Electric Material

Current (1)

- Current Type

$$I = \frac{dQ}{dt} = \int_S \vec{J} \cdot d\vec{S} = \int_L \vec{K} \cdot dL\vec{a}_N$$

I : Current (A)

$\vec{J}$: Current density ($\mathrm{A/m^2}$)

$\vec{K}$: Surface current (A/m)

Current (2)

- Current Density

$$\vec{J} = \rho_v \vec{v}$$

ρ_v : Volume charge density $(\mathrm{C/m^3})$

$\vec{v}$: Charge velocity $(\mathrm{m/s})$

- Continuity of Current

$$\nabla \cdot \vec{J} = -\frac{\partial \rho_v}{\partial t}$$

Conductor

- Conductor Characteristic

$$\vec{J} = \sigma \vec{E}$$

- Conductivity and Resistivity

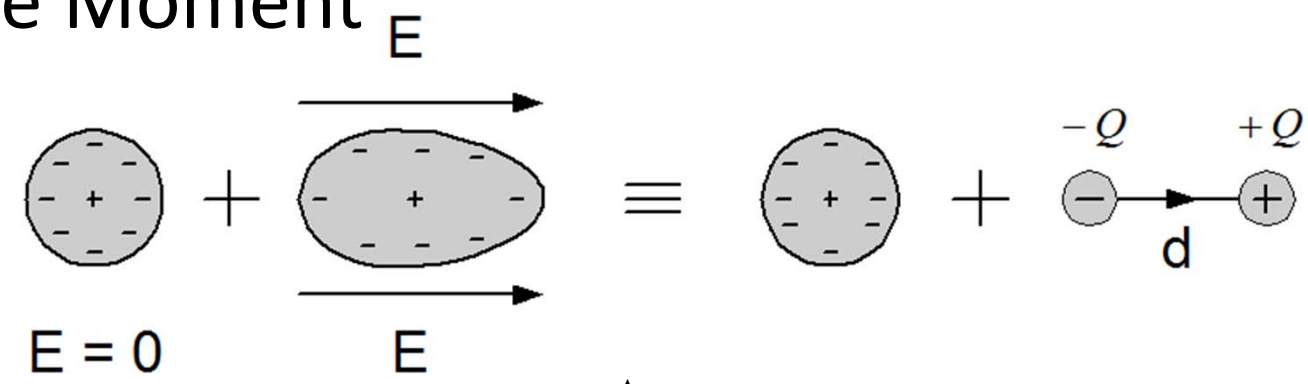
$$\sigma = \frac{1}{\rho}$$

σ : Conductivity (S/m)

ρ : Resistivety (Ω/m)

Dielectric (1)

- Dipole Moment



$$\vec{p} = Q_b \vec{d} \qquad \vec{p}_{total} = \sum_{i-1}^{n\Delta v} p_i \qquad \vec{P} = \lim_{v \to 0} \frac{\vec{p}_{total}}{v}$$

$\vec{p}$: Dipole moment $(\mathrm{C \cdot m})$

$\vec{p}_{total}$: Total dipole moment $(\mathrm{C \cdot m})$

$\vec{P}$: Polarization $(\mathrm{C/m^2})$

$\mathrm{Q_b}$: Bound charge (C)

$\vec{d}$: Distance form negative to positive charge (m)

Dielectric (2)

