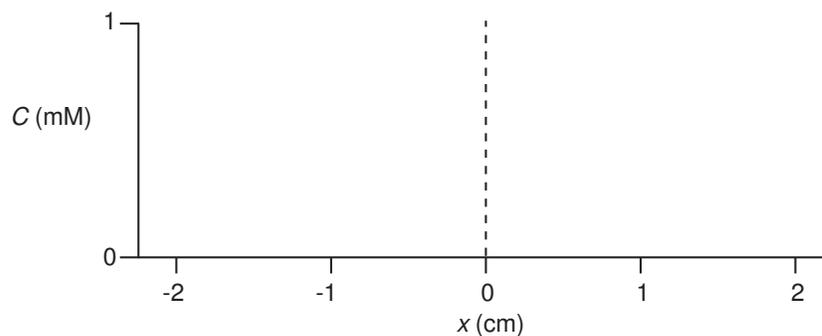
(b) What are the units for $\partial C/\partial x$?

(c) What is the maximum value of $\partial C/\partial x$ at the beginning of the experiment.

(d) At what position in the tube is the flux of molecules the greatest, at the beginning of the experiment and after two days? Explain your reasoning.

(e) At what position in the tube is the speed of an individual molecule greatest, at the beginning of the experiment and after two days? Explain your reasoning.