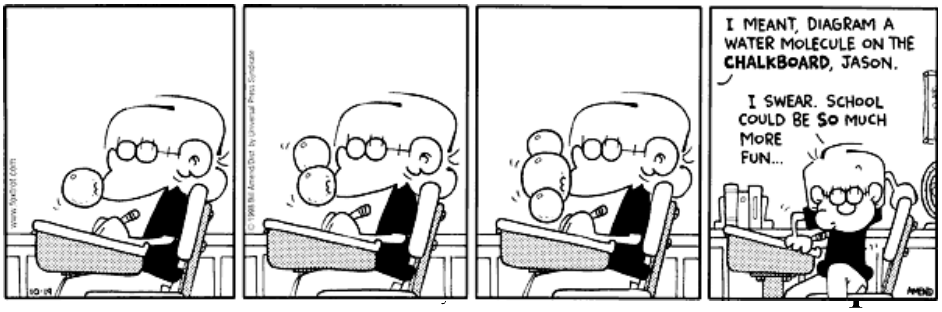
October 26, 2016 Physics 131 Prof. E. F. Redish

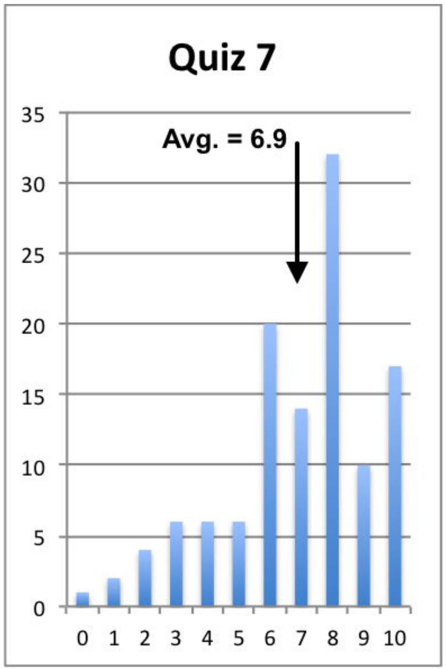
- **Theme Music: Robert Alda**
  Luck Be a Lady ***(from Guys & Dolls)***
- **Cartoon: Bill Amend**
  FoxTrot



Quiz 7

	1.1	1.2	2
a	0%	44%	21%
b	82%	39%	65%
c	3%	4%	4%
d	8%	8%	3%
e	13%	10%	75%
f	11%	10%	4%

	3
1	5%
2	3%
3	3%
4	8%
5	81%



Foothold idea: Coulomb's Law

- Point charges attract each other with a force whose magnitude is given by

$$\vec{F}_{q\to Q} = -\vec{F}_{Q\to q} = \frac{k_C qQ}{r_{qQ}^2}\hat{r}_{q\to Q}$$

- k_C is put in to make the dimensions come out right.

$$\left[k_C\right] = \left[\frac{Fr^2}{q_1 q_2}\right] = \frac{\mathrm{ML}}{\mathrm{T}^2}\frac{\mathrm{L}^2}{\mathrm{Q}^2} = \frac{\mathrm{ML}^3}{\mathrm{Q}^2\mathrm{T}^2}$$

Adding forces for many charges!

$$\vec{F}_q = \vec{F}_{Q_1\to q} + \vec{F}_{Q_2\to q} + \vec{F}_{Q_3\to q} + \vec{F}_{Q_4\to q} + \ldots$$

$$\vec{F}_q = \frac{k_C qQ_1}{r_1^2}\hat{r}_1 + \frac{k_C qQ_2}{r_2^2}\hat{r}_2 + \frac{k_C qQ_3}{r_3^2}\hat{r}_3 + \frac{k_C qQ_4}{r_4^2}\hat{r}_4 + \ldots$$

where

$r_1 =$ distance from Q_1 to q $\hat{r}_1 =$ direction from Q_1 to q (mag. 1, no units!)

$r_2 =$ distance from Q_2 to q $\hat{r}_2 =$ direction from Q_2 to q (mag. 1, no units!)

...

E field for many charges!

$$\vec{E} = \frac{\vec{F}_q}{q}$$

$$\vec{F}_q = \frac{k_C q Q_1}{r_1^2}\hat{r}_1 + \frac{k_C q Q_2}{r_2^2}\hat{r}_2 + \frac{k_C q Q_3}{r_3^2}\hat{r}_3 + \frac{k_C q Q_4}{r_4^2}\hat{r}_4 + \ldots$$

where

$r_1 =$ distance from Q_1 to q $\quad$ $\hat{r}_1 =$ direction from Q_1 to q (mag. 1, no units!)

$r_2 =$ distance from Q_2 to q $\quad$ $\hat{r}_2 =$ direction from Q_2 to q (mag. 1, no units!)

...