- Dielectric Characteristic

$$\vec{D} = \varepsilon_r \varepsilon_0 \vec{E} = \varepsilon \vec{E}$$

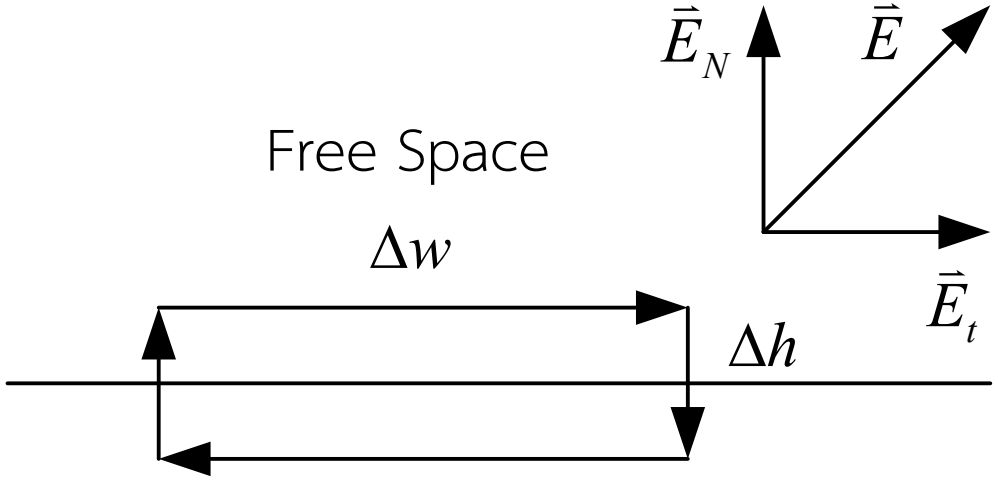
$\varepsilon = \varepsilon_r \varepsilon_0$: Permittivity (F/m)

ε_r : Relative permittivity or dielectric constant

Electric Boundary Condition and Capacitance

Boundary Condition of Conductor (1)

- Tangent

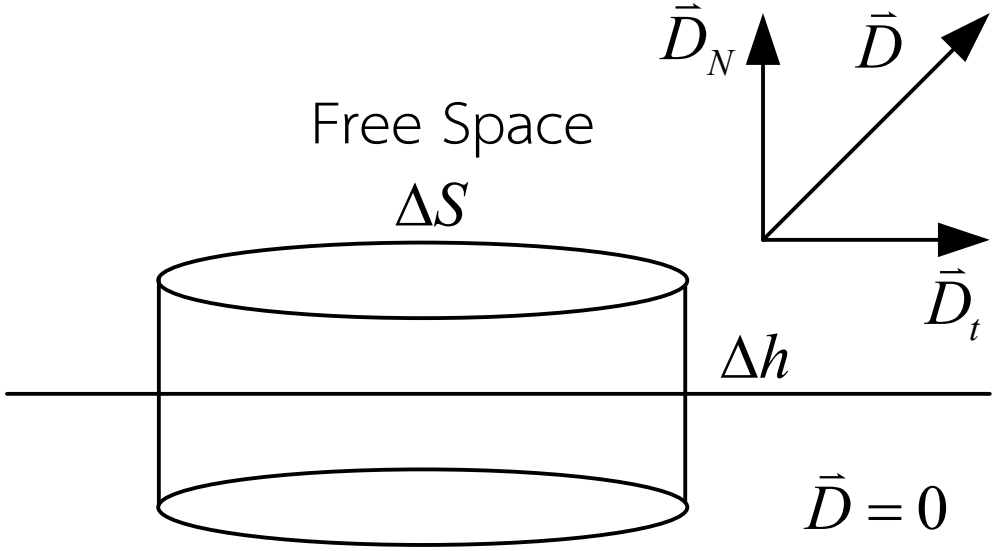


$$\oint \vec{E} \cdot d\vec{L} = 0 \qquad \Delta h \to 0$$

$$\vec{E}_t = 0$$

Boundary Condition of Conductor (2)

