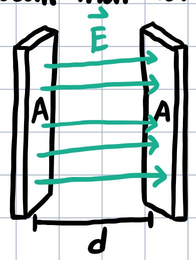
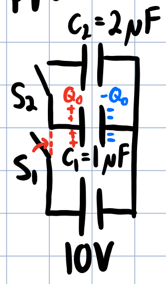
Dielectrics

- Recall that for a capacitor, its energy is $U=\frac{1}{2}Q^2\frac{d}{A\varepsilon_0}=\frac{1}{2}\times\frac{Q^2}{C}=\frac{1}{2}CV^2=\underbrace{\overset{\text{energy density}}{u}}_{\frac{1}{2}E^2\varepsilon_0}Ad$

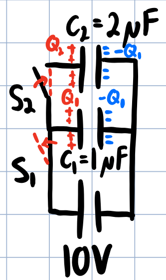


- Suppose we have the following scenario:



If we close S_1 "for a long time", $Q_0=C_1V=10\mu C$.

U stored in $C_1=\frac{1}{2}C_1V^2=50\mu J$



If we open S_1 and close S_2 "for a long time", $V_{C_1}=V_{C_2}\rightarrow\frac{Q_1}{C_1}=\frac{Q_2}{C_2}\rightarrow 2Q_1=Q_2$.

We also know $Q_0=Q_1+Q_2\rightarrow Q_1=3.33\mu C$ and $Q_2=6.67\mu C$.

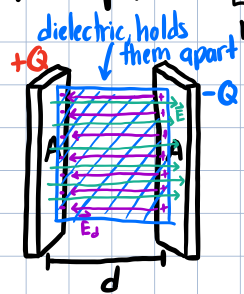
$U_1=\frac{1}{2}\times\frac{Q_1^2}{C_1}=5.56\mu J$, $U_2=11.12\mu J\rightarrow U=16.68\mu J$

  - Why does U decrease?
    I. Energy is used to move the charges
    II. Charges are not as concentrated

- If we want square capacitors 1mm apart with capacitance $1\mu F$, what should the side length be?

  $C=\frac{\varepsilon_0 A}{d}=10^{-6}=\frac{(8.85\times10^{-12})\times x^2}{10^{-3}}\rightarrow x=10.6\,m$

- If we put an <u>insulating material</u> in a capacitor, it changes things
  referred to as dielectric



Without dielectric, $C_0=\frac{\varepsilon_0 A}{d}=\frac{Q}{V_0}=\frac{Q}{E_0 d}$.

With dielectric, atoms become slightly polarized, forming electric field $\vec{E}_d$ that goes against $\vec{E}_0$.

$C=\frac{Q}{V}=\frac{Q}{(E_0-E_d)d}=KC_0$; $C>C_0$, $\frac{C}{C_0}=K=$ dielectric constant.

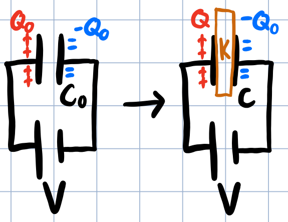
Note that $E_0=KE\rightarrow V=\frac{V_0}{K}$.

- We can use Gauss' Law to find the electric field in a dielectric:

$$\oint \vec{E}_{plates} \cdot d\vec{A} = \frac{Q_{plates}}{\varepsilon_0}$$

$$\rightarrow \oint K\vec{E} \cdot d\vec{A} = \frac{Q_{plates}}{\varepsilon_0} \quad \text{(Idk check textbook)}$$

- What if we put a dielectric in a circuit capacitor?



$C = KC_0 \rightarrow \frac{Q}{V} = K\frac{Q_0}{V_0}$; V stays constant (battery) $\rightarrow Q = KQ_0$.