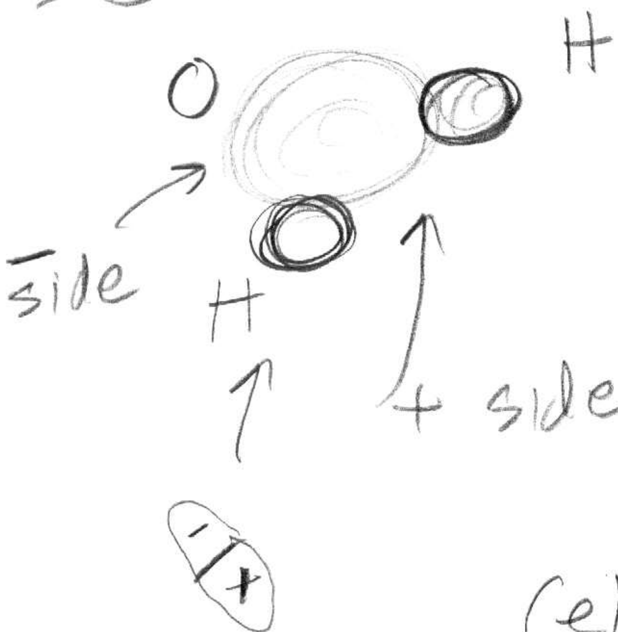
Dielectrics

"2".

The root idea ... atoms are neutral, but their + and − charge can get separated, in which case they acquire a dipole moment.

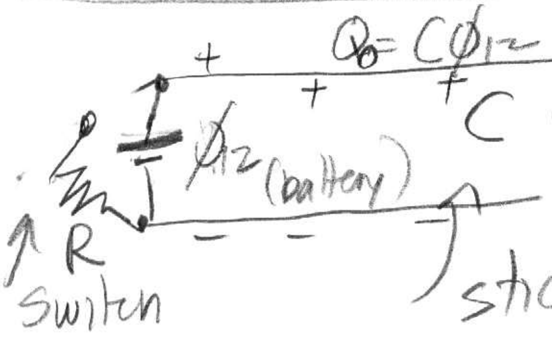
Example Water:



H "donates" electrons to O

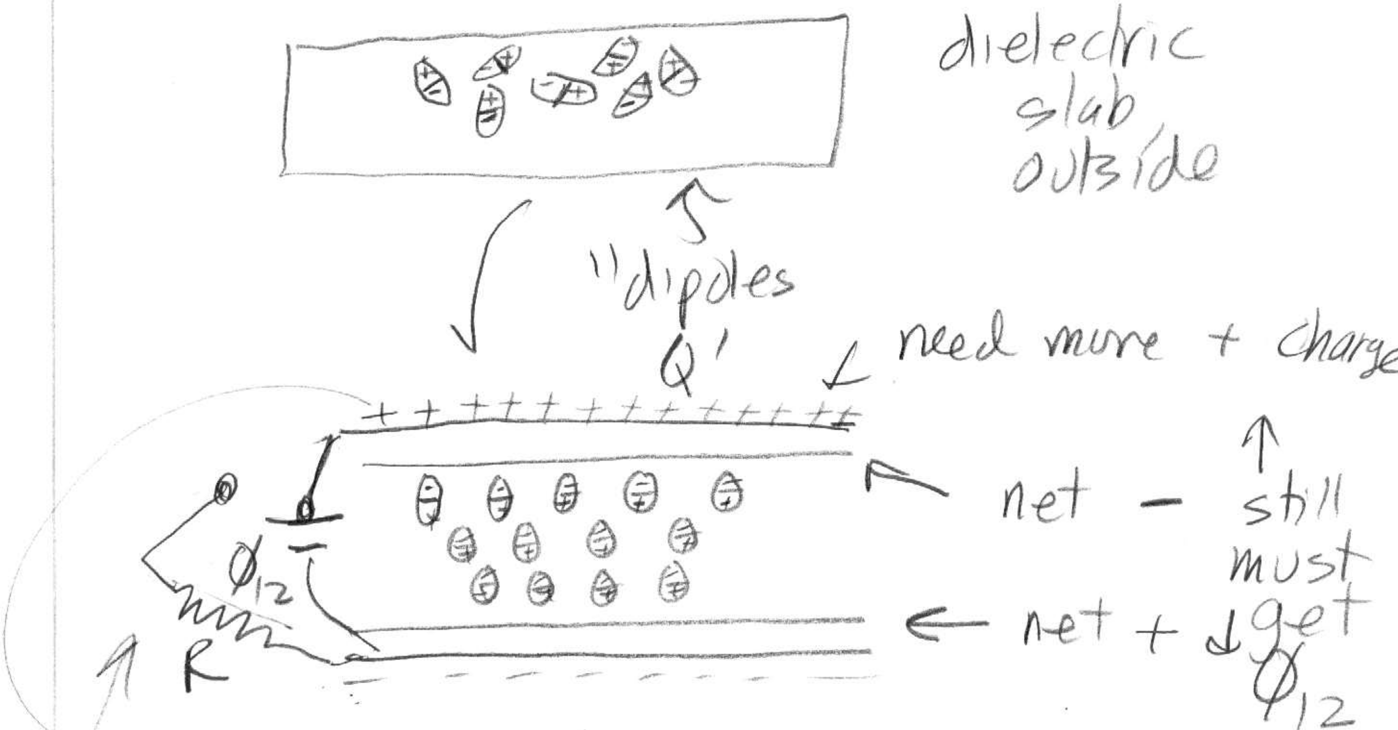
⇐ separation means dipole moment (electrically neutral)

