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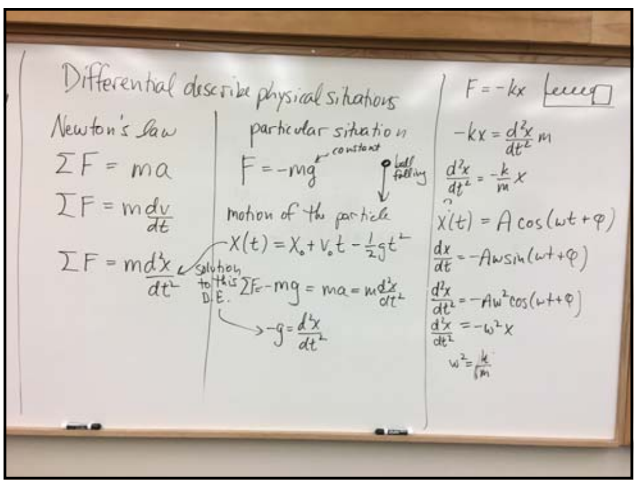

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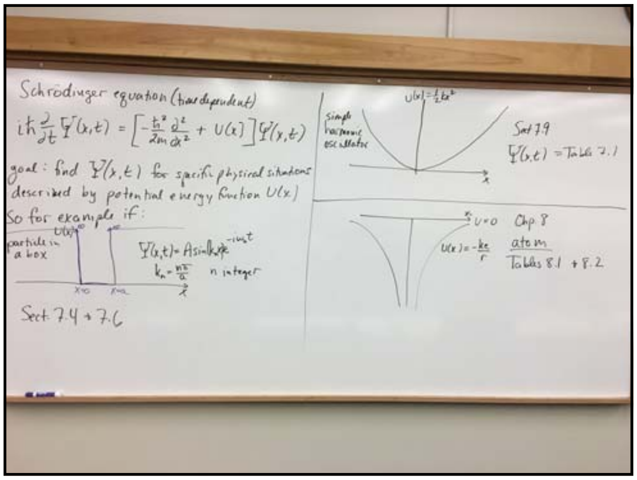

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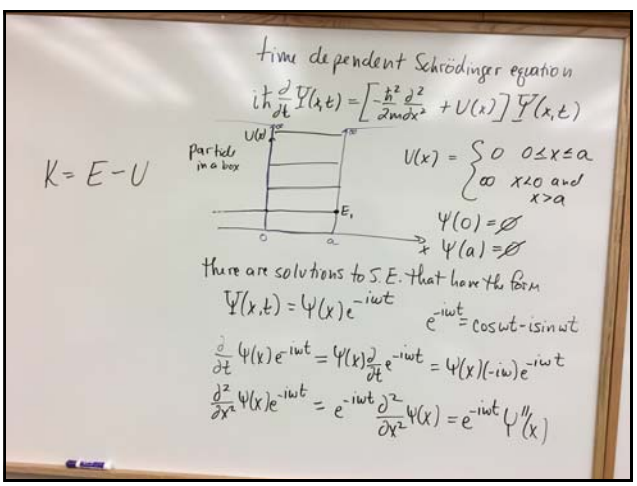

