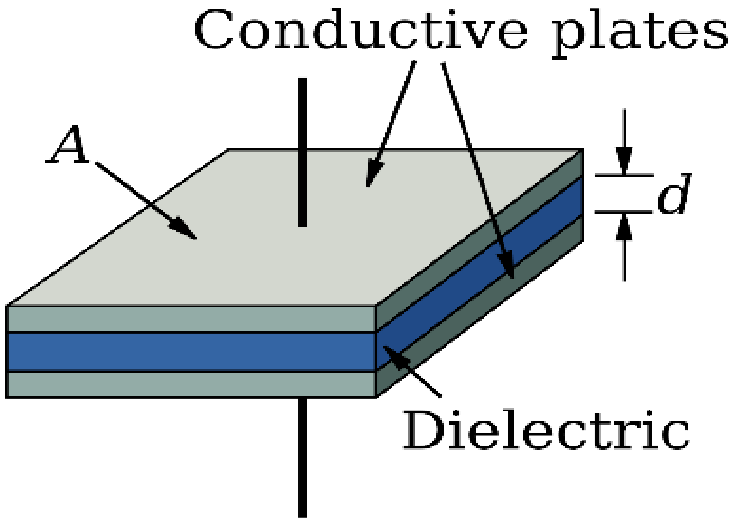
Dielectrics:

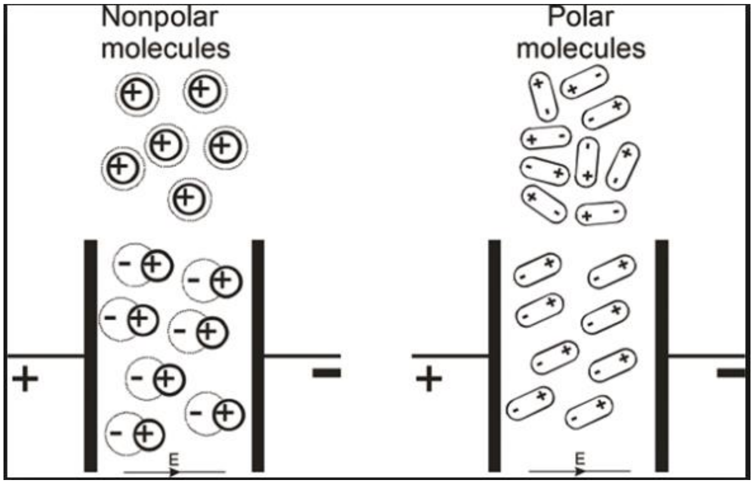


It is an insulating material (non-conducting) which has no free electrons. But a microscopic displacement of charges is observed in the presence of an electric field. It is found that the capacitance increases as the space between the conducting plates are filled with dielectrics.

Polar and Non-polar Dielectrics:

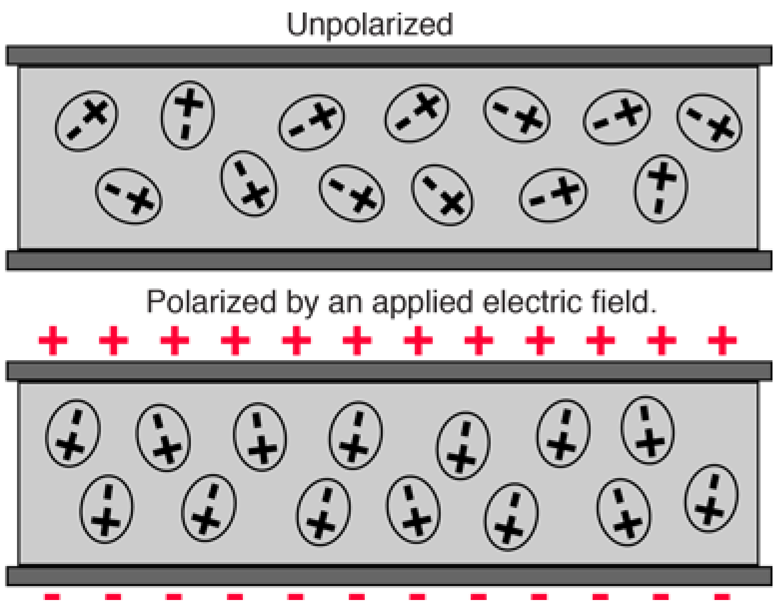
Each atom is made of a positively charged nucleus surrounded by electrons. If the centre of the negatively charged electrons does not coincide withthe centre of the nucleus, then a permanent dipole (separation of charges over a distance) moment is formed. Such molecules are called *polar molecules.* If a polar dielectric is placed in an electric field, the individual dipoles experience a torque and try to align along the field.

