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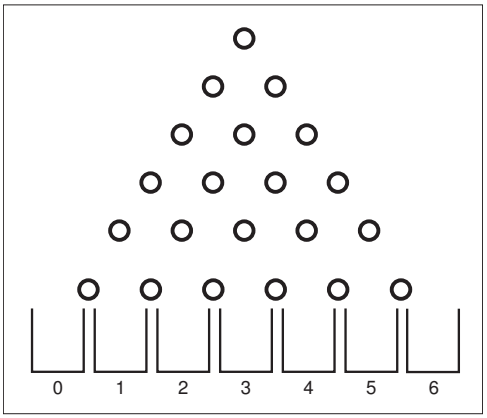
Biology 3820
Physical Principles in Biology
Fall Semester 2015

Mid-Term Exam
23 October 2015

100 points total
Please write your name on each page.
Be sure to show your work and include correct units in all of your answers!

1. Consider the 6-row Plinko shown below:



   (a) (4 pts) What is the total number of paths that a single ball can take through the Plinko?

(b) (8 pts) Calculate the probabilities, $p(0)$, $p(3)$ and $p(6)$, where $p(i)$ is the probability of landing in bin i.

(c) (8 pts) Just before "The Price is Right" is about to air, someone has tampered with the Plinko! This fiend has carefully filed down each of the pegs so that the ball is slightly more likely to go to the left than the right: The probability of going to the left is now 0.6, instead of 0.5.

For this altered Plinko, calculate the probabilities, $p(0)$ and $p(6)$.

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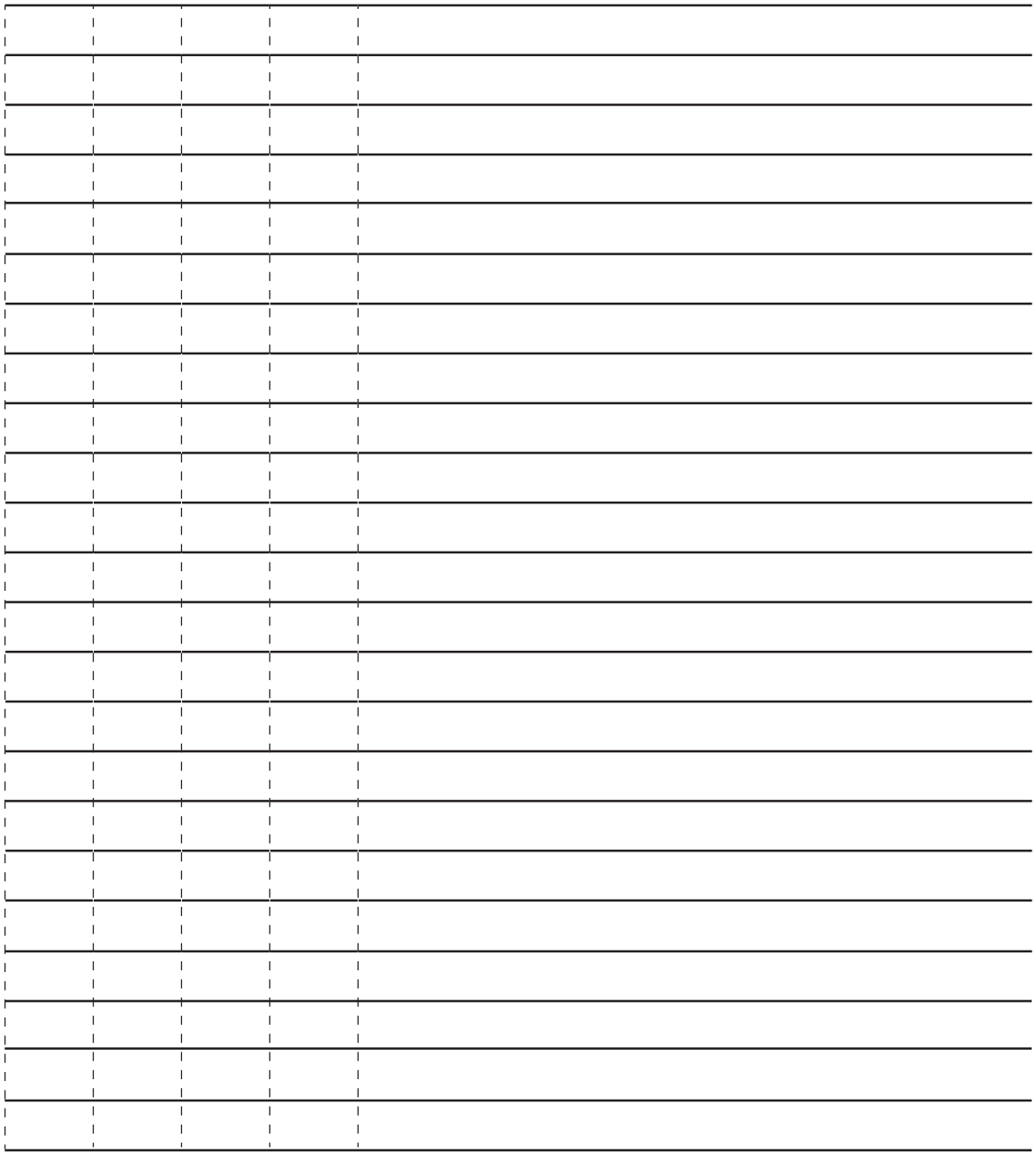
2. (25 pts) Write a Python function definition to simulate the six-row Plinko described in the previous problem, biased or not. Your function should accept two input variables: p = probability of a ball falling to the left at each peg, and n = the number of balls to simulate. The function should print the bin number for each dropped ball. At the end, the function should print the string, "average = ", followed by the average bin number. Above the function definition, include import statements for any modules that your function needs.

