Biology 3820
Physical Principles in Biology
Spring Semester 2011

Quiz 3
3 March 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.

Some (possibly) useful constants:
Boltzmann's constant: $k = 1.38 \times 10^{-23}$ J/K
Avogadro's number: 6.02×10^{23}
$1\,\mathrm{L} = 10^{-3}\,\mathrm{m}^2$
Diffusion coefficient for CO_2 at atmospheric pressure and 25°C: $1.5 \times 10^{-5}\,\mathrm{m}^2\mathrm{s}^{-1}$

As discussed in class, the stomata in plants serve as pores that allow gasses in the atmosphere to diffuse into and out of leaves, as required for photosynthesis and respiration. The stomatal pore can be approximated as a cylinder $10\,\mu\mathrm{m}$ in diameter and $40\,\mu\mathrm{m}$ long. For all of the questions below, assume that the temperature is 25°C.

1. (3 pts) Calculate the average time required for a CO_2 molecule to cross the stomatal pore. More specifically, calculate the time required such that the RMS distance traveled by a large number of molecules along the the length of the pore equals $40\,\mu\mathrm{m}$.

2. (5 pts) Calculate the average *total* distance that a CO_2 molecule would move during the time required to cross the pore. (*i.e.* calculate the sum of distances moved in all of the random-walk steps.)

3. (5 pts) If the concentration of CO_2 is $15\,\mu$m outside of the leaf, and half that inside the leaf, what is the flux of CO_2 molecules across a stomatal pore? Give your answer in units of molecules per second per m^2.

4. (4 pts) Briefly explain why the CO_2 concentration inside the leaf remains lower than that outside, in spite of the continuous flow of molecules into the leaf.

5. (4 pts) Suppose that one mole of CO_2 at a concentration of $15\,\mu$M is allowed to expand so that its concentration decreases to $7.5\,\mu$M. Calculate the change of entropy associated with this expansion, assuming that the temperature remains constant at 25°C.

6. (4 pts) What is the maximum amount of work that could be obtained from the gas expansion described in the previous question?