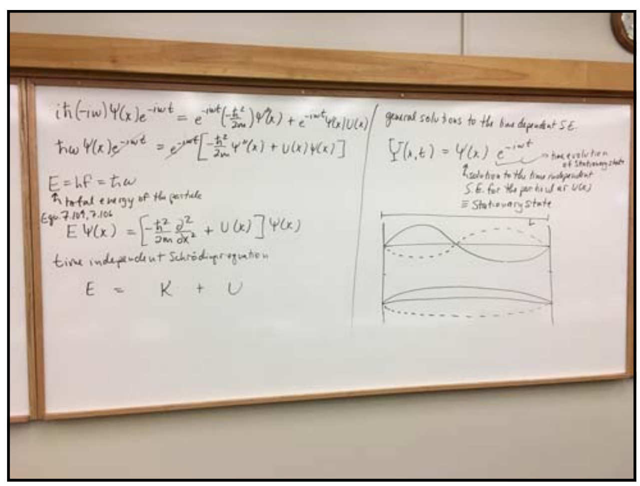

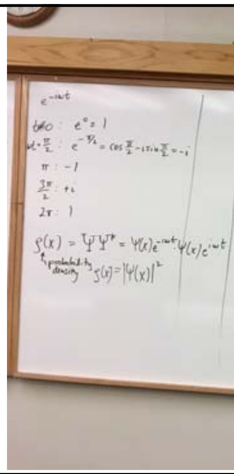

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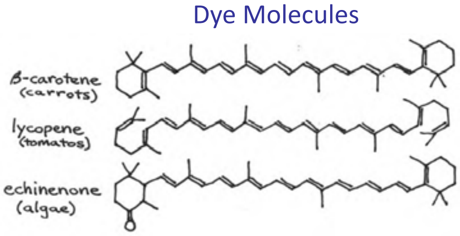
Dye Molecules



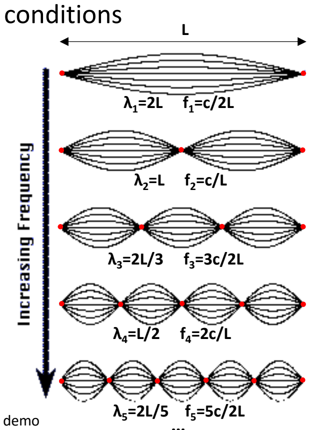
- Carbon atom at each vertex.
- Single vs double line tells what kind of bond.
- Typically one or two free electrons per carbon atom.
- Basic behavior predicted with ignoring internal structure.
- Free electrons = particles.
- Dye molecule = box.

Waves with boundary conditions

- Boundary conditions mean that waves only have discrete frequencies.
- e.g., guitar strings

$\lambda_n = 2L/n$
$f_n = nc/2L$

• = node = fixed point that doesn't move



PHET: normal modes + standing wave demo

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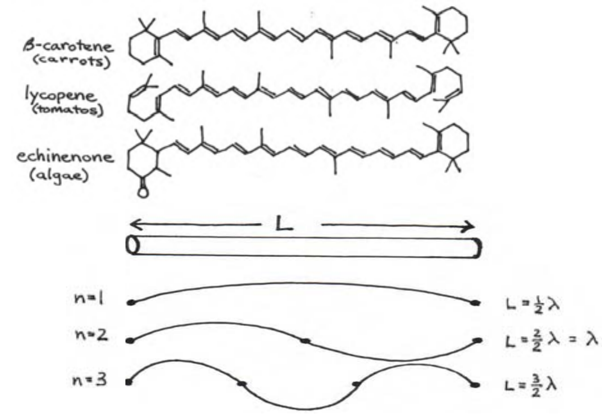

