Variable Dielectric constant, Breakdown voltage

Variable dielectric constant

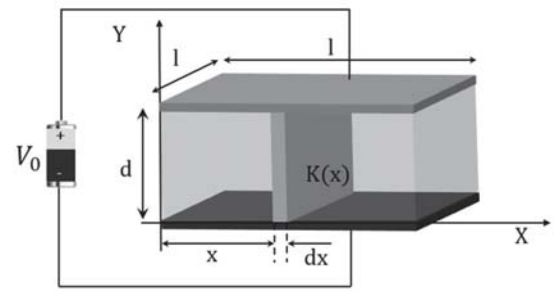
In this scenario, the dielectric constant K changes as a function of position x. Let's take a small segment of the dielectric located at a distance x from one end. This segment has a thickness dx. Given that capacitor plates are connected at the lower and upper ends of this segment, we can treat this segment as a capacitor. The entire dielectric slab is composed of numerous such segments connected in parallel.

If the length of each segment is l, then its cross-sectional area is denoted as dA = ldx.

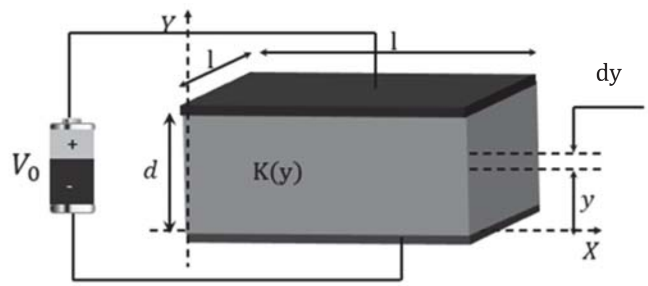
The capacitance of a small strip, dc $= \frac{\varepsilon_k(x)ldx}{d}$

The equivalent capacitance of the capacitor can be determined through integration, considering that the strips are arranged in parallel.

$$C_{eq} = \frac{\varepsilon_o l}{d}\int_0^l K(x)dx$$



In this context, the dielectric constant K changes along the y-axis. Let's consider a small strip of dielectric material located at a distance y from one of the plates, with a thickness dy. The entire dielectric slab consists of several such strips connected in series. If the length of each strip is l, its cross-sectional area is l^2.

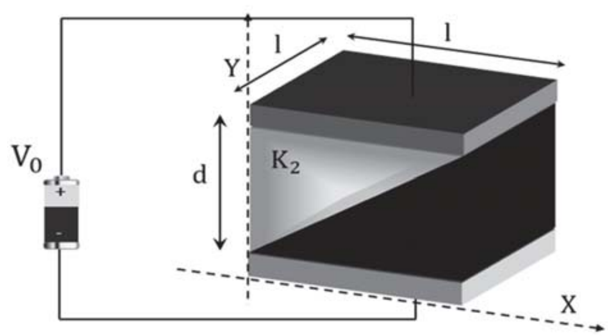


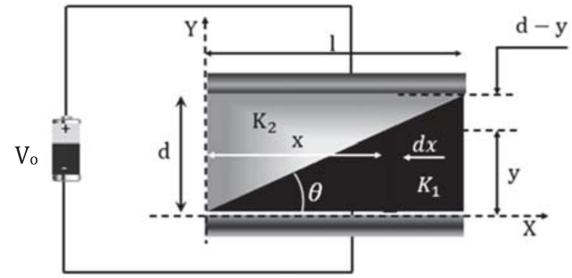
The capacitance associated with a small strip, dc $= \frac{g_0 k(y) l^2}{dy.}$

The equivalent capacitance of the capacitor can be determined through the process of integration.

$$\frac{1}{C_{eq}} = \frac{1}{\varepsilon_o l^2}\int_0^d \frac{dy}{K(y)}$$

Two dielectric materials are positioned in such a way that the dielectric constant varies continuously. Let's examine a small strip located at a distance x from one end, with a thickness of dx. From the bottom, the dielectric constant up to a length y is K_1, while the remaining length d−y has a dielectric constant K_2.

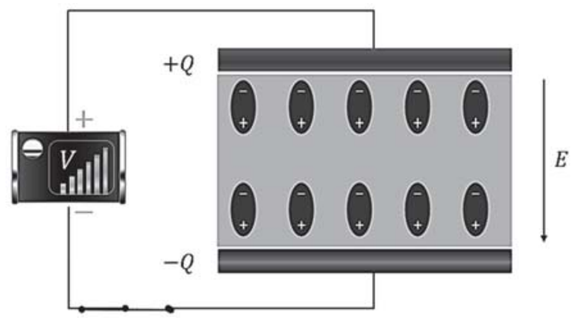




$$\tan\,\theta = \frac{d}{l} = y/x$$
$$y = \frac{xd}{l}$$

Dielectric strength and Breakdown voltage

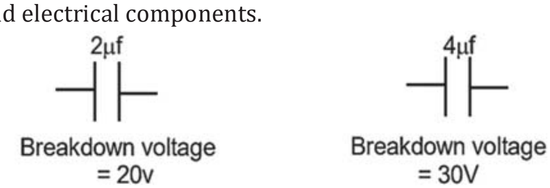
As the electric field applied to a material intensifies, the force acting on molecular dipoles within the material also amplifies. Despite the equilibrium condition where the net force cancels out due to the equal and opposite nature of these forces, the material experiences stress. At a certain threshold of electric field intensity, the material ruptures under the stress. This upper limit of electric field strength that a material can endure without breaking is referred to as its dielectric strength. The dielectric strength is contingent upon the specific properties of the material involved. The electric field intensity, denoted as E_0, represents the threshold at which stress initiates within the dielectric material, leading to its collapse. This critical point, characterized by the onset of stress-induced breakdown in the dielectric material, is termed dielectric strength.



The outcome is contingent upon the specific characteristics of the material.

Breakdown voltage

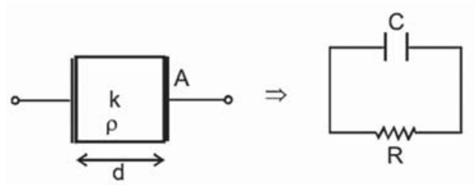
The voltage level reached across a capacitor when the flow of current initiates through the capacitor is referred to as the breakdown voltage, is the minimum voltage required to cause electrical breakdown in a dielectric material. Electrical breakdown occurs when the electric field across the material exceeds its dielectric strength, causing the insulating properties of the material to fail, and allowing the flow of current. Breakdown voltage is a critical parameter in determining the safety and reliability of electrical systems. It is often used to specify the voltage rating of insulating materials and electrical components.



For example, insulating materials used in transformers, cables, and electronic components are rated based on their breakdown voltage to ensure they can withstand the expected operating conditions without failure.

In summary, dielectric strength quantifies the insulation ability of a material, while breakdown voltage indicates the voltage at which electrical breakdown occurs in the material.

Leakage current:



here $C = \frac{\varepsilon_0 kA}{d}$

Resistance $(R) = \frac{\rho d}{A}$

In theory, when a capacitor is disconnected from a power source, its charge should remain unchanged. However, in practice, the resistance of the materials used in the capacitor leads to a gradual discharge of the stored energy. This gradual discharge is commonly referred to as leakage current. Therefore, in order to minimize this leakage current and ensure the capacitor retains its charge effectively, it is imperative for the capacitor's resistance (denoted by 'R') to be high. In essence, a higher resistance value in the capacitor contributes to reducing the leakage current, thereby enhancing its performance as a reliable energy storage component.