Capacitance and Dielectric Constant ε



C (vacuum) → $C = \dfrac{A}{4\pi s}$ (parallel plates)

Dielectric → • insulator, non-conductive.



$$Q = C'\phi_{12}$$

bigger

same

$\therefore C' > C$

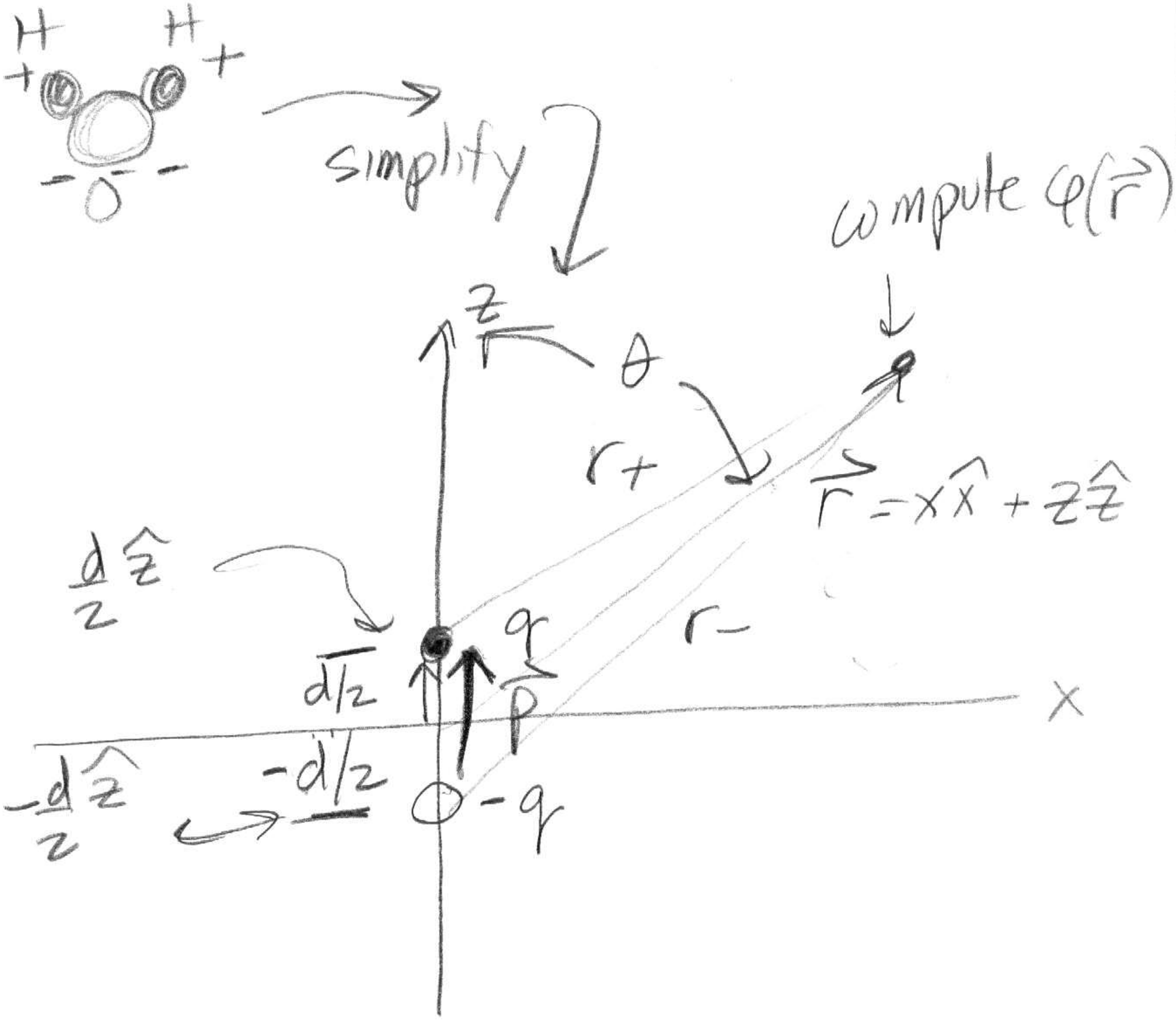
$$\boxed{\frac{Q}{Q_0} = \frac{C'}{C} \equiv \varepsilon \quad \text{"dielectric constant"} \qquad \varepsilon > 1}$$

