ACCESS Physics Week #2

Three Computer Simulation activities

Activity 1 (p1/5):
The Normal (Gaussian) Distribution

- Generating Gaussian (normally distributed) deviates:
  - Use the norminv(p,mu,sigma)
    - p=cumulative probability between 0 and 1 (which you will supply from the ran() function
    - mu=mean (average) of the distribution
    - Sigma=standard deviation of the distribution
- Open your "50,000" XLS files, rename as "norm.xls"

Activity 1 (p2/5)

- In cell B1: insert

  =norminv(rand(),0,1)

- This will generate a random number distributed like a bell curve centered at x=0.0 and has standard deviation (kind of like half-width) of 1.0
- Select B1 and “copy”
- Select B2-B1000 (999 cells) and paste…this might take a couple of seconds

Activity 1 (p3/5)

- In column D, in cells D1-D31, create an array of number from -3.0 to +3.0 incremented by 0.2
  - For example, put -3.0 in D1, =D1+0.2 in D2; select and copy D2 and paste into D3-D31
- SAVE NOW: BE CAREFUL: the next step may result in a stuck computer that might require a manual power off

Activity 1 (p4/5)

- Select cells E1-E31
- You are about to enter a “group formula” which must be ended with a ctrl-shift-Enter instead of a simple “Enter” key-stroke
- While E1-E31 are selected, type in

  =frequency(B1:B1000,D1:D31) ,

  And end this with ctrl-shift-Enter instead of just “Enter”
- This creates a frequency table (a.k.a. “histogram” for the random numbers to fall in “bins” of width 0.2 from -3 to +3.

Activity 1 (p5/5)

- Now select the two columns D and E, and insert an x-y scatter-plot chart
- You should see a distribution from -3 to +3 that resembles a bell curve (with fluctuations), centered at 0.0 and with half-width of ~1.0
- Save and upload this excel file (with the chart)

Activity 2 (p1/4)

Applying Normal Dist to Kinetic Theory

- Close the previous file and open the original "50,000" file again, and generate another 1000 random Gaussian deviates (see activity 1 p1-2) in column B. Save as "kin.xls"
- In column C, take the absolute value of the corresponding random number in column B
  - For example, in C1 enter =abs(B1) …etc.
- **In cell D1, take the average of column C**

  =average(c1:c1000):
- **In column E take the square of column B and find the average of column E in cell F1**

Activity 2 (p2/4)

- What average value did you get?
- When we derived the Idea Gas Law from Kinetic Theory, we used the fact that the velocity v of a gas has the Boltzmann distribution

  $\exp(-mv^2/2kT)$

  The standard form of a normal distribution is

  $\exp(-(x-x0)^2/2s^2)$

  So one can think of the Boltzmann distribution as a Gaussian in v with standard deviation s=square root of kT/m

Activity 2 (p3/4)

- The simulation we just did calculates the average of a Gaussian with s=1:
  - You can think of this as the Boltzmann distribution $\exp(-mv^2/2kT)$ but where the velocity has been expressed in units of sqrt(kT/m)
  - Remember what we usually mean by a "UNIT"…it is a standard quantity by which we divide a measured quantity to get a number
  - E.g.: 3.2 meters means the length in question is 3.2 times that of a standard "meter stick" in Paris.
  - Here I want you to think of sqrt(kT/m) as a UNIT
- **In Kinetic Theory we had used an average "speed" (absolute value of v) of sqrt(kT/m), Is this the correct average from our simulation? If not, what should it really be?**

Activity 2 (p4/4)

- **In Kinetic Theory we actually started with average kinetic energy = ½kT, or average square velocity $<v^2>=kT/m$. Is this the correct average from our simulation? If not, what should it really be?**
- Answer the two questions above in the spreadsheet, save it (with the charts) and upload it.

Activity 3 (p1/5)

Simulating Brownian Motion in 1D

- In this third and final acitivty you will simulate Brownian motion by generating **10** random steps taken by a particle in 1-D
- We will simulate **999** particles: the computer will take quite a few seconds for each recalculation
  - look at the lower left croner of the spreadsheet; don’t do anything until it is done recalculating.
- We will generate each step with a Gaussian distribution of average zero (equal probability of moving left or right), and sigma of 1.0

Activity 3 (p2/5)

- Open a blank Excel file, and save it as "bsim.xls"
- We will generate each particle in a row, instead of a column
- In cell A1: enter =norminv(rand(),0,1)
  - This generates the first step, and A1 represents the popsition x(1) of particle 1 after 1 step
- In cell B1: enter =A1+ norminv(rand(),0,1)
  - This takes a further random step from the previous step

Activity 3 (p3/5)

- Now select B1, and “copy” select C1-J1, paste
  - Column J1 will now represent the position x(10) of particle #1 after 10 steps
- Now select row 1, copy, and then select the rows 2-999, and paste
- Now select the first five rows and use them to insert a “line chart” (not xy scatter-plot)
  - This gives you a plot of the motion (x as a function of step #, or time if you like) of particles 1-5 over the 10 steps

Activity 3 (p4/5)

- The predictions of Brownian motion is that $<x^2>$ should be proportional to time (or step number), where <> means averaging over all the particles (like you did ion your lab)
- In cell A1001, enter =A1^2, select A1001 and copy, then select A1001-J1001, and paste
  - This calculated x^2 for the first particle over 10 steps
- Select Row 1001, copy, then select rows 1002-1999, paste.
  - We now have x^2 for all 999 particles over ten steps

Activity 3 (p5/5)

- In cell A2001, enter =average(A1001:A1999)
  - This calculated $<x^2>$ for the 1st step
- Select A2001, copy, select B2001-J2001, copy
  - We now have $<x^2>$ over ten steps
- Select row 2001, and insert a line chart:
- What is the slope of $<x^2>$ vs step #?
- Answer the question, save file (with both charts) and upload.

- You are Done!!!