- Normal

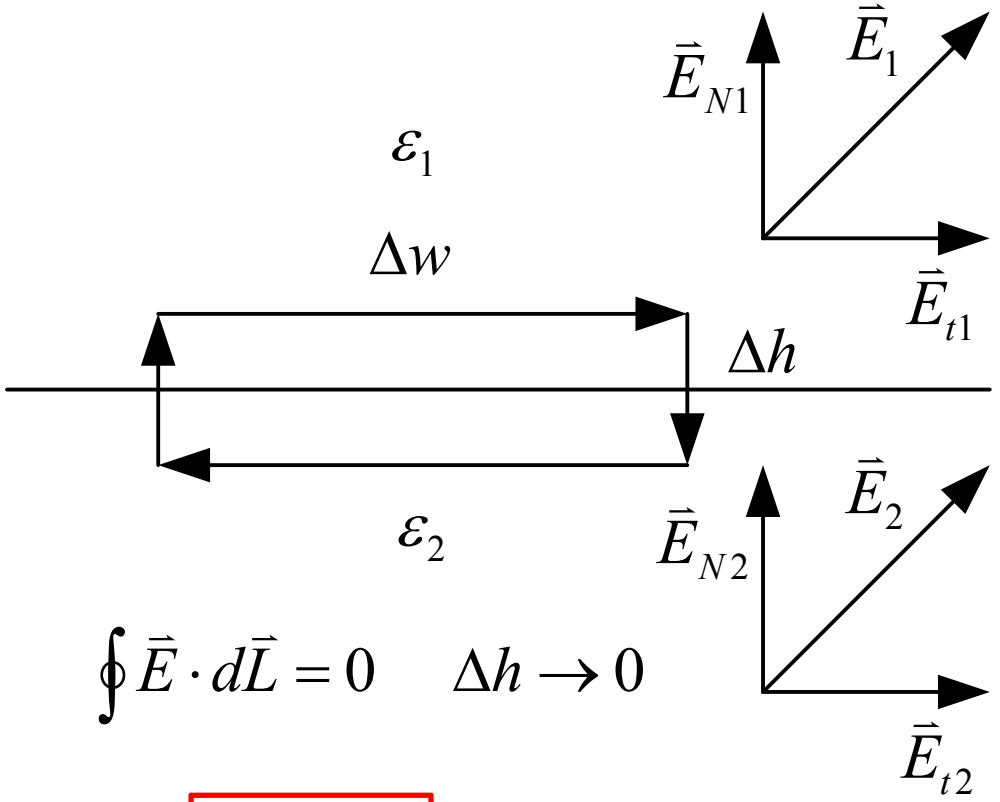


$$\oint_S \vec{D} \cdot d\vec{S} = Q \qquad \Delta h \to 0$$

$$\vec{D}_N = \rho_S \vec{a}_N$$

Boundary Condition of Dielectric (1)

- Tangent

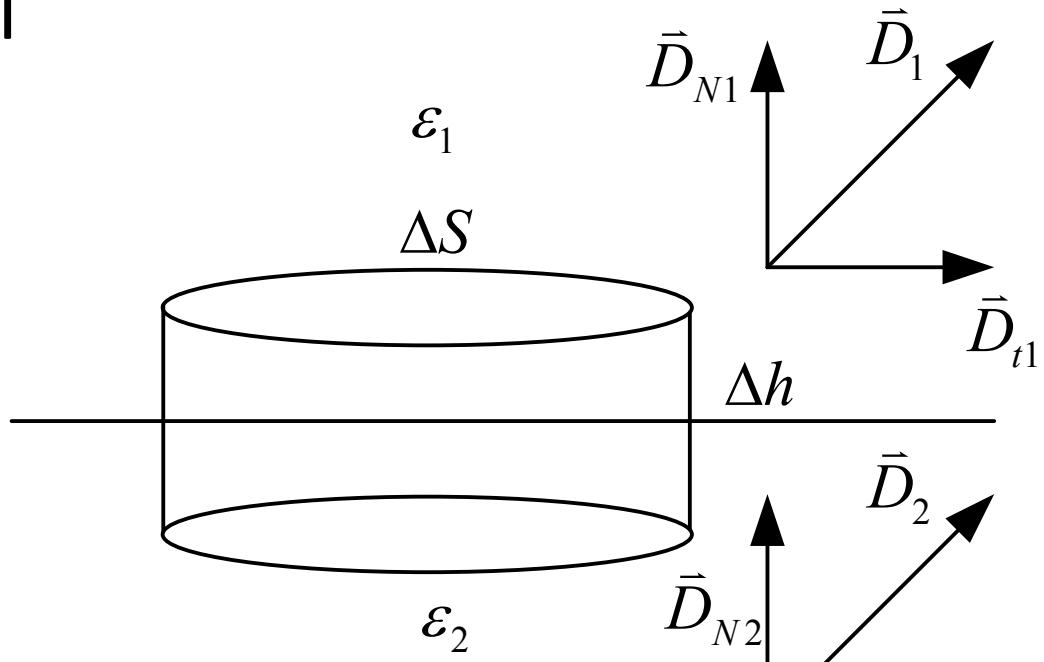


$$\oint \vec{E} \cdot d\vec{L} = 0 \qquad \Delta h \to 0$$

$$\vec{E}_{t1} = \vec{E}_{t2}$$

Boundary Condition of Dielectric (2)