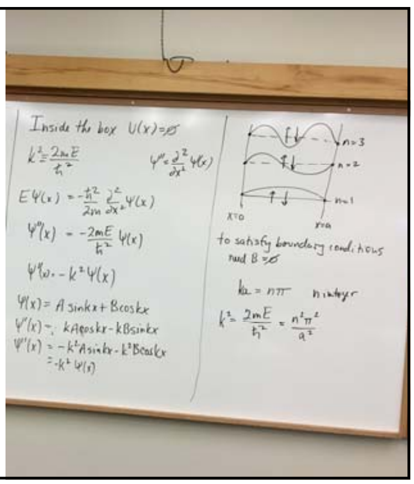

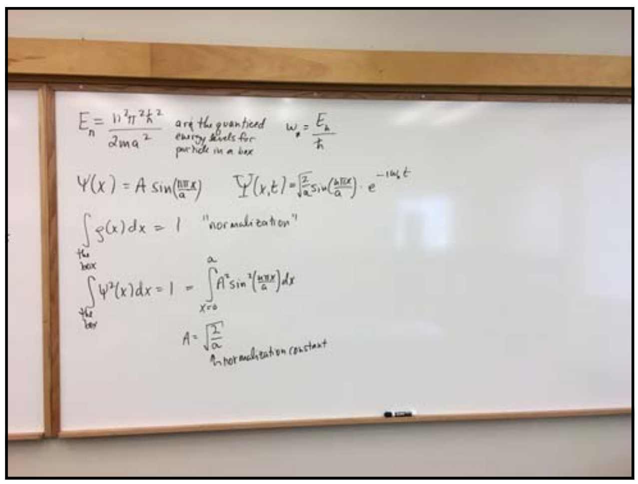

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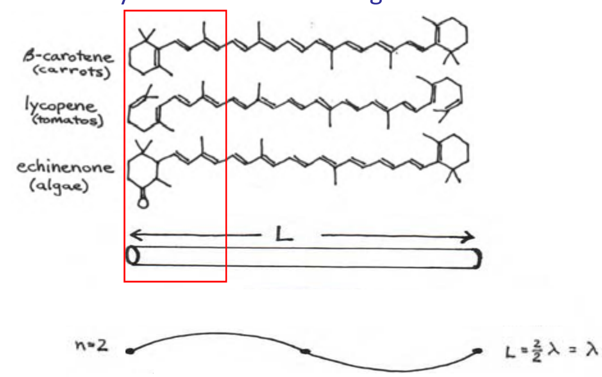
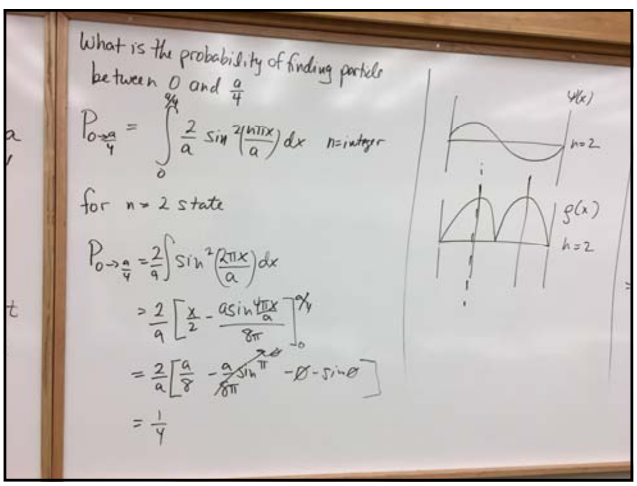
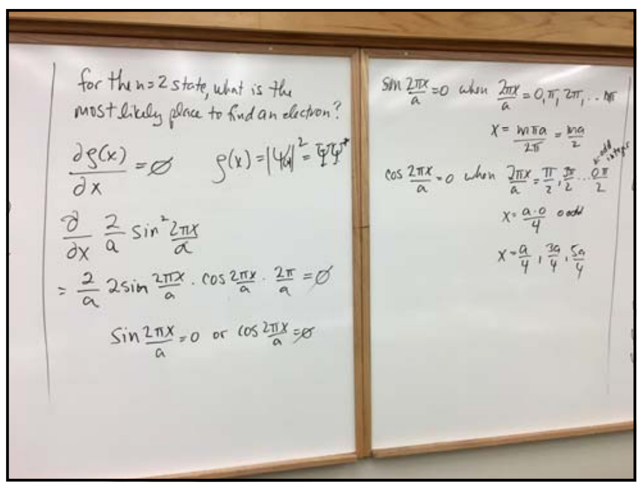
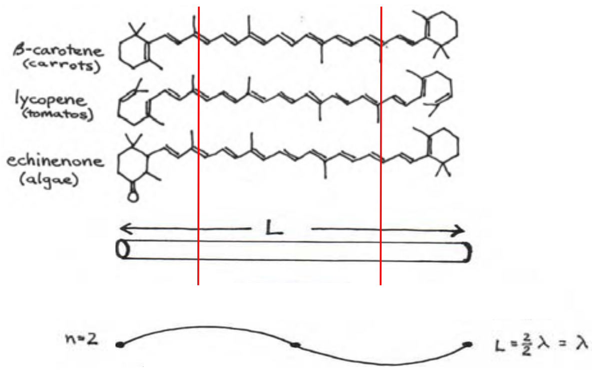
Probability to find electron in region inside red box?

