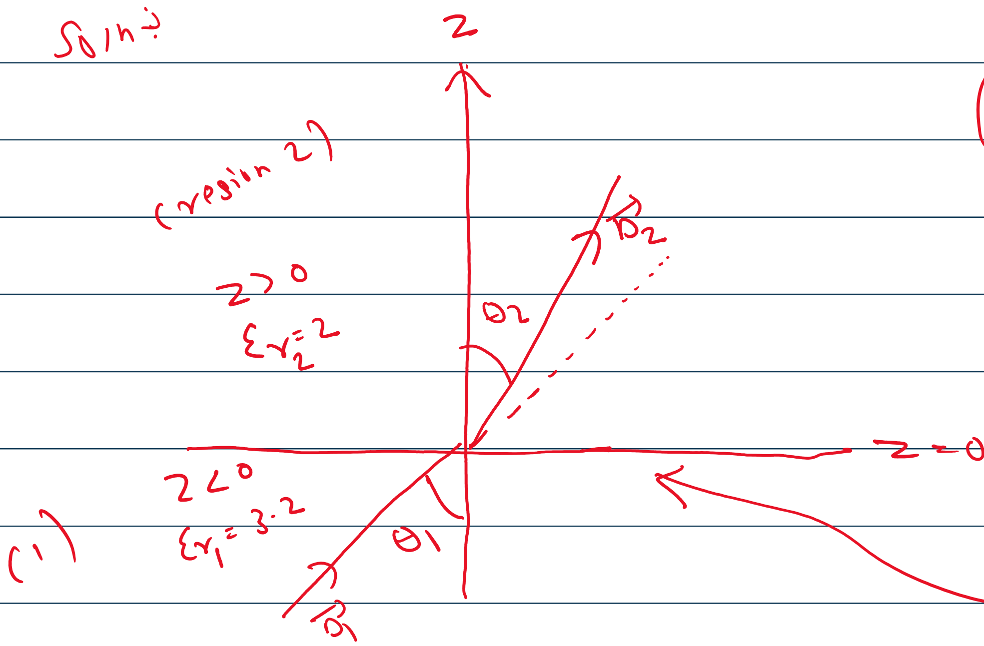
① Consider the region $z<0$ be composed of a uniform dielectric material for which $\varepsilon_r = 3.2$ while the region $z>0$ is characterized by $\varepsilon_r = 2$. let $\vec{D}_1 = -30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z$ nC/m². Find (a) $\vec{D}_{t_1}$ (b) Polarization $\vec{P}_1$ (c) E_{n_2} (d) E_{t_2} (e) $\vec{D}_2$ (f) θ_1 (g) θ_2

Soln:



(any axis can be given)

$(\varepsilon_{r_1} > \varepsilon_{r_2})$

so

$(\theta_1 > \theta_2)$

so this typ of fig:

Now,

$$\vec{D}_1 = -30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z \ \text{nC/m}^2$$

(a) $D_{n_1} = \vec{D}_1 \cdot \hat{a}_z$ (question ma z-axis reference)

mag $= \left[(-30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z)\times 10^{-9}\right]\cdot \hat{a}_z$ C/m²

$= 70\times 10^{-9}$ C/m²

vector $\vec{D}_{N1} = 70\,\hat{a}_z$ nc/m^2

~~Also~~ we know

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

$$\boxed{\begin{aligned}\vec{D}_{t1} &= \vec{D}_1 - \vec{D}_{N1} \\ &= (\cancel{-3a_z} - 30\,\hat{a}_z + 50\,\hat{a}_y + 70\,\hat{a}_z) - (70\,\hat{a}_z) \\ &= -30\,\hat{a}_z + 50\,\hat{a}_y \text{ nc/m}^2\end{aligned}}$$

nc/m^2

(3) Polarization $(\vec{P}_1) = ?$

Derivation

~~As~~ we know

$$\boxed{\vec{D}_1 = \varepsilon_0 \vec{E}_1 + \vec{P}_1}$$

$\vec{P}_1 = \chi_e \varepsilon_0 \vec{E}_1$
(use this instead)
$\chi_e = \varepsilon_{r1} - 1$

Here

$\vec{D} = \varepsilon \vec{E} = \varepsilon_r \varepsilon_0 \vec{E}$ —(*)