- Normal

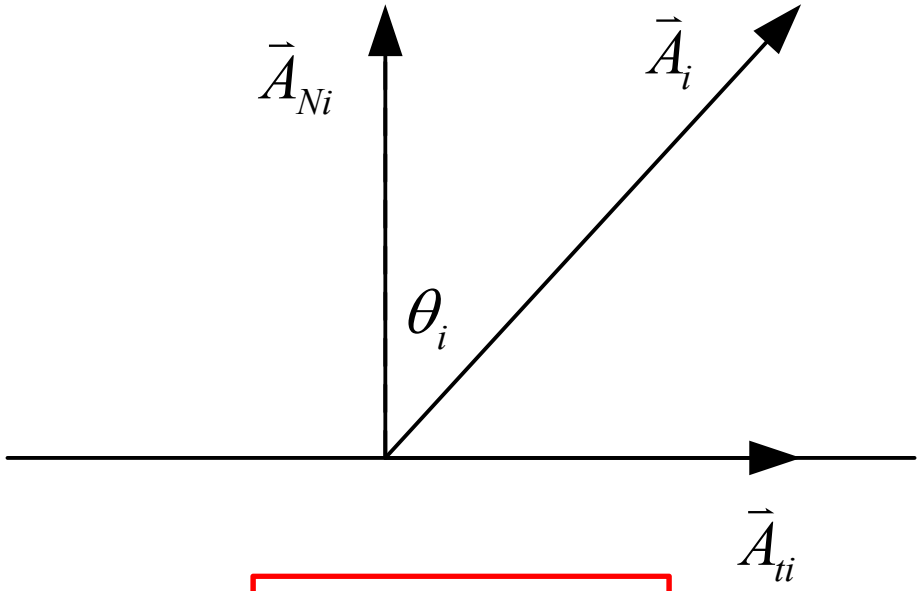


$$\oint_S \vec{D} \cdot d\vec{S} = Q \qquad \Delta h \to 0$$

$$\vec{D}_{N1} = \vec{D}_{N2}$$

Boundary Condition Dielectric (3)

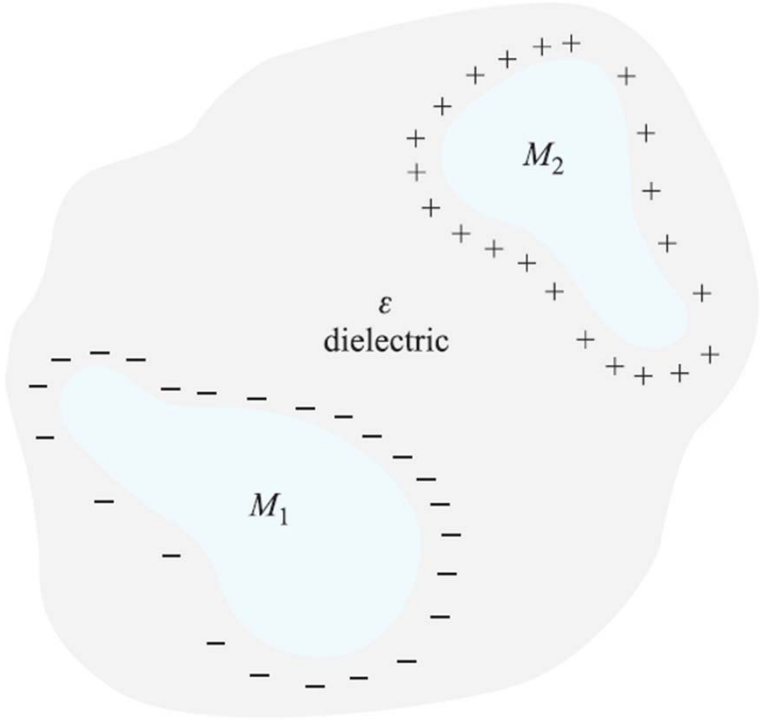
- Angle



$$\theta_i = \tan^{-1}\left(\frac{A_{ti}}{A_{Ni}}\right)$$

A: E or D, i: 1 or 2

Capacitance



$$C = \frac{Q}{V}$$

C : Capacitance (F)