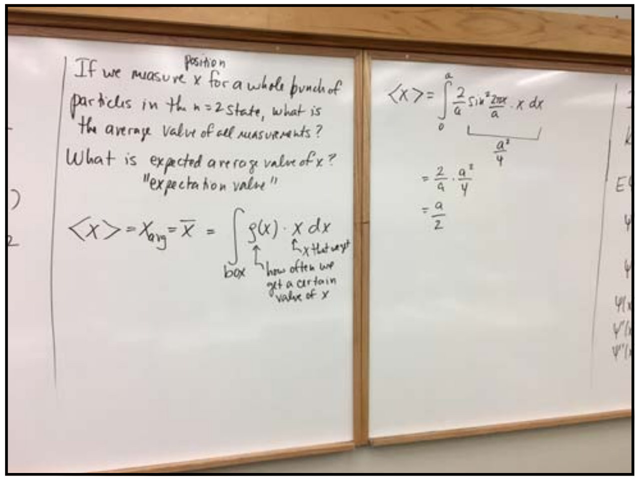




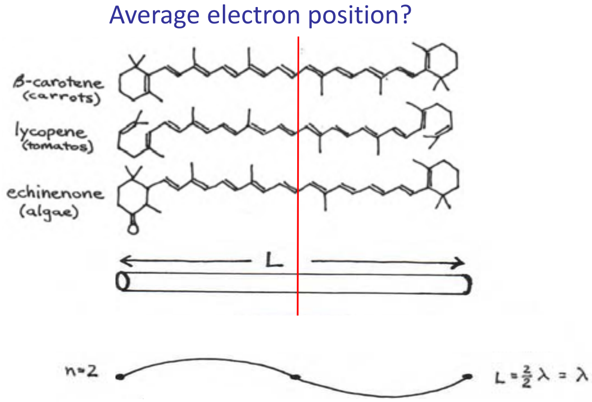


Most likely place to find the electron?





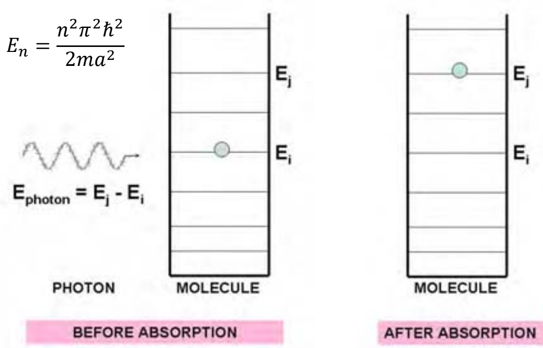
Average electron position?



Absorption of Photons

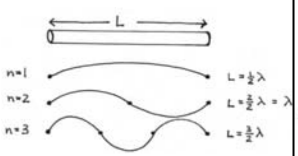
Energy spacing given by:

$$E_n = \frac{n^2\pi^2\hbar^2}{2ma^2}$$

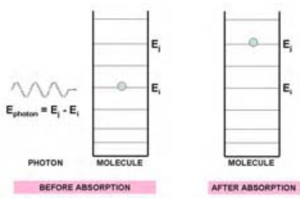


Two Wavelength Danger

length of box determines allowed **electron** wavelengths and hence energy levels



electron energy levels determine allowed **light** absorption wavelengths



Derive equation 10

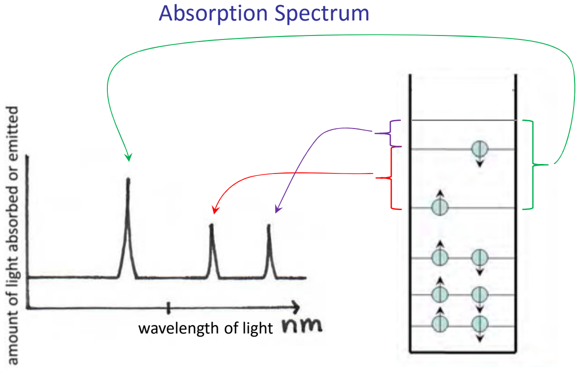
What is the wavelength of a photon that can excite a particle from the m to n state? $n > m$

$$\Delta E_{nm} = E_n - E_m = (n^2 - m^2)\left(\frac{\pi^2 \hbar^2}{2ma^2}\right)$$

$$\Delta E_{nm} = h f_{nm} = \frac{hc}{\lambda_{nm}}$$

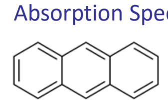
$$\lambda_{nm} = \frac{8cma^2}{h(n^2 - m^2)}$$

