HIGH VOLTAGE TECHNIQUES
Refraction of Electric Fields
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Non-parallel configuration

What happens to electric field if the plates are NOT parallel?

In order to evaluate that, we have to know the behaviour of field lines at boundary surfaces.
Refraction

Assume an electric field line coming through a boundary which connects two different dielectric.

In such a case, Electric Field vector will REFRACT to the other dielectric.
Refraction of electric field lines & equipotential lines
What is what?

• $\alpha_1$, $\alpha_2$: Refraction angles of electric field lines.
• $\beta_1$, $\beta_2$: Refraction angles of equipotential lines
(REMEMBER: always perpendicular to the field lines!!!)
• $E_{t1}$, $E_{t2}$: tangent component of the electric fields $E_1$ and $E_2$
• $E_{n1}$, $E_{n2}$: normal (perpendicular) component of the electric fields $E_1$ and $E_2$

• **Normal component** of the field vector forces dielectric to BREAKDOWN!
• **Tangent component** of the field vector forces the dielectric to FLASHOVER!
At the interface field lines are refracted so that:

\[ E_{t1} = E_{t2} \]

- According to \( \int D \cdot dS = 0 \) and considering \( D = \varepsilon E \rightarrow E = D/\varepsilon \)

\[ \frac{D_{t1}}{D_{t2}} = \frac{\varepsilon_1}{\varepsilon_2} \]
Refraction of electric displacement field

Similar to the electric field lines, displacement lines are refracted at the interface so that;

\[ D_{n1} = D_{n2} \]
Displacement vectors
According to $\int D \cdot dS = 0$ (one more time),

\[
\frac{E_{n1}}{E_{n2}} = \frac{\varepsilon_2}{\varepsilon_1}
\]
Simple trigonometric concepts

For electric field vector components:

\[ E_{t1} = E_1 \sin \alpha_1 \]
\[ E_{t2} = E_2 \sin \alpha_2 \]

For displacement vector components:

\[ D_{n1} = D_1 \cos \alpha_1 = \varepsilon_1 E_1 \cos \alpha_1 \]
\[ D_{n2} = D_2 \cos \alpha_2 = \varepsilon_2 E_2 \cos \alpha_2 \]
Because $E_{t1} = E_{t2}$ and $D_{n1} = D_{n2}$; we can write

\[
\frac{E_{t1}}{D_{n1}} = \frac{E_{t2}}{D_{n2}} \rightarrow
\]

\[
\frac{E_1 \sin \alpha_1}{\varepsilon_1 E_1 \cos \alpha_1} = \frac{E_2 \sin \alpha_2}{\varepsilon_2 E_2 \cos \alpha_2}
\]

\[
\frac{\tan \alpha_1}{\tan \alpha_2} = \frac{\varepsilon_1}{\varepsilon_2}
\]
Refraction of equipotential lines

\[ \beta_1 = 90 - \alpha_1 \]
\[ \beta_2 = 90 - \alpha_2 \]

Refraction angles of equipotential lines.

\[ \frac{\tan(90 - \beta_1)}{\tan(90 - \beta_2)} = \frac{\varepsilon_1}{\varepsilon_2} \]

\[ \frac{\tan \beta_1}{\tan \beta_2} = \frac{\varepsilon_2}{\varepsilon_1} \]
TIME FOR EXAMPLES