Example

กำหนดให้บริเวณที่ 1 ($z > 0$) มี $\varepsilon_{r1} = 10$ และบริเวณที่ 2 ($z < 0$) มี $\varepsilon_{r2} = 7$ มี $\vec{E}_2 = 20\vec{a}_x - 50\vec{a}_y + 100\vec{a}_z$ V/m จงหา $\vec{E}_1$, $\vec{D}_1$, $\vec{D}_2$, θ_1 , θ_2

Solution (1)

หา $\vec{D}_2$ ได้

$$\begin{aligned}\vec{D}_2 &= \varepsilon_{r2}\varepsilon_0\vec{E}_2 \\ &= 7\times\frac{1}{36\pi}\times10^{-9}\times\left(20\vec{a}_x-50\vec{a}_y+100\vec{a}_z\right) \\ &= 1.24\vec{a}_x-3.09\vec{a}_y+6.19\vec{a}_z \ \text{ nC/m}^2\end{aligned}$$

พิจารณาในแนวสัมผัส

$$\begin{aligned}\vec{E}_{t1} &= \vec{E}_{t2} \\ &= 20\vec{a}_x-50\vec{a}_y \ \text{ V/m}\end{aligned}$$

$$\begin{aligned}\vec{D}_{t1} &= \varepsilon_{r1}\varepsilon_0\vec{E}_{t1} \\ &= 10\times\frac{1}{36\pi}\times10^{-9}\times\left(20\vec{a}_x-50\vec{a}_y\right) \\ &= 1.77\vec{a}_x-4.42\vec{a}_y \ \text{ nC/m}^2\end{aligned}$$

Solution (2)

พิจารณาในแนวตั้งฉาก

$$\vec{D}_{N1} = \vec{D}_{N2} = 6.19\vec{a}_z \ \text{nC/m}^2$$

$$\vec{E}_{N1} = \frac{1}{\varepsilon_{r1}\varepsilon_0}\vec{D}_N = \frac{1}{10 \times \frac{1}{36\pi} \times 10^{-9}} \times 6.19 \times 10^{-9}\vec{a}_z$$

$$= 70.01\vec{a}_z \ \text{V/m}$$

จะได้

$$\vec{E}_1 = \vec{E}_{t1} + \vec{E}_{N1}$$

$$= 20\vec{a}_x - 50\vec{a}_y + 70.01\vec{a}_z \ \text{V/m}$$

$$\vec{D}_{N1} = \vec{D}_{t1} + \vec{D}_{N1}$$

$$= 1.77\vec{a}_x - 4.42\vec{a}_y + 6.19\vec{a}_z \ \text{nC/m}^2$$

Solution (3)

หามุมได้

$$\theta_1 = \tan^{-1}\left(\frac{Et_1}{E_{N1}}\right) = \tan^{-1}\left(\frac{\sqrt{20^2 + (-50)^2}}{70.01}\right)$$
$$= 37.57^\circ$$

$$\theta_2 = \tan^{-1}\left(\frac{Et_2}{E_{N2}}\right) = \tan^{-1}\left(\frac{\sqrt{20^2 + (-50)^2}}{100}\right)$$
$$= 28.30^\circ$$

Quiz 4

กำหนดให้บริเวณที่ 1 ($z > 0$) มี $\varepsilon_{r1} = 10$ และบริเวณที่ 2 ($z < 0$) มี $\varepsilon_{r2} = 7$ มี $\vec{E}_1 = 20\vec{a}_x - 50\vec{a}_y + 100\vec{a}_z$ V/m จงหา $\vec{E}_2$, $\vec{D}_1$, $\vec{D}_2$, θ_1 , θ_2