Absorption Spectrum

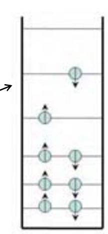


Absorption Spectra of Real Molecules

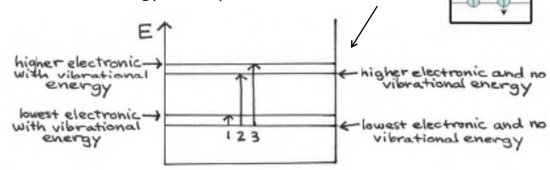
anthracene



electron energy levels only



electron energy levels plus vibrational levels



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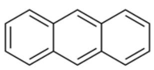
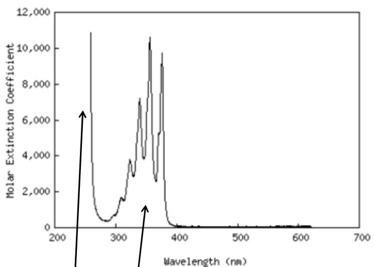




Real molecules

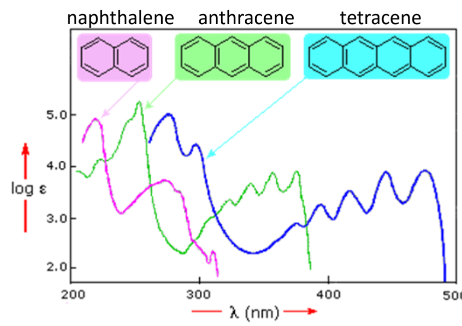
- Vibrate
- Rotate
- Contact other things (molecules, solution)

And their spectra reflect these complications

these peaks in spectra are due to vibrational modes within an electron energy level

this peak is from a different electron energy level

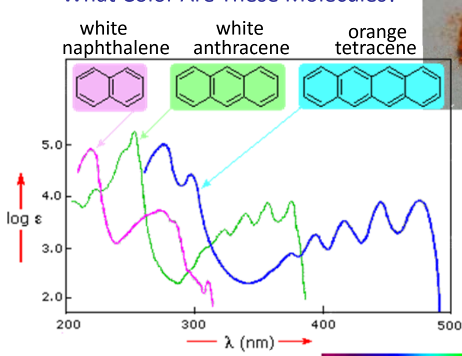
Absorption Range Shifts With Size of Molecule

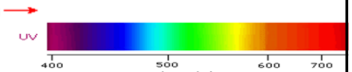


$$\lambda = \frac{8mca^2}{h(n^2 - m^2)}$$

Despite real world complications, particle in a box model provides basic description.

What Color Are These Molecules?





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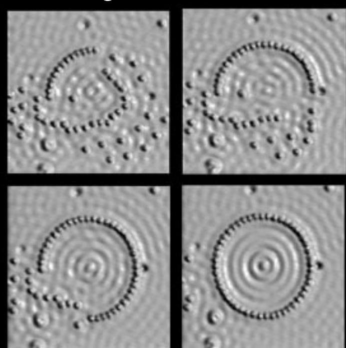
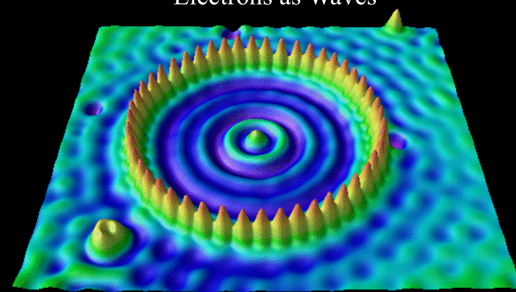
Moving Atoms with an STM

Fe atoms on Cu



M.F. Crommie, C.P. Lutz, D.M. Eigler.
Confinement of electrons to quantum corrals on a metal surface.
Science 262, 218-220 (1993).

Electrons as Waves



48 Fe atoms and resulting electron standing wave pattern on a Cu(111) surface

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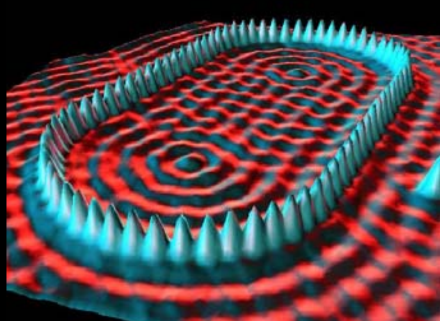
Electron Wave Echo Chamber



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Waves on a metal surface and quantum corrals.
Surface Review and Letters 2 (1), 127-137 (1995).