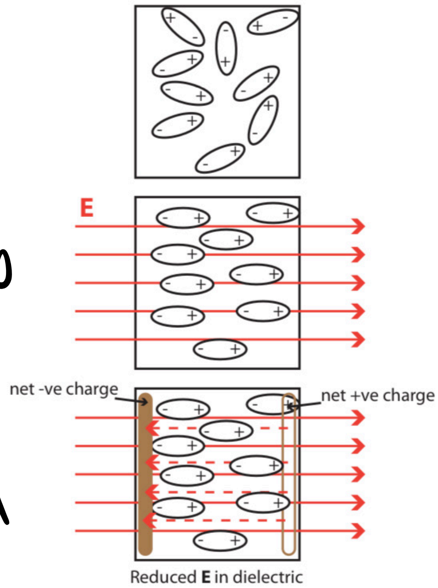
Polarisation

Let's consider the dielectric to be made from many polar molecules. Initially they will orientated randomly.



Now, applying an electric field will cause these to rotate and align.

In the centre there are equal numbers of positive & negative charges. However, on the left end there are mainly negative charge; the opposite on the right.

The induces a magnetic field in the opposite direction and reduces the overall electric field in the dielectric.

This reduces the electric field from $\underline{E_0}$ to $\underline{E_D}$,

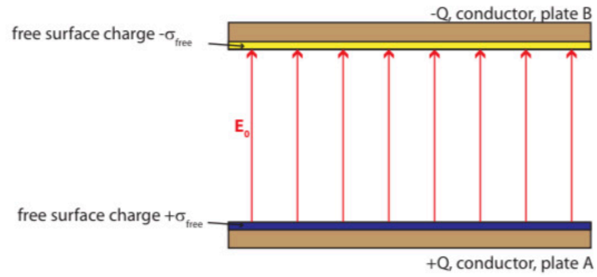
$$\underline{E_D} = \frac{\underline{E_0}}{\kappa} \quad (\kappa > 1)$$

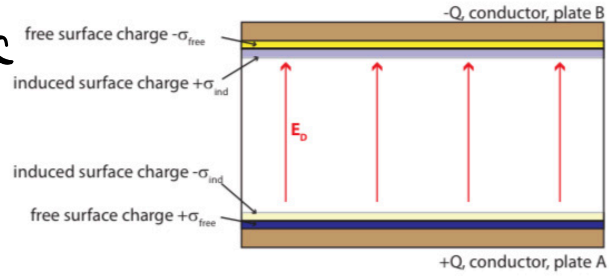
κ — dielectric constant

☆ If we add charge to a conductor it will evenly distribute around the conductor. Added charge on a dielectric does not move, a build up of charge can be dangerous.

Dielectrics in Capacitors

On a parallel plate capacitor, there will initially be a surface charge of $\pm\sigma_{free}$ and an electric field $\underline{E}_0$.



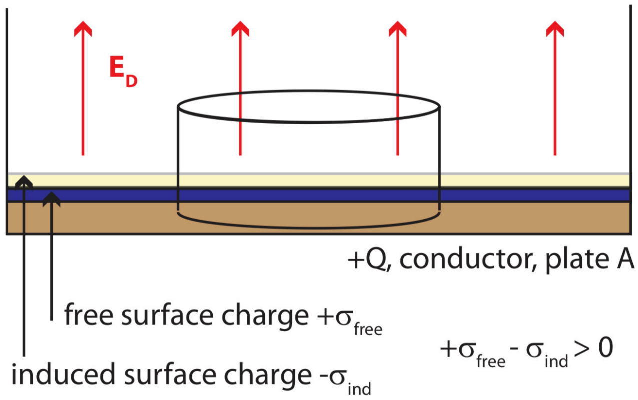


Adding a dielectric will induce a surface charge $\pm\sigma_{ind}$ and will also reduce the electric field to $\underline{E}_D$.

$$E_0 = KE_D = K\frac{\sigma_{free}}{\epsilon_0}$$

$$E_D = \frac{\sigma_{free}}{K\epsilon_0} = \frac{\sigma_{free}}{\epsilon} \qquad (\epsilon\text{ - permittivity})$$

Now we can apply gauss' law to the volume. The electric flux out is just E_DA given area A and contained charge $A(\sigma_{free} - \sigma_{ind})$.



$$E_DA = \frac{A(\sigma_{free} - \sigma_{ind})}{\epsilon_0}$$

$$E_D = \frac{\sigma_{free} - \sigma_{ind}}{\epsilon_0}$$

Now lets combine with $E_D = \dfrac{\sigma_{free}}{K\epsilon_0}$

$$\frac{\sigma_{free}}{K\epsilon_0} = \frac{\sigma_{free} - \sigma_{ind}}{\epsilon_0} \Rightarrow \sigma_{free} = K(\sigma_{free} - \sigma_{ind})$$

$$\sigma_{ind} = \sigma_{free}\left(1 - \frac{1}{K}\right)$$

Adding a dielectric will also change the capacitance of the capacitor. The PD of the capacitor will <u>drop</u>

$$V_D = E_D d = \left(\frac{E_0}{K}\right)d = \frac{V_0}{K}$$

The charge on each plate will remain the same, so we can now find the new capacitance.

$$C_D = \frac{Q_{free}}{V_D} = \frac{KQ_{free}}{V_0} = KC$$

The capacitance increases by a factor of K. We can view this as the capacitor can hold the same charge with a lower voltage.

The energy stored in the capacitor $U = \frac{1}{2}C_D V^2$ will now be $(C_D = KC)$

$$U_D = \frac{1}{2}KCV^2 = KU_0$$

The energy stored increases by a factor of K.