$\vec{D}_1 = 1.77\vec{a}_x - 4.42\vec{a}_y + 8.84\vec{a}_z$ nC/m^2

$\vec{E}_2 = 20\vec{a}_x - 50\vec{a}_y + 142.83\vec{a}_z$ V/m

$\vec{D}_2 = 1.24\vec{a}_x - 3.09\vec{a}_y + 8.84\vec{a}_z$ nC/m^2

$\theta_1 = 28.30^\circ$

$\theta_2 = 20.66^\circ$

1; $z > 0$ $\varepsilon_{r1} = 10$

2; $z < 0$ $\varepsilon_{r2} = 7$

$\vec{E}_1 = 20\vec{a}_x - 50\vec{a}_y + 100\vec{a}_z$ V/m

$\vec{D}_1 = \varepsilon_{r1}\varepsilon_0\vec{E}_1$

$= 10 \cdot \frac{1}{36\pi} \cdot 10^{-9} \cdot (20\vec{a}_x - 50\vec{a}_y + 100\vec{a}_z)$

$\vec{D}_1 = 1.77\vec{a}_x - 4.42\vec{a}_y + 8.84\vec{a}_z$ nC/m²

$\vec{E}_{t2} = \vec{E}_{t1}$

$= 20\vec{a}_x - 50\vec{a}_y$ V/m

$\vec{D}_{t2} = \varepsilon_{r2}\varepsilon_0\vec{E}_{t2}$

$= 7 \cdot \frac{1}{36\pi} \cdot 10^{-9} \cdot (20\vec{a}_x - 50\vec{a}_y)$

$= 1.24\vec{a}_x - 3.09\vec{a}_y$ nC/m²

$\vec{D}_{N1} = \vec{D}_{N2} = 8.84\vec{a}_z$ nC/m²

$\vec{E}_{N2} = \frac{1}{\varepsilon_{r2}\varepsilon_0}\vec{D}_N = \frac{1}{7 \cdot \frac{1}{36\pi} \cdot 10^{-9}} \cdot 8.84 \times 10^{-9}\vec{a}_z$

$= 142.83\vec{a}_z$ V/m

$\vec{E}_2 = \vec{E}_{t2} + \vec{E}_{N2}$

$= 20\vec{a}_x - 50\vec{a}_y + 142.83\vec{a}_z$ V/m

$\vec{D}_2 = \varepsilon_{r2}\varepsilon_0\vec{E}_2$

$= 7 \cdot \frac{1}{36\pi} \cdot 10^{-9} \cdot (20\vec{a}_x - 50\vec{a}_y + 142.83\vec{a}_z)$

$\vec{D}_2 = 1.24\vec{a}_x - 3.09\vec{a}_y + 8.84\vec{a}_z$ nC/m²

$\theta_1 = \tan^{-1}\left(\frac{E_{t1}}{E_{N1}}\right)$

$= \tan^{-1}\left(\frac{\sqrt{20^2 + (-50)^2}}{100}\right)$

$\theta_1 = 28.30^\circ$

$\theta_2 = \tan^{-1}\left(\frac{E_{t2}}{E_{N2}}\right)$

$= \tan^{-1}\left(\frac{\sqrt{20^2 + (-50)^2}}{142.83}\right)$

$\theta_2 = 20.66^\circ$

$\vec{D}_1 = 1.77\vec{a}_x - 4.42\vec{a}_y + 8.84\vec{a}_z$ nC/m²

$\vec{E}_2 = 20\vec{a}_x - 50\vec{a}_y + 142.83\vec{a}_z$ V/m

$\vec{D}_2 = 1.24\vec{a}_x - 3.09\vec{a}_y + 8.84\vec{a}_z$ nC/m²

$\theta_1 = 28.30^\circ$

$\theta_2 = 20.66^\circ$

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Assignment 4

กำหนดให้บริเวณที่ 1 ($y > 0$) มี $\varepsilon_{r1} = 6$ และบริเวณที่ 2 ($y < 0$) มี $\varepsilon_{r2} = 3$ มี $\vec{D}_2 = 2\vec{a}_x - \vec{a}_y + 3\vec{a}_z$ nC/m^2