switch thrown -- more charge must flow through!

$\varepsilon_{wax} \simeq 2.1 - 2.5$

$\varepsilon_{water} \simeq 80!$ (polar molecule)

Microphysics



$$r_+ = \sqrt{x^2 + (z - d/2)^2}$$

$$r_- = \sqrt{x^2 + (z + d/2)^2}$$

$$\varphi(\vec{r}) = \frac{q}{\sqrt{x^2+(z-d/2)^2}} - \frac{q}{\sqrt{x^2+(z+d/2)^2}}$$

$$\sqrt{x^2+(z\pm d/2)^2} \simeq \left(x^2+z^2 \pm zd\right)^{1/2} \quad \text{(neglect } d^2\text{!)}$$

$$\simeq \sqrt{x^2+z^2}\left(1 \pm \frac{zd}{x^2+z^2}\right)^{1/2}$$

$$\simeq \sqrt{x^2+z^2}\left(1 \pm \frac{zd}{2(x^2+z^2)}\right)$$

$$\frac{1}{\sqrt{x^2+(z\pm d/2)^2}} \simeq \frac{1}{\sqrt{x^2+z^2}}\left(1 \mp \frac{zd}{2(x^2+z^2)}\right)$$

$$\varphi(\vec{r}) = \frac{1}{\sqrt{x^2+z^2}}\left(\cancel{q} + \frac{zdq}{2(x^2+z^2)} - \cancel{q} + \frac{zdq}{2(z^2+x^2)}\right)$$

$$= \frac{(dq)\cdot(z)}{(x^2+z^2)^{3/2}} = \frac{\vec{p}\cdot\vec{r}}{r^3}$$

$\vec{p}$: $\cdot$ length = distance between +/- charges

$p = |\vec{p}| =$ length $\cdot\, q$

direction: from − charge to + charge

$$\varphi(\vec{r}) = \frac{\vec{p}\cdot\hat{r}}{r^2} \quad \propto 1/r^2 \;!! \quad (\text{not } 1/r)$$

$$E_x = -\frac{\partial \varphi}{\partial x} = \frac{3pxz}{(x^2+z^2)^{5/2}} =$$

$$\boxed{E_x = \frac{3p\sin\theta\cos\theta}{r^3}}$$

$$E_z = -\frac{\partial \varphi}{\partial z} = p\left[\frac{3z^2}{(x^2+z^2)^{5/2}} - \frac{1}{(x^2+z^2)^{3/2}}\right]$$

$$\boxed{E_z = \frac{p(3\cos^2\theta - 1)}{r^3}}$$