Review harmonic oscillator applet

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial V}{\partial y^2} = 0$$

Sch Eqn $\text{const} \frac{\partial}{\partial t} \Psi = \text{const}' \frac{\partial^2 \Psi}{\partial x^2} + U(x)\Psi$

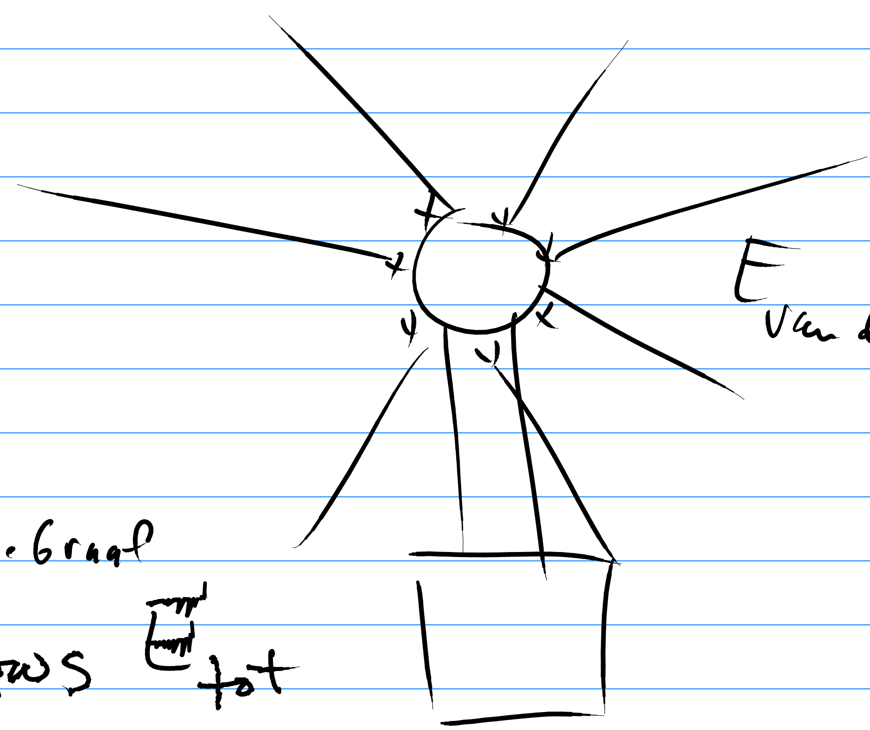
Sep Variable $\Rightarrow$ solns that

don't solve a general bndry condition

- one difference between Sch & Laplace is 1 time & 1 space variable vs 2 space variables
- large n result does not yield classical harmonic oscillator
- applet plots $\Psi\Psi^*$ not Ψ
- perfect gaussian shown is not correct

Next applet:

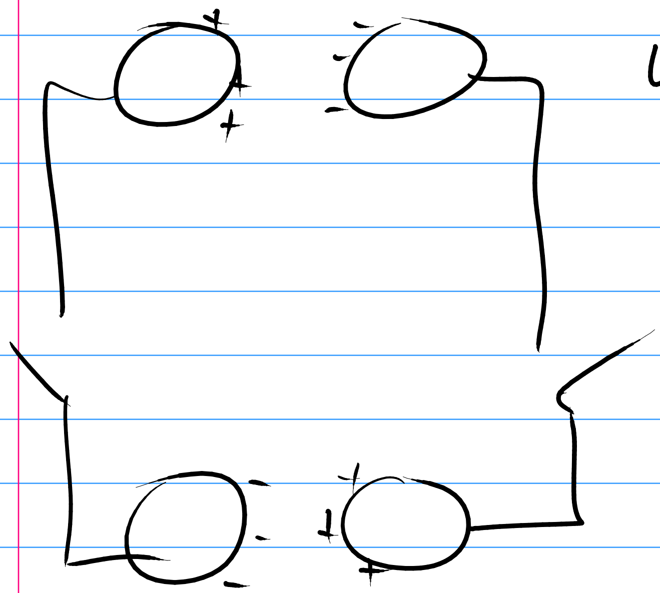
$\oplus$
q



$E_{\text{Van de Graaf}}$

$$\vec{F} = q\vec{E}_{\text{van de Graaf}}$$

but applet shows $\vec{E}_{tot}$

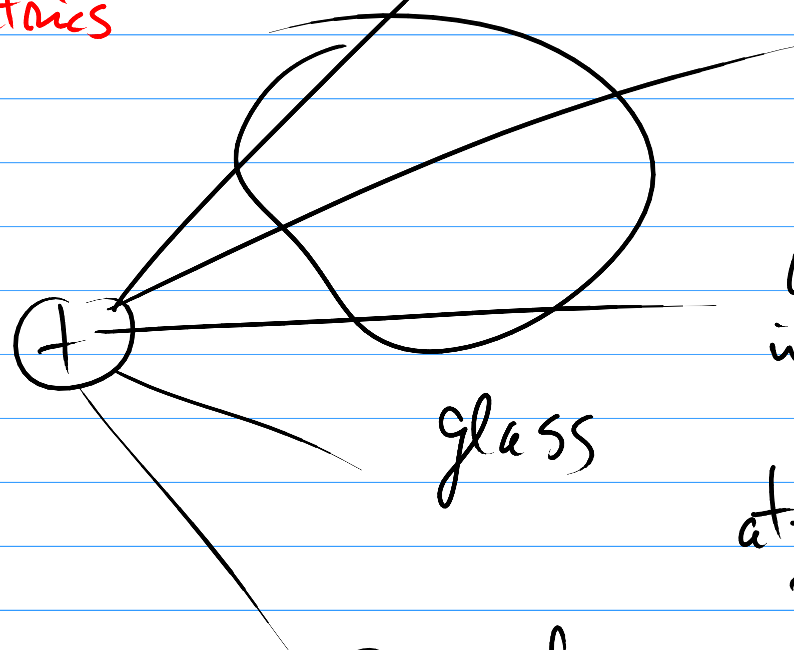


What happens when switches are closed?

$$\text{energy} = \frac{1}{2}\epsilon_0 \int E^2 \, d\tau$$

which is minimized when charge moves to yield zero charge on each of the 4 spheres

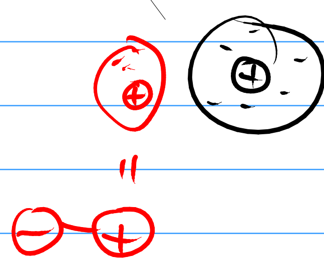
Dielectrics



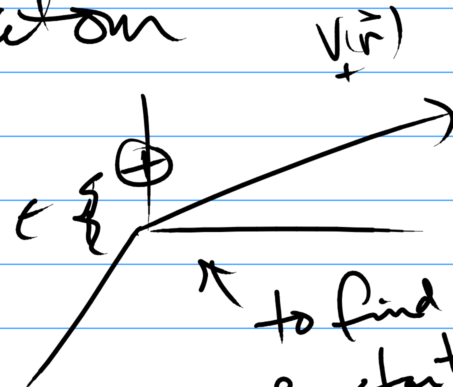
What happens in the glass?

glass

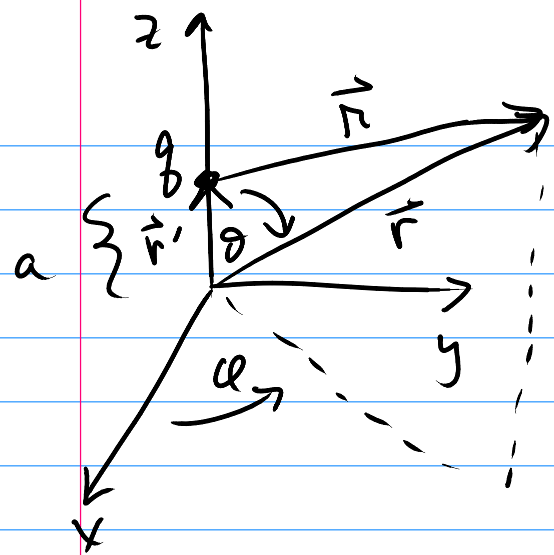
atoms become polarized



atom



to find V for a dipole start here then add neg charge



$$V(r,\theta) = \frac{1}{4\pi\epsilon_0}\frac{q}{\imath} = \frac{q}{4\pi\epsilon_0}\frac{1}{\left(r^2+a^2-2ar\cos\theta\right)^{1/2}}$$