   Hint: The bin numbers, as defined in the previous problem, represent the number of right turns that a ball takes in the path to that bin.



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3. One day, a turtle wakes up at the center of a circular island 1 km in diameter. The turtle takes off on a walk in which she walks in a straight line for 1 m (which takes her 30 s) and then changes direction, completely at random, and walks another 1 m. She repeats this process for all day, for a total of 13 hours.

   (a) (8 pts) What is the total distance the turtle walks in 13 hours?

   (b) (8 pts) If the turtle were somehow to be transported back to the center of the island at the end of each day, for many days, to repeat the walk the next day, what would be the RMS distance from the center of the island traveled per day?

   (c) (8 pts) Do you think that it is very likely for the turtle to reach the shore of the island in a given day? Why or why not?

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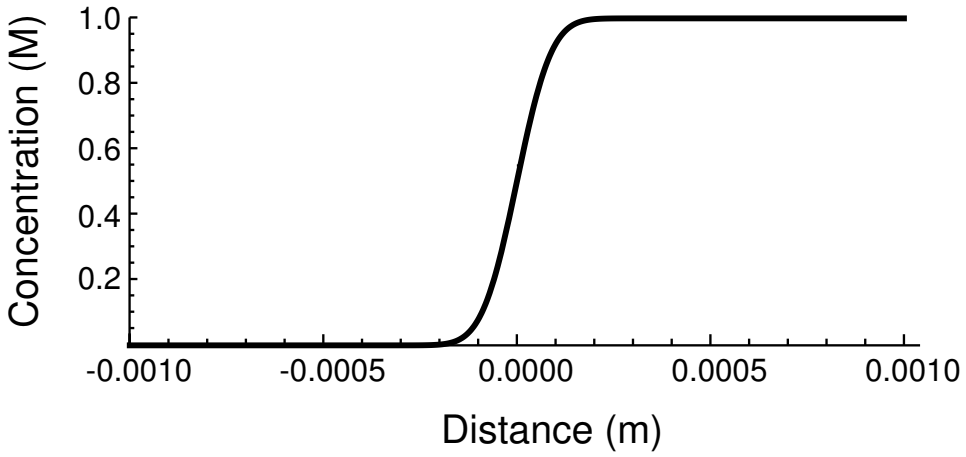
4. The graph below represents the concentration of molecules as a function of distance, after a period of diffusion from a sharp boundary initially present at $x = 0$.



For the following, assume that the diffusion coefficient, D, for the molecules is $10^{-11}\,\mathrm{m^2 s^{-1}}$ and the solution is contained within a cylinder 1 cm in diameter.

(a) (5 pts) Suppose that the molecules were allowed to diffuse for a much longer time. Add to the graph above a sketch of the concentration profile that you would expect to observe.

(b) (8 pts) From the original graph, calculate the concentration gradient at the position where $x = 0$.

(c) (8 pts) Calculate the flux, J, of diffusing molecules at $x = 0$.

(d) (10 pts) Two students, after observing an experiment like this one, are having an argument. One of the students says that the flux of molecules is greatest at position $x = 0$ and, therefore, the individual molecules must be moving fastest there. The other student insists that the molecules are moving at the same rate, on average, throughout the solution. Who do you think is correct? Explain your answer and try to address what is wrong with the alternative view.