AAPT Workshop, Brownian Motion to Diffusion Random Walks in Introductory Physics
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The files described here and included on this cololectiona re part of a curricular unit on diffusion developed at the George Washington University by Mark Reeves, Rahul Simha, Robert Donaldson, and Carl Pearson. This is a collaboration between physics, biology, and computer science to develop material to teach quantitative skills to students in biology classes (the Biology of Proteins BISC 183) and the first semester of the calculus based physics course (University Physics, Physics 21). The physics class comprises mostly engineering students, but the material described here is being developed so that it can be integrated into the premed physics course. Also, the material is taught in the week-long workshop for our REU program.

In whatever class this is taught, the material is designed for inquiry-based instruction, using the SCALE_UP methodology. As such, there are a number of components for those familiar: ponderables, tangibles, more formal lab, and written material to supplement text. Today will concentrate on the hands-on/lab portion for this workshop. This material, and full package are available and updated at the IPLS website (www.gwu.edu/~ipls/2010AAPTDC/, and soon on the WIKI (https://www.phys.gwu.edu/iplswiki) that a group of us (Tim McKay, Suzanne Amador Kane, Catherine Crouch, Mark Reeves) have put together to enable the sharing of curricular material and ideas for new approaches to teaching introductory physics to life sciences students (IPLS).

The description here is necessarily brief due to time constraints and will consist only of a description of the files contained here. More detailed instructions can be found at the links above.

The diffusion unit is designed to take the students from microscopic considerations of the random thermal motion to the macroscopic manifestation of this phenomena, diffusion. Observations of Brownian motion provide the microscopic data and the random-walk model is developed as a theoretical framework to model the observations. The link between the microscopic and macroscopic is statistics. Since statistics plays an important role here, and this subject is not often well developed in introductory classes, the

These files are designed to run on mac or pc platforms. Data are collected from still images taken by a digital camera and from video captures made through the eyepiece of a microscope. Mac or PC platforms can be used, however, video capture is easier on the pc because there are more options for inexpensive frame grabbers. Once videos are in hand, then the analysis is easier on the mac or the pc but some of the software used for each is different. Any computer running this software shoul have java installed on it.

List of files given here: Unless otherwise noted the files run on either mac or the pc machines

1. stats2.pdf: background readings on statistics for the students
2. Ponderables on statistics (www.gwu.edu/~ipls/2010AAPTDC): Includes simple coin flipping problems, considerations of binomial distribution for equally and unequally weighted probabilities. Ideas of distributions, mean, standard deviation are developed and linked to the concepts of average and variance.
3. Statistical kinetics (stochastic motion) videos are captured from a microscope using an inexpensive black and white camera and a frame grabber. Here a pc platform is used. Videos are captures to files using loggerpro (insert video capture) or virtualdub (http://www.virtualdub.org/)
4. Video analysis: Once movies are captured, they are analyzed with ImageJ, found at http://rsbweb.nih.gov/ij/. This is a java-base program, freely available that can analyze still and video images. Videos are imported as a sequence of .jpg images (pc) or as .mp4 files (mac). ImageJ parses the videos frame by frame and returns the centroid of the polystyrene bead. The xy coordinates of the centroid are returned, from which can be plotted particle trajectories and histograms of particle position using any standard plotting software.

   Before starting ImageJ, a plug-in written by us here at GW should be installed, **Bead Find (included)**. Simply copy the bead find folder into the Analyze folder of the Plugins folder of the ImageJ installation on your computer.

   a. For mac platforms: video files (saved as .avi format) need to be converted to .mp4, using a program called **Isquint (included here).** Mp4 files are imported to imageJ using the file menu, import using Quicktime. Aways choose convert to grayscale.
   b. For the pc platform: videos are converted to a sequence of .jpg images using virtualdub. These sequences are imported using the file menu, import Image Sequence. Aways choose convert to grayscale.

5. Once the video is imported, select the area of interest, and then choose the bead find routines under the plug-ins menu. Using a threshold value of 0.3 is a good choice and be sure to check the generate boundary box.
6. Diffusion is studied by observing the spreading of a 30 microliter drop of Bromophenol Blue (BPB) in a 1% (10 mg/ml) agarose gel. Gels are poured into petri dishes and once dried, a core of material is removed from the center of the plate using a pipette. Into the hole left by the core is injected the BPB. The BPB will diffuse over a period of 3 days, and the students take pictures of the gels several times per day (every 8 hrs for the first 24 hrs, then every 12 hours). To make the images a digital camera, light box, and home-made hood are used. The pictures are downloaded and then analyzed using ImageJ. The Plot Profile function (under the Analyze menu) is used to plot gray-scale profiles for lines selected across the gels. These intensity vs. position plots are nice bell-shaped

curves that can be fit to Gaussians to extract their standard deviations. Alternately, the FWHM can be measured from plots of the data. The values of standard deviation vs. time are plotted to reveal the $t^{1/2}$ dependence typical of the random-walk model.