Foothold principles: Fick's first Law

- If a set of molecules is not distributed uniformly in 1D (there is a concentration gradient) there will be an effective flow of those molecules according to

$$J = -D\frac{dn}{dx}$$

(or in 3D) $\vec{J} = -D\vec{\nabla}n$

- In a gas, the diffusion constant D is given by $\frac{1}{2\sqrt{3}}\lambda\bar{v}$
- In a liquid, the diffusion constant is given by $D = \frac{k_B T}{6\pi\mu R}$

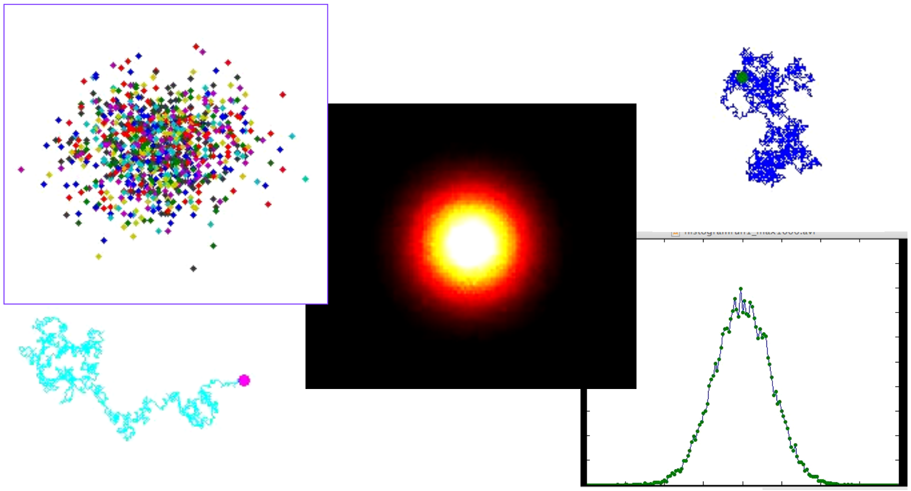
Foothold principles: Fick's second Law

- The average square displacement of a random walking molecule in a thermal bath after a time t is given in 3D by Fick's second law:

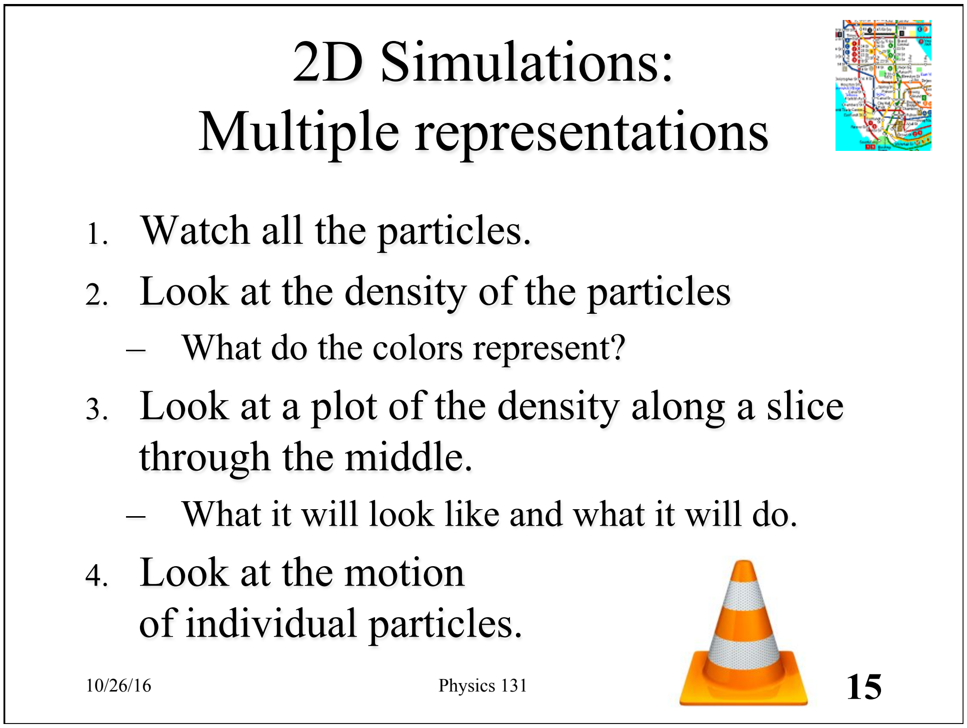
$$\langle \Delta r^2 \rangle = \langle \Delta x^2 \rangle + \langle \Delta y^2 \rangle + \langle \Delta z^2 \rangle = 6D\Delta t$$

- The radius of a small blob of chemical in a liquid will grow at this rate.
- The displacement, $\Delta r = \sqrt{\langle \Delta r^2 \rangle}$, only grows like $\sqrt{\Delta t}$ For larger organisms, this is too slow and is the reason transport systems for air and blood have evolved.

2D Simulations: Multiple representations



Simulations by Alex Morozov & Kerstin Nordstrom



2D Simulations: Multiple representations

1. Watch all the particles.
2. Look at the density of the particles
   - What do the colors represent?
3. Look at a plot of the density along a slice through the middle.
   - What it will look like and what it will do.
4. Look at the motion of individual particles.