DAY 28 PH 631 (1) Instructor Ethan Minot

summary and preview of next quarter

$$\nabla\cdot\left(\epsilon_0\vec{E}+\vec{P}\right)=\rho_{free}$$

$$\nabla\times\left(\frac{\vec{B}}{\mu_0}-\vec{M}\right)-\frac{\partial}{\partial t}\left(\epsilon_0\vec{E}+\vec{P}\right)=\vec{J}$$

$$\vec{\nabla}\times\vec{E}+\frac{\partial\vec{B}}{\partial t}=0$$

$$\vec{\nabla}\cdot\vec{B}$$

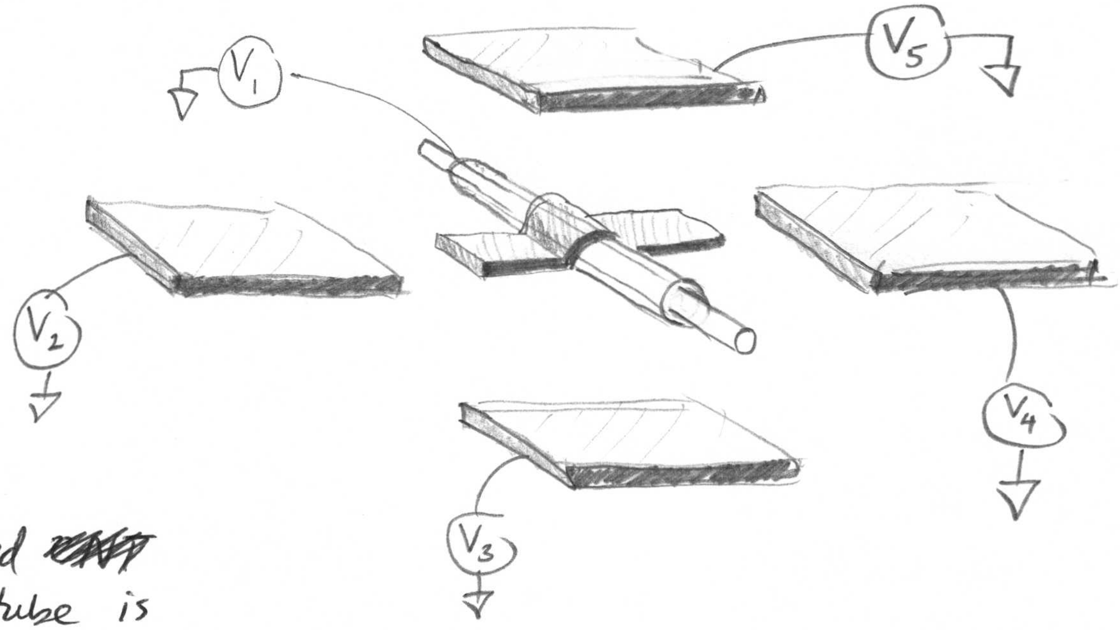
Maxwell's equations in matter

where $\frac{\partial\rho_{free}}{\partial t}+\nabla\cdot\vec{J}=0$ & $\vec{F}=q\left(\vec{E}+\vec{v}\times\vec{B}\right)$

We've spent all our time studying the first equation. Fortunately we've developed techniques that will help with the next 3 equations.

With just the first equation, there are many exciting and relevant phenomena to study. Here are some examples from modern research....

- The world's smallest electric motor (circa 2005)

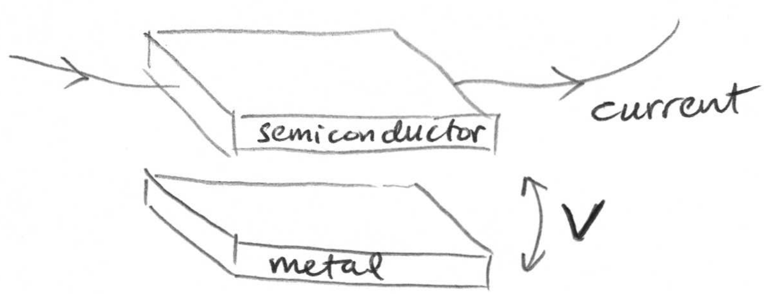


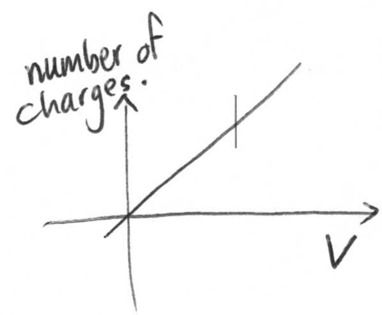
Double-walled carbon nanotube is used as the axil.
Diameter ~2nm.

