Dielectrics

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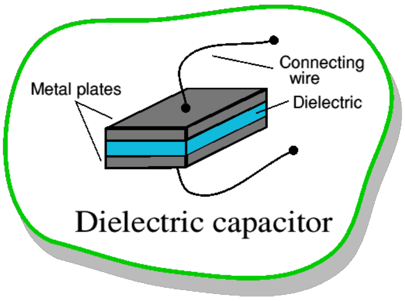
Introduction to Dielectrics



Dielectrics are insulators, plain and simple. Dielectric material is a non-conducting substance whose bound charges are polarized under the influence of an externally applied electric field.

Dielectrics in capacitors serve three purposes:

1. to keep the conducting plates from coming in contact, allowing for smaller plate separations and therefore higher capacitances;
2. to increase the effective capacitance by reducing the electric field strength, which means you get the same charge at a lower voltage; and
3. to reduce the possibility of shorting out by sparking (more formally known as dielectric breakdown) during operation at high voltage.

In manycapacitors there is an insulating material such as paper or plastic between the plates. Such material, called a dielectric, can be used to maintain a physical separation of the plates. Since dielectrics break down less readily than air, charge leakage can be minimized, especially when highvoltage is applied.

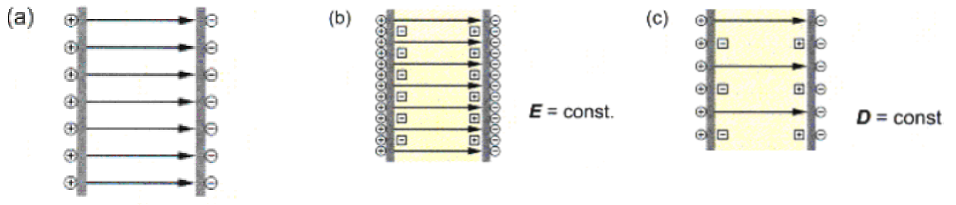
Experimentally it was found that capacitance C increases when the space between the conductors is filled with dielectrics. To see how this happens, suppose a capacitor has a capacitance C_0 when there is no material between the plates. When a dielectric material is inserted to completely fill the space between the plates, the capacitance increases to C

$$C= ?_e C_0$$

Where k_e is called the dielectric constant. In the Table below, we show some dielectric materials with their dielectric constants. Experiments indicate that all dielectric materials have $k_e > 1$. Note that every dielectric material has a characteristic dielectric strength which is the maximum value of an electric field before breakdown occurs and charges begin to flow.

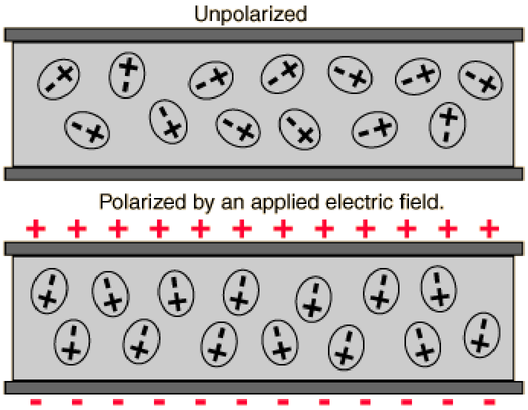
Material	k_e	Dielectric strength (10^6 V/m)
Air	1.00059	3
Paper	3.7	16
Glass	4–6	9
Water	80	–

To get the central idea, imagine a basic experiment involving a plate capacitor with oppositely charged plates and no material inserted. According to the surface charge density, a certain electric field E is created inside. If dielectric material is inserted, polarized charges will neutralize some of the charges on the plates. In this way, one talks about free (unneutralized) and bound charges (neutralized) on the plates. As only free charges create an electric field, a current must raise the free charge density and keep E constant.



If dielectric material is inserted and current source is disconnected, the polarized charges neutralize some of the free charges on the plates. In consequence, a constant D results in a decrease of the electric field between the plates.

Polarization of Dielectric



If a material contains polar molecules, they will generally be randomly and variously oriented when no electric field is applied.

Applying an electric field will polarize the material by orienting the dipole moments of polar molecules.

The presence of the dielectric decreases the electric field produced by a given charge density.

$$E_{effective} = E - E_{polarization} = \frac{\sigma}{k\varepsilon_0}$$

The factor k by which the effective field is decreased by the polarization of the dielectric is called the dielectric constant of the material.

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