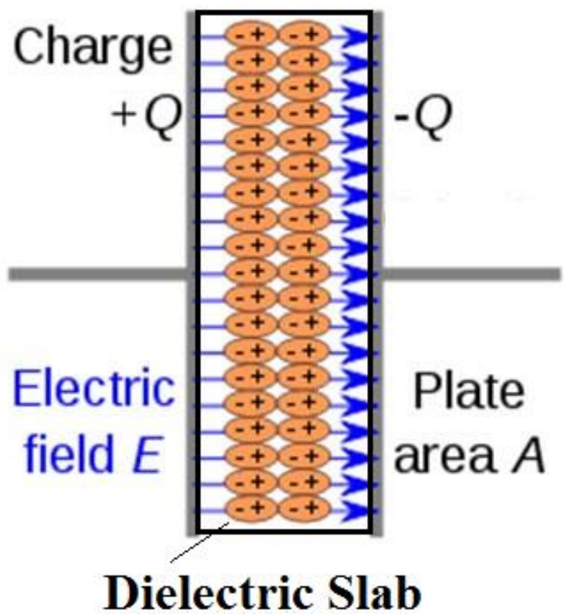
In non-polar molecules, the centres of the positive and negative charge distributions coincide. There is no permanent dipole moment created. But in the presence of an electric field, the centres are slightly displaced. This is called *induced dipole moments.*



Polarization of a Dielectric Slab

It is the process of inducing charges on the dielectric and creating a dipole moment. Dipole moment appears in any volume of a dielectric. The *polarization vector* $\vec{p}$ is defined as the dipole moment per unit volume.





Dielectric Constant

Let $\vec{E_0}$ be the electric field due to external sources and $\vec{E_p}$ be the field due to polarization (induced). The resultant field is

$\vec{E} = \vec{E_0} + \vec{E_p}$

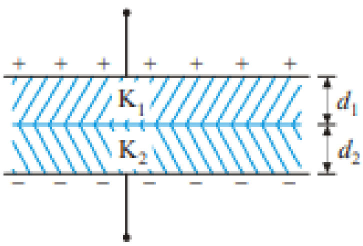
The induced electric field is opposite in direction to the applied field. But the resultant field is in the direction of the applied field with reduced magnitude.

$\vec{E} = \frac{\vec{E_0}}{K}$ K is called the dielectric constant or relative permittivity of the dielectric. For vacuum, $\vec{E_p} = 0$, K = 1. It is also denoted by ϵ

Effect of Dielectric in Capacitance

Dielectric Slabs in Series

A parallel plate capacitor contains two dielectric slabs of thickness d_1, d_2 and dielectric constant k_1 and k_2 respectively. The area of the capacitor plates and slabs is equal to A.



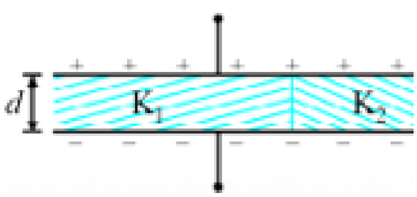
Considering the capacitor as combination of two capacitors in series, the equivalent capacitance C is given by:

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$

$\frac{1}{C} = \frac{d_1}{k_1 \epsilon_0 A} + \frac{d_2}{k_2 \epsilon_0 A}$

$C = \frac{\epsilon_0 A}{\frac{d_1}{k_1} + \frac{d_2}{k_2}}$

Dielectric Slabs in Parallel



Consider a capacitor with two dielectric slabs of same thickness d placed inside it as shown. The slabs have dielectric constants k_1 and k_2 and areas A_1 and A_2 respectively. Treating the combination as two capacitors in parallel,

$$C = C_1 + C_2$$

C = $C = \frac{k_1 \epsilon_0 A_1}{d} + \frac{k_2 \epsilon_0 A_2}{d} \Rightarrow C = \frac{\epsilon_0}{d}[k_1 A_1 + k_2 A_2]$

Dielectric and Vacuum

If there exits a dielectric slab of thickness t inside a capacitor whose plates are separated by distance d, the equivalent capacitance is given as:

$C=\epsilon_0 A t k+d-t 1 (k=1 for vacuum)$

$C=\epsilon_0 A t k+d-t$

The equivalent capacitance is not affected by changing the distance of slab from the parallel plates. If the slab is of metal, the equivalent capacitance is: $C=\epsilon_0 A d-t$ (for a metal, k =)