The metal paddle spins around when the voltage is cycled to

$$V_2 \rightarrow V_3 \rightarrow V_4 \rightarrow V_5$$

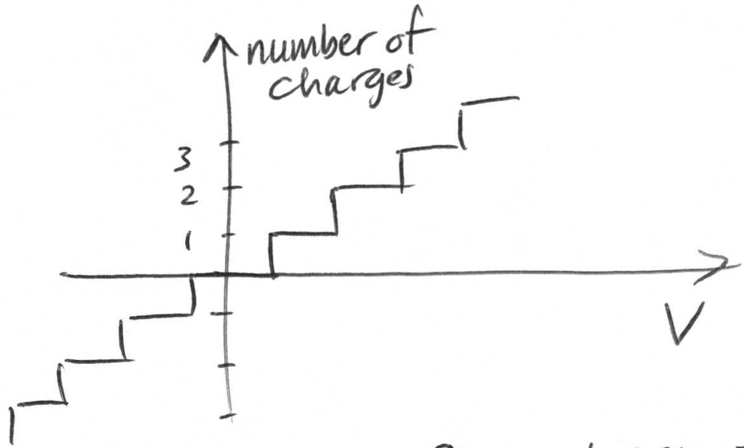
- Single electron transistors (circa 1990)





In a standard transistor the voltage V is used to change the amount of charge in the semiconductor, thus changing its resistance.

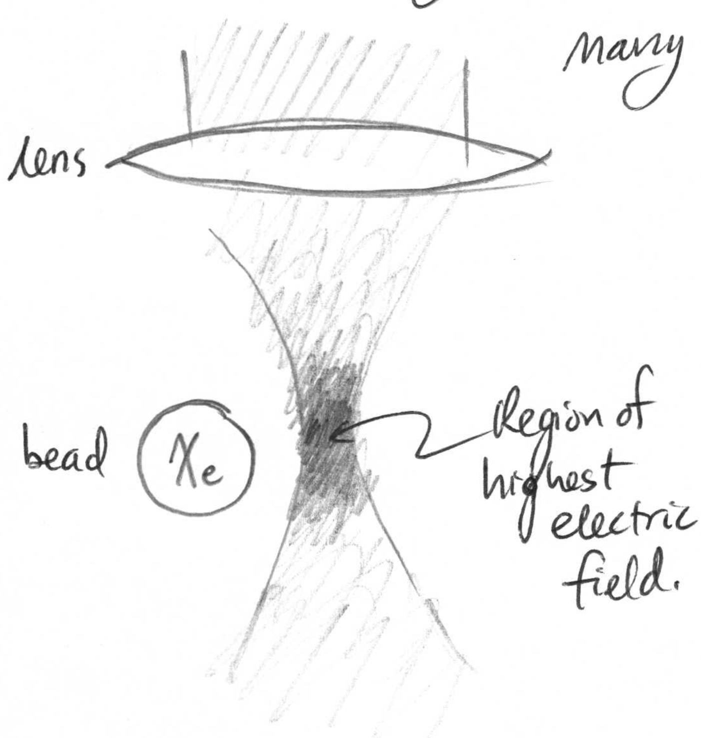
In the single electron transistor,
we observe the discrete nature of electrons



Current can only flow if V is set to the edge of a step.

- Laser trapping / Optical tweezers

Many applications pioneered in 1990s.



A dielectric sphere will be pulled into the focal point of a focussed laser.

Problem 3.41 Buckminsterfullerine is a molecule of 60 carbon atoms arranged like the stitching on a soccer-ball. It may be approximated as a conducting spherical shell of radius $R = 3.5\,\text{Å}$. A nearby electron would be *attracted*, according to Prob. 3.9, so it is not surprising that the ion C_{60}^{-} exists. (Imagine that the electron—on average—smears itself out uniformly over the surface.) But how about a *second* electron? At large distances it would be *repelled* by the ion, obviously, but at a certain distance r (from the center), the net force is zero, and closer than this it would be attracted. So an electron with enough energy to get in that close should bind.

(a) Find r, in Å. [You'll have to do it numerically.]

(b) How much energy (in electron volts) would it take to push an electron in (from infinity) to the point r?

[Incidentally, the C_{60}^{--} ion has been observed.][21]