In region -1

$\vec{D}_1 = \varepsilon_1 \vec{E}_1 = \varepsilon_{r1} \varepsilon_0 \vec{E}_1 = 3.2\,\varepsilon_0 \vec{E}_1$

so $\vec{E}_1 = \dfrac{\vec{D}_1}{3.2\,\varepsilon_0} = \dfrac{\vec{D}_1}{\varepsilon_0 \varepsilon_{r1}}$

$$\vec{E}_1 = \frac{(-30\,\hat{a}_x + 50\,\hat{a}_y + 70\,\hat{a}_z) \text{ nc/m}^2}{3.2 \times \varepsilon_0}$$

$$= \frac{1}{\varepsilon_0}\left(-9.375\,\hat{a}_x + 15.625\,\hat{a}_y + 21.875\right) nC/m^2$$

Now,

$$\left(-30\,\hat{a}_x + 50\,\hat{a}_y + 70\,\hat{a}_z\right) = \varepsilon_0 \times \frac{1}{\varepsilon_0}\left(-9.375\,\hat{a}_x + 15.625\,\hat{a}_y + 21.875\,\hat{a}_z\right) + \vec{P}_1$$

$\checkmark$ nC/m^2

$$\vec{P}_1 = -30\,\hat{a}_x + 50\,\hat{a}_y + 70\,\hat{a}_z - \left(-9.375\,\hat{a}_x + 15.625\,\hat{a}_y + 21.875\,\hat{a}_z\right)$$

$$= \left(-20.625\,\hat{a}_x + 34.375\,\hat{a}_y + 48.125\,\hat{a}_z\right) nC/m^2$$

(i) Using boundary condition

$$\vec{D}_{n1} = \vec{D}_{n2}$$

or $70\,\hat{a}_z\ nC/m^2 = \varepsilon_2 \vec{E}_{n2}$

or $70\,\hat{a}_z = \varepsilon_0 \varepsilon_{r2} \vec{E}_{n2}$

or $\dfrac{70}{\varepsilon_0 \times 2}\,\hat{a}_z = \vec{E}_{n2}$

$\therefore \vec{E}_{n2} = 3.95 \times 10^3\,\hat{a}_z\ V/m$

$E_{n2} = 3.95 \times 10^3\ V/m$

(d) Using boundary condition

$\vec{E} = \vec{E}$

(d) Using boundary condition

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

$$\vec{D}_{t1} = \varepsilon_1 \vec{E}_{t1}$$

$$\vec{E}_{t1} = \frac{\vec{D}_{t1}}{\varepsilon_0 \varepsilon_{r1}} = \frac{(-30\hat{a}_x + 50\hat{a}_y)\ nC/m^2}{\varepsilon_0 \times 3.2}$$

$$= -1.05\times10^3\,\hat{a}_x + 1.76\times10^3\,\hat{a}_y \ V/m$$

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

$$\text{so, } E_{t2} = \sqrt{(-1.05\times10^3) + (1.76\times10^3)}$$

$$= 2.056\times10^3\ V/m$$

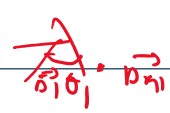
(e) $$\vec{D}_{t2} = \varepsilon_0 \varepsilon_{r2} \vec{E}_{t2}$$

$$= \varepsilon_0 \times 2 \times (-1.058\times10^3\,\hat{a}_x + 1.76\times10^3\,\hat{a}_y)$$

$$= (-18.726\,\hat{a}_x + 31.223\,\hat{a}_y)\ nC/m^2$$

(f) $$\vec{D}_2 = \vec{D}_{n2} + \vec{D}_{t2} = (-18.726\,\hat{a}_x + 31.223\,\hat{a}_y + 70\,\hat{a}_z)\ nC/m^2$$

$$\boxed{|D_{n1}| = |D_1| \cos\theta_1}$$



(f) $$\theta_1 = \cos^{-1}\frac{|\vec{D}_{n1}|}{|\vec{D}_1|} = \cos^{-1}\frac{70}{91.90} = 39.79^\circ$$

(g) $$\theta_2 = \cos^{-1}\frac{|\vec{D}_{n2}|}{} = \cos^{-1}\frac{70}{} = 27.479^\circ$$

