Lab 3, Part 3: What does 'Random' motion look like? Characterizing Random Motion and Exploring the Form of the Diffusion Constant

Introduction

Here is the broad structure of Lab 3, as it was presented to you in the first week of this lab:

- **Collect three videos;**
- **Analyze the first video to characterize the behavior of the random motion;**
- **Analyze all the videos to determine how the variation of parameters affects diffusion;** and
- **Write a lab report to synthesize the data gathered by you and the class and to summarize your findings regarding random motion and diffusion.**

Last week you fully characterized the random motion of beads in fluid using histograms of different types of displacement at different times and began to determine how changing parameters of the solutions (beads in fluid) can affect the diffusion constant, D. In this final week of the lab, you will finish analyzing videos 2 and 3, combine your results with those from the rest of the class, and determine how varying parameters of the bead solutions will affect the diffusion constant. You will present your work to your classmates and write a lab report.

This Week in Lab

This week in lab, you will:

1. **Finish Analyzing Videos 2 and 3:** Analyzing this data will allow you to combine your results with other groups' work and make claims about how varying the investigated parameter affects the diffusion constant. Make a back-up of your data before you begin. Also, make a plan for how to manipulate your data BEFORE you do any calculations in your spreadsheet. (Planning now saves time later!) What are the diffusion constants for videos 2 and 3? (Graphs of r^2 vs. t should have vertical error bars. How can this uncertainty be determined?)
2. **Examine Diffusion:** (We did not explore the dependence of the diffusion constant, D, on temperature. Discuss with your group how you might expect D to vary as a function of temperature.) Using the data that all of the lab groups have collected over the course of this lab, you are expected to make an argument for a plausible expression for the diffusion constant, D, as a function of some (or all) of the following parameters: temperature, fluid viscosity, bead size, and bead mass. (An argument should contain a Claim, Data, and a Warrant—i.e., an explanation of how the claim is related to the data.) You should confirm that this mathematical model for D is plausible by performing a dimensional analysis.
3. **Give Presentations:** Before finishing your lab reports, you should present your work to your peers for critical evaluation. Being part of a community of scientists means <u>sharing</u> your work (in professional journals, through symposia, and at conference talks and poster sessions) for critical evaluation and revision by the community. To model this important aspect of scientific practice, you will create posters presenting your methods, findings, and conclusions. Highlight the important features of your work, your analysis, and your results. During the presentations, ask other groups about what they have done and do not be afraid to ask challenging questions. Your goal is to understand what they have done and how they can improve their work. When you present your work to them, they should ask the same types of

challenging questions of you and your group. This should spark some interesting discussions that you can incorporate into your lab report in the evaluation/critic's section.

4. **Things to consider including in your lab report:** As you know, what goes into your lab report should be determined by the ideas necessary to explain and support your work—in designing the experimental protocol, in collecting and analyzing your data, and in forming your conclusions. Here are a few questions you might consider answering:
   - What characteristics have you observed for random motion? (How would these characteristics be similar or different for directed motion?)
   - If the average total displacement in either the x- or the y-direction is zero for all times, why is the RMS displacement NOT zero? How does the RMS displacement change with time?
   - What is the mathematical model that you have constructed for the diffusion constant, D? How is this justified by your experimental data? Do the dimensions work out? Where should temperature go?
   - How could we design an experiment to find the exact form for the diffusion constant (i.e., how could we figure out the numerical constants that accompany the scaling of D with bead mass, bead radius, viscosity, and temperature)?
   - What could you have done better in your own design and analysis?
   - How are these ideas of random motion and diffusion constants related to (important in) Biology?

Group # (Parameter) (each parameter will be investigated by two distinct groups, allowing you to 'double check' the results)	**Video 1** (condition for testing r^2 vs. t dependence)	**Video 2**	**Video 3**
1 & 2 (bead size)	2-micron silica beads in water	5-micron silica beads in water	1-micron silica beads in water
3 & 4 (fluid viscosity)	2-micron silica beads in water	2-micron silica beads in low viscosity glycerol/water mix	2-micron silica beads in high viscosity glycerol/water mix
5 & 6 (bead mass & viscosity)	2-micron polystyrene beads in water	2-micron polystyrene beads in low viscosity glycerol/water mix	2-micron polystyrene beads in high viscosity glycerol/water mix

Approximate Timing: (~2 hours)

- Introduction: 10 minutes
- Finish Analyzing first video Videos 2 and 3: 30 minutes
- Compare Data to Determine Form of D: 15 minutes
- Prepare Posters for Presentation: 15 minutes
- Presentations: & Class Discussion: 20 minutes
- Finalize and Submit Lab Report: 20 minutes