จงหา $\vec{E}_1$, $\vec{D}_1$, $\vec{E}_2$, θ_1 , θ_2

$\vec{E}_2 = 75.40\vec{a}_x - 37.70\vec{a}_y + 113.10\vec{a}_z$ V/m

$\vec{E}_1 = 75.40\vec{a}_x - 18.85\vec{a}_y + 113.10\vec{a}_z$ V/m

$\vec{D}_1 = 4.00\vec{a}_x - 1.00\vec{a}_y + 6.00\vec{a}_z$ nC/m^2

$\theta_1 = 82.10^\circ$

$\theta_2 = 74.50^\circ$

1) $y>0$ $\quad \epsilon_{r1} = 6$

2) $y<0$ $\quad \epsilon_{r2} = 3$

$\vec{D}_2 = 2\vec{a}_x - \vec{a}_y + 3\vec{a}_z \ nC/m$

$\vec{D}_2 = \epsilon_{r2}\epsilon_0 \vec{E}_2$

$\vec{E}_2 = \dfrac{\vec{D}_2}{\epsilon_{r2}\epsilon_0}$

$= \dfrac{(2\vec{a}_x - \vec{a}_y + 3\vec{a}_z)}{3 \cdot \frac{1}{36\pi} \cdot 10^{-9}}$

$\vec{E}_2 = 75.40\vec{a}_x - 37.70\vec{a}_y + 113.10\vec{a}_z \ V/m$

$\vec{E}_{t1} = \vec{E}_{t2}$

$= 75.40\vec{a}_x + 113.10\vec{a}_z \ V/m$

$\vec{D}_{t1} = \epsilon_{r1}\epsilon_0 \vec{E}_{t1}$

$= 6 \cdot \frac{1}{36\pi} \cdot 10^{-9} \cdot (75.40\vec{a}_x + 113.10\vec{a}_z)$

$\vec{D}_{t1} = 4.00\vec{a}_x + 6.00\vec{a}_z \ nC/m$

$\vec{D}_{N1} = \vec{D}_{N2} = -\vec{a}_y \ nC/m^2$

$\vec{E}_{N1} = \dfrac{1}{\epsilon_{r1}\epsilon_0}\vec{D}_N$

$= \dfrac{1}{6 \cdot \frac{1}{36\pi} \cdot 10^{-9}} \cdot -10^{-9}\vec{a}_y$

$\vec{E}_{N1} = -18.85 \ V/m$

$\vec{E}_1 = \vec{E}_{t1} + \vec{E}_{N1}$

$= 75.40\vec{a}_x - 18.85\vec{a}_y + 113.10\vec{a}_z \ V/m$

$\vec{D}_1 = \epsilon_{r1}\epsilon_0 \vec{E}_1$

$= 6 \cdot \frac{1}{36\pi} \cdot 10^{-9} (75.40\vec{a}_x - 18.85\vec{a}_y + 113.10\vec{a}_z)$

$\vec{D}_1 = 4.00\vec{a}_x - 1.00\vec{a}_y + 6.00\vec{a}_z \ nC/m^2$

$\theta_1 = \tan^{-1}\left(\dfrac{Et_1}{E_{N1}}\right)$

$= \tan^{-1}\left(\dfrac{\sqrt{75.40^2 + 113.10^2}}{|-18.85|}\right)$

$\theta_1 = 82.10^\circ$

$\theta_2 = \tan^{-1}\left(\dfrac{Et_2}{E_{N2}}\right)$

$= \tan^{-1}\left(\dfrac{\sqrt{75.40^2 + 113.10^2}}{|-37.70|}\right)$

$\theta_2 = 74.50^\circ$

$\vec{E}_2 = 75.40\vec{a}_x - 37.70\vec{a}_y + 113.10\vec{a}_z \ V/m$

$\vec{E}_1 = 75.40\vec{a}_x - 18.85\vec{a}_y + 113.10\vec{a}_z \ V/m$

$\vec{D}_1 = 4.00\vec{a}_x - 1.00\vec{a}_y + 6.00\vec{a}_z \ nC/m^2$

$\theta_1 = 82.10^\circ$

$\theta_2 = 74.50^\circ$

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