(b) $\theta_2 = \cos^{-1} \frac{|\vec{D}_{n2}|}{|\vec{D}_2|} = \cos^{-1} \frac{70}{78.902} = 27.479^\circ$

#

1. The electric field intensity in polystyrene ($\varepsilon_r = 2.55$) filling the space between the plates of a parallel-plate capacitor is 10 kV/m. The distance between the plates is 1.5 mm. Calculate:
   a. D
   b. P
   c. The surface charge density of free charge on the plates
   d. The surface density of polarization charge
   e. The potential difference between the plates.

soln ÷

(a) $D = \varepsilon_0 \varepsilon_r E = \varepsilon_0 \times 2.55 \times 10 \times 10^3 = 225.4 \ nc/m^2$

(b) $P = \chi_e \varepsilon_0 E = (\varepsilon_r - 1)\varepsilon_0 E = (2.55-1)\varepsilon_0 \times 10 \times 10^3$
$= 137.23 \ nc/m^2$

(c) $\rho_s = \vec{D} \cdot \hat{a}_N = D_N = 225.4 \ nc/m^2$

(d) $\rho_{sp} = \vec{P} \cdot \hat{a}_N = P_N = 137.23 \ nc/m^2$

(e) $V = Ed = 10^4 \times (1.5 \times 10^{-3}) = 15 V$

#

2. Two extensive homogeneous isotropic dielectrics meet on plane z=0. For z>0, $\varepsilon_{r1} = 4$ and for z<0, $\varepsilon_{r2} = 3$. A uniform electric field $\vec{E}_1 = 5\,\hat{a}_x - 2\hat{a}_y + 3\,\hat{a}_z$ kV/m exists for $z \geq 0$. Find:

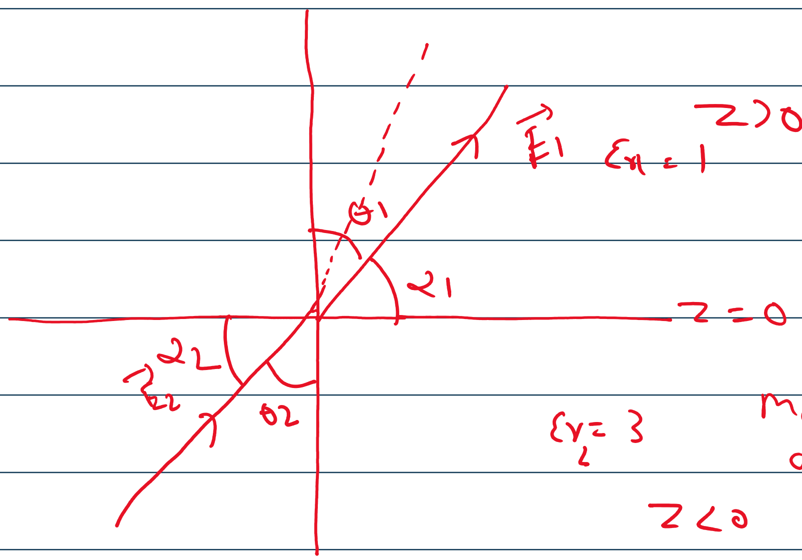
   a. $\vec{E}_2$ for $z \leq 0$.

   b. The angles $\vec{E}_1$ and $\vec{E}_2$ make with the interface.

   c. The energy densities (J/m³) in both dielectrics.

   d. The energy within a cube of side 2m centered at (3,4,-5).

Solution:



$\varepsilon_{r1} > \varepsilon_{r2}$

so

$\theta_1 > \theta_2$

make fig according to this

ⓐ $\vec{E}_2 = \vec{E}_{t2} + \vec{E}_{N2}$ —— (i)

$\vec{E}_1 = (5\hat{a}_x - 2\hat{a}_y + 3\hat{a}_z) \times 10^3$ V/m

$\vec{E}_N = \vec{E}_1 \cdot \hat{a}_z = (5\hat{a}_x - 2\hat{a}_y + 3\hat{a}_z) \times 10^3 \cdot \hat{a}_z$