For $r>a$ expand $\frac{1}{\imath}$ in small parameter $\underbrace{\frac{a^2}{r^2}-\frac{2a}{r}\cos\theta}_{\epsilon}$

binomial theorem

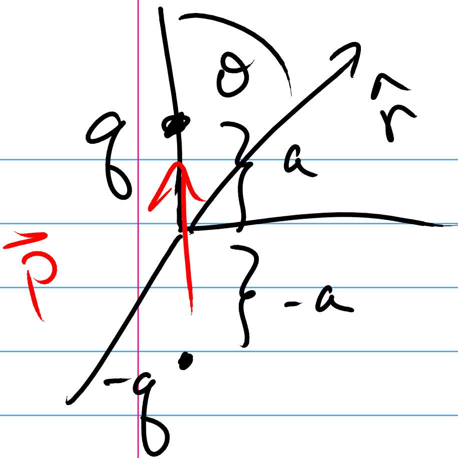
$$\frac{1}{(\quad)^{1/2}} = \frac{1}{r(1+\epsilon)^{1/2}} = \frac{1}{r}\left[1-\frac{1}{2}\left(\frac{a^2}{r^2}-\frac{2a}{r}\cos\theta\right)+\frac{3}{8}\left(\frac{a^2}{r^2}-\frac{2a}{r}\cos\theta\right)^2 + \dots\right]$$

Arranging in powers of $\frac{a}{r} \ll 1$

$$\frac{1}{r(\quad)^{1/2}} = \frac{1}{r}\left\{1+\left(\frac{a}{r}\right)\cos\theta+\left(\frac{a}{r}\right)^2\left[\frac{3\cos^2\theta-1}{2}\right]+\dots\right\}$$

$$= \frac{1}{r}\sum_{l=0}^{\infty}\left(\frac{a}{r}\right)^l P_l(\cos\theta) \qquad r>a$$

As $\frac{a}{r}\to 0$ $\quad V \to \frac{q}{4\pi\epsilon_0}\frac{1}{r}$



$$V = V_q + V_{-q} = \frac{q}{4\pi\epsilon_0}\begin{cases} \frac{1}{r}\left[1 + \frac{a}{r}\cos\theta + \cdots\right. \\ -\frac{1}{r}\left[1 - \frac{a}{r}\cos\theta + \cdots\right. \end{cases}$$

$$V_{\text{dipole}} \simeq \frac{q}{4\pi\epsilon_0}\,\frac{2a\cos\theta}{r^2}$$

let $p = 2qa$

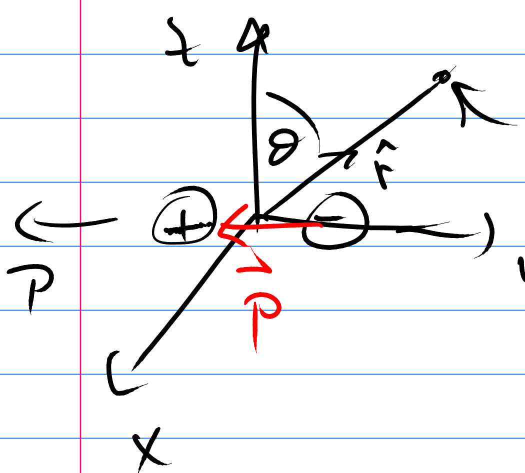
$$\vec{p} = \sum_i q_i \vec{r}_i$$

$$= q a \hat{z} - q(-a\hat{z})$$

$$= 2aq\,\hat{z}$$

$$V_{\text{dipole}} = \frac{\vec{p}\cdot\hat{r}}{4\pi\epsilon_0 r^2}$$

$$= \frac{p|\hat{r}|\cos\theta}{4\pi\epsilon_0 r^2}$$



in the y-z plane

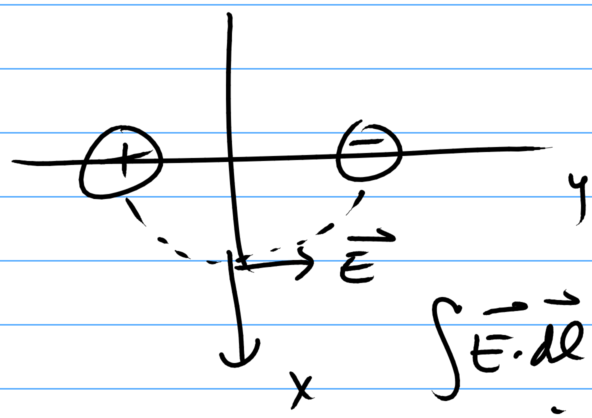
$$V = \frac{p|\hat{r}|\cos(90+\theta)}{4\pi\epsilon_0 r^2}$$

if $\vec{r}$ is in the x-z plane then $\vec{p} = p(-\hat{y})$

$$\vec{r} = r\hat{x}$$

$$\vec{p}\cdot\vec{r} = 0$$

Note that in x-z plane (looking down the z axis)



$\int \vec{E} \cdot \vec{dl}$ along x axis is 0 since $\vec{E} \perp \vec{dl}$

So $V = 0$ in x-z plane