⊥ z-axis $= 3 \times 10^3$ V/m

$\vec{E}_N = 3 \times 10^3\,\hat{a}_z$ V/m $= E_N\,\hat{a}_z$

Now,

$$\vec{E_{t1}} = \vec{E_1} - \vec{E_{N1}} = (5\hat{a_x} - 2\hat{a_y}) \times 10^3 \ V/m$$

using boundary condition

$$\vec{D_{N1}} = \vec{D_{N2}}$$

or, $\varepsilon_0 \varepsilon_{r1} \vec{E_{N1}} = \varepsilon_0 \varepsilon_{r2} \vec{E_{N2}}$

or, $\vec{E_{N2}} = \dfrac{\varepsilon_{r1} \vec{E_{N1}}}{\varepsilon_{r2}} = \dfrac{4}{3} \times 3 \times 10^3 \hat{a_z}$

$$= 4 \times 10^3 \hat{a_z} \ V/m$$

Again boundary condition

$$\vec{E_{t1}} = \vec{E_{t2}}$$

or, $(5\hat{a_x} - 2\hat{a_y}) \times 10^3 = \vec{E_{t2}}$

$\therefore \vec{E_{t2}} = (5\hat{a_x} - 2\hat{a_y}) \times 10^3 \ V/m$

from (i)

$$\boxed{\vec{E_2} = \vec{E_{t2}} + \vec{E_{N2}} = (5\hat{a_x} - 2\hat{a_y} + 4\hat{a_z}) \times 10^3 \ V/m}$$

(b) $\theta_1 = \cos^{-1} \dfrac{|\vec{E_{N1}}|}{|\vec{E_1}|} = \cos^{-1} \dfrac{3 \times 10^3}{\sqrt{38} \times 10^3} = 60.87^\circ$

$$\boxed{\alpha_1 = 90 - 60.87 = 29.121^\circ}$$

$$\theta_2 = \cos^{-1}\frac{|\vec{E}_{N2}|}{|\vec{E}_2|} = \cos^{-1}\frac{4\times10^3}{3\sqrt{5}\times10^3} = 53.59^\circ$$

$$\boxed{\alpha_2 = 90^\circ - 53.59^\circ = 36.60^\circ}$$

(c) energy densities $(w_{E1}) = \frac{1}{2}\varepsilon_1 E_1^2$

$$= \frac{1}{2}\varepsilon_0 \varepsilon_{r1} E_1^2$$

$$= 672\ \mu J/m^3$$

$$w_{E2} = \frac{1}{2}\varepsilon_0 \varepsilon_{r2} E_2^2 = 597\ \mu J/m^3$$

(d) At the centre $(3,4,-5)$ of the cube of side 2m,

$V = 2\times2\times2 = 8\ m^3$

$(Z = -5 < 0$, implies the cube is in region 2$)$

Total energy $(W) = w_{E2}\times V$

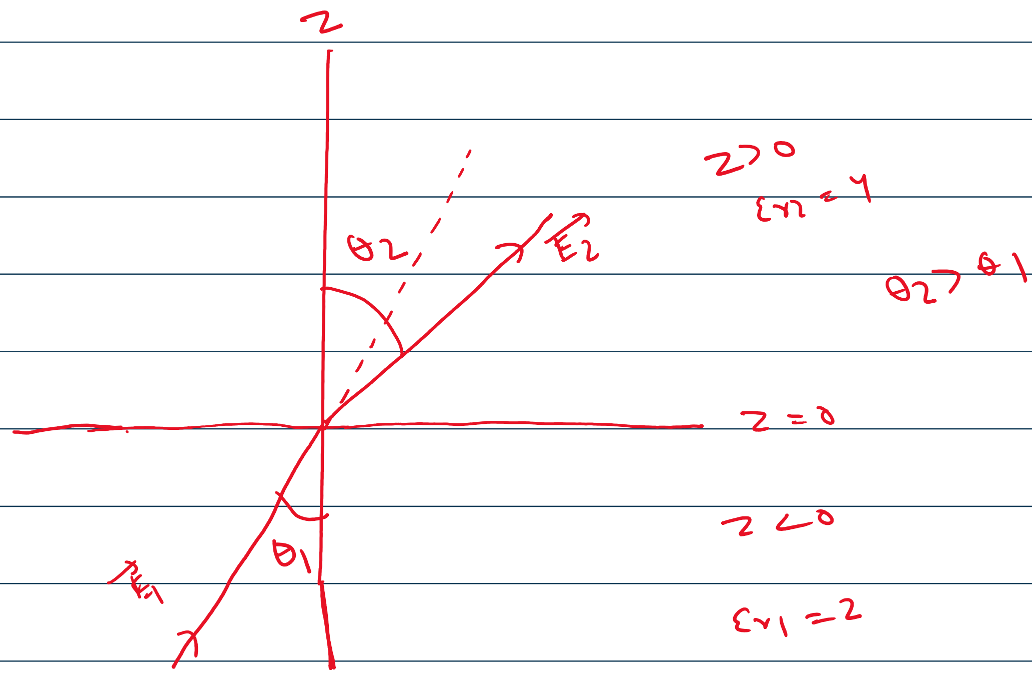
$$= 597\times10^{-6}\times 8$$

$$= 4.78\times10^{-3}\ J$$

#

4. The region z<0 contains a dielectric material for which $\varepsilon_{r1} = 2$, while the region z>0 is characterized by $\varepsilon_{r2} = 4$. Let $\vec{E_1} = -30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z$ V/m. Find: (a) E_{n_1} (b) E_{t1} (c) θ_1 (d) D_{n2} (e) D_{t2} (f) $\vec{D_2}$ (g) $\vec{P_1}$ (h) θ_2 *[2064 Shrawan]*

Sol^n ÷



Now,

(a) E_{n_1} is component of $\vec{E_1}$ along z-axis

$$E_{n_1} = \vec{E_1} \cdot \hat{a}_z = 70 \text{ V/m} \quad \Big| \quad \vec{E_{n_1}} = 70\hat{a}_z \text{ V/m}$$

(b) $\vec{E_{t_1}} = ?$

$$\vec{E_1} = \vec{E_{n_1}} + \vec{E_{t_1}}$$

$$\vec{E_{t_1}} = -30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z - 70\hat{a}_z$$

$$= -30\hat{a}_x + 50\hat{a}_y$$

$$E_{t1} = -30\,a_x + 50\,a_y + 70\,a_z - 70\,a_z$$

$$= -30\,\hat{a}_x + 50\,\hat{a}_y$$

$$E_{t1} = \sqrt{(-30)^2 + (50)^2} = 50.30\ \text{V/m}$$

(c) $$\theta_1 = \cos^{-1}\frac{|\vec{E}_{N1}|}{|\vec{E}_1|}$$

$$|\vec{E}_{N1}| = 70\ \text{V/m} \qquad |\vec{E}_1| = \sqrt{(-30)^2 + 50^2 + 70^2}$$

$$= 91.104\ \text{V/m}$$

$$\theta_1 = \cos^{-1}\frac{70}{91.104} = 39.79^\circ$$

(d) From boundary condition

$$\vec{D}_{n2} = \vec{D}_{n1}$$

$$= \varepsilon_0 \varepsilon_{r1} \vec{E}_{n1}$$

$$= \varepsilon_0 \times 2 \times 70\,\hat{a}_z$$

$$= 1.2395\,\hat{a}_z\ \text{nC/m}^2$$

$$D_{n2} = 1.2395\ \text{nC/m}^2$$

(e) From boundary condition

(e) From boundary condition

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

$= -30\hat{a}_x + 50\hat{a}_y$ V/m

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

$= \varepsilon_0 \times 4 \times (-30\hat{a}_x + 50\hat{a}_y)$

$= -1.0625\hat{a}_x + 1.77\hat{a}_y$ nC/m^2

$|\vec{D}_{t2}| = \sqrt{(-1.0625\times10^{-9})^2 + (1.77\times10^{-9})^2}$

$= 2.06$ nC/m^2

(f) $\vec{D}_2 = \vec{D}_{n2} + \vec{D}_{t2} = 1.2395\hat{a}_z + -1.0625\hat{a}_x + 1.77\hat{a}_y$ nC/m^2

$= -1.0625\hat{a}_x + 1.77\hat{a}_y + 1.2395\hat{a}_z$ nC/m^2

(g) $\vec{P}_1 = \chi_e \varepsilon_0 \vec{E}_1$

$= (\varepsilon_{r1} - 1)\varepsilon_0 \vec{E}_1$

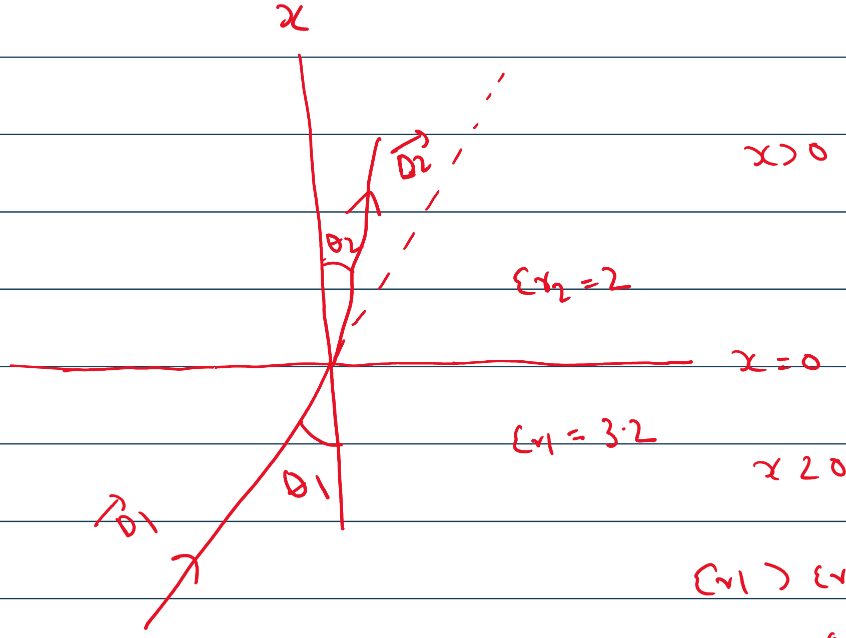
$= (2-1) \times \varepsilon_0 \times (-30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z)$

$= -265.62\hat{a}_x + 442.70\hat{a}_y + 619.79\hat{a}_z$ pC/m^2

(h) $\theta_2 = \cos^{-1}\dfrac{|\vec{D}_{n2}|}{|\vec{D}_2|} = \cos^{-1}\dfrac{1239}{2407.46} = 59.025^\circ$

#

5. **The region x<0 is composed of a uniform dielectric material for which ε_{r1} = 3.2 while region x>0 is characterized by ε_{r2} = 2. The electric flux density at region x<0 is $\vec{D} = 30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z$ nC/m², then find polarization $(\vec{P})$ and electric field intensity $(\vec{E})$ in both regions.** *[2068 Chaitra]*



$\varepsilon_{r1} > \varepsilon_{r2}$

$\theta_1 > \theta_2$

Now,

Since boundary is at x=0,

$$D_{n_1} = \vec{D_1} \cdot \hat{a}_x = (30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z) \times 10^{-9} \cdot \hat{a}_x$$

$$= 30 \times 10^{-9} \; C/m^2$$

$$\vec{D_{n_1}} = D_{n_1}\hat{a}_x = 30\hat{a}_x \; nC/m^2$$

Now, $\vec{D_{t_1}} = \vec{D_1} - \vec{D_{n_1}}$

$$= 30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z - 30\hat{a}_x$$

Now, $D_{t1} = D_1 - D_{n1}$

$$= 30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z - 30\hat{a}_x$$

$$= 50\hat{a}_y + 70\hat{a}_z \quad nC/m^2$$

$$\vec{D}_{t1} = \varepsilon_1 \vec{E}_{t1}$$

or, $$\vec{E}_{t1} = \frac{\vec{D}_{t1}}{\varepsilon_0 \varepsilon_{r1}} = \frac{(50\hat{a}_y + 70\hat{a}_z) \times 10^{-9}}{\varepsilon_0 \times 3.2}$$

$$= 1.76\hat{a}_y + 2.47\hat{a}_z \quad kV/m$$

From boundary condition, $\vec{D}_{n2} = \vec{D}_{n1}$

or, $$\vec{E}_{n2} = \frac{\vec{D}_{n2}}{\varepsilon_0 \varepsilon_{r2}} = \frac{\vec{D}_{n1}}{\varepsilon_0 \varepsilon_{r2}} = \frac{30\hat{a}_x \ nC/m^2}{\varepsilon_0 \times 2}$$

$$= 1.69 \quad kV/m$$

From boundary condition $\vec{E}_{t2} = \vec{E}_{t1}$

$$= 1.76\hat{a}_y + 2.47\hat{a}_z \quad kV/m$$

Now

$$\vec{E}_1 = \frac{\vec{D}_1}{\varepsilon_0 \varepsilon_{r1}} = \frac{(30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z) \times 10^{-9}}{\varepsilon_0 \times 3.2}$$

$$= (1059.32\hat{a}_x + 1765.53\hat{a}_y + 2471.75\hat{a}_z) \quad V/m$$

$= (1059.32\hat{a}_x + 1765.53\hat{a}_y + 2471.75\hat{a}_z)$ V/m

$\vec{E}_2 = \vec{E}_{n2} + \vec{E}_{t2}$

$= (1.694\times10^3\,\hat{a}_x) + (1.76\times10^3\,\hat{a}_y + 2.47\times10^3\,\hat{a}_z)$

$= 1694\,\hat{a}_x + 1764\,\hat{a}_y + 2470.58\,\hat{a}_z$ V/m

Now,

Polarization vector in region 1

$(\vec{P}_1) = \chi_e \varepsilon_0 \vec{E}_1$

$= (\varepsilon_{r1}-1)\cdot\cancel{\varepsilon_0}\cdot\dfrac{\vec{D}_1}{\cancel{\varepsilon_0}\,\varepsilon_{r1}}$

$= \dfrac{\varepsilon_{r1}-1}{\varepsilon_{r1}}\vec{D}_1$

$= \dfrac{3.2-1}{3.2}(30\hat{a}_x + 50\hat{a}_y + 70\hat{a}_z)\times10^{-9}$

$= 20.625\hat{a}_x + 34.375\hat{a}_y + 48.125\hat{a}_z$ nC/m^2

$\vec{P}_2 = \chi_e \varepsilon_0 \vec{E}_2$

$= (\varepsilon_{r2}-1)\varepsilon_0 \vec{E}_2$

$= (2-1)\times\varepsilon_0\times(1964\,\hat{a}_x + 1764.7\,\hat{a}_y + 2470.58\,\hat{a}_z)$

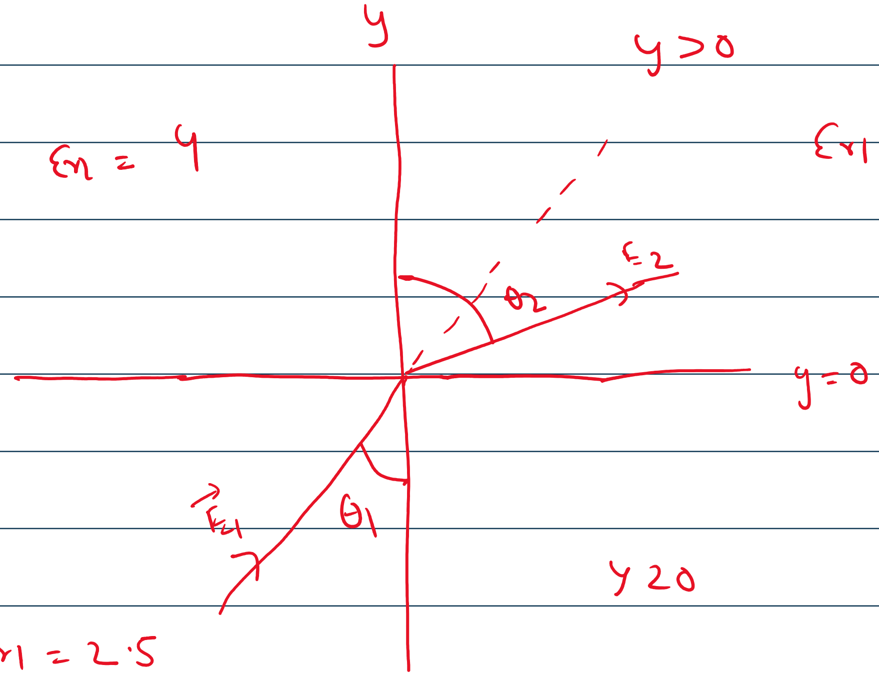
$= 17.38\hat{a}_x + 15.624\hat{a}_y + 21.87\hat{a}_z$ nC/m^2

$= 17.38\hat{a_x} + 15.624\hat{a_y} + 21.87\hat{a_z}\ nC/m^2$

\# The region $y<0$ contains a dielectric material for which $\epsilon_{r1} = 2.5$ while the region $y>0$ is characterized by $\epsilon_{r2} = 4$. let, $\vec{E_1} = -30\hat{a_x} + 50\hat{a_y} + 70\hat{a_z}$ V/m and find (a) $\vec{E_{N1}}$ (b) $\vec{E_{t1}}$ (c) $|E_{t1}|$ (d) $|E_1|$ (e) θ_1

(ii) $\vec{D_{N2}}$, $|D_{t2}|$, $\vec{D_2}$ (iii) $\vec{P_2}$ (iv) θ_2

Soln ÷



$\vec{E_1} = -30\hat{a_x} + 50\hat{a_y} + 70\hat{a_z}$

plane $y=0$ seperates two dielectric material to this plane.

so $|\vec{E_{N1}}| = \vec{E_1} \cdot \hat{a_y}$

$= 50$ V/m

So, $|E_{N1}| = E_1 \cdot a_y$

$= 50 \ V/m$

$\vec{E}_{N1} = E_{N1} \cdot \hat{a}_y$

$= 50 \hat{a}_y \ V/m$

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

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

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

$= -30 \hat{a}_x + 70 \hat{a}_z \ V/m$

$|E_{t1}| = 76.158 \ V/m$

$|E_1| = 91.104 \ V/m$

Now,

$|\vec{E}_{N_1}| = |\vec{E}_1| \cos\theta_1$

or, $50 = 91.104 \cos\theta_1$

$\therefore \theta_1 = 56.7^\circ$

Boundary condition

$\vec{D}_{N1} = \vec{D}_{N2} = \varepsilon_0 \varepsilon_{r1} \vec{E}_{N1}$

$= \varepsilon_0 \times 2.5 \times 50 \, \hat{a_y}$

$= 1.107 \, \hat{a_y} \; nC/m^2$

$\perp$ boundary

$\varepsilon_{t1} = \varepsilon_{t2}$

$\vec{\varepsilon_{t2}} = -30 \hat{a_x} + 70 \hat{a_z} \quad V/m$

$\vec{D_{t2}} = \varepsilon_0 \varepsilon_r \vec{E_{t2}}$

$= \varepsilon_0 \times 4 \times (-30 \hat{a_x} + 70 \hat{a_z}) \; C/m^2$

$= (-1.062 \hat{a_x} + 2.479 \hat{a_z}) \; nC/m^2$

$|D_{t2}| = 2.697 \; nC/m^2$

now,

$\vec{D_2} = \vec{D_{t2}} + \vec{D_{N2}}$

$= (-1.062 \hat{a_x} + 2.479 \hat{a_z} + 1.107 \hat{a_y}) \; nC/m^2$

$\vec{P_2} = \chi_e \varepsilon_0 \vec{E_2}$

$\vec{E_2} = \vec{E_{t2}} + \vec{E_{N2}}$

Now $\vec{D_{N1}} = \vec{D_{N2}}$

$\cancel{\varepsilon_0} \varepsilon_{r1} \vec{E_{N1}} = \cancel{\varepsilon_0} \varepsilon_{r2} E_{N2}$

$\vec{E_{N2}} = \frac{\varepsilon_{r1} \vec{E_{N1}}}{\varepsilon_{r2}}$

$$E_{N2} = \frac{\varepsilon_{r1}}{\varepsilon_{r2}} E_{N1}$$

$$= \frac{2.5}{4} \cdot 50\,\hat{a}_y$$

$$= 31.25\,\hat{a}_y$$

$$\vec{E}_2 = -30\,\hat{a}_x + 31.25\,\hat{a}_y + 70\,\hat{a}_z$$

So,
$$\vec{P}_2 = (\varepsilon_{r2} - 1)\,\varepsilon_0\,\vec{E}_2$$
$$= (4-1)\,\varepsilon_0\,(-30\,\hat{a}_x + 31.25\,\hat{a}_y + 70\,\hat{a}_z)$$
$$= (-0.797\,\hat{a}_x + 0.830\,\hat{a}_y + 1.859\,\hat{a}_z)\ nC/m^2$$

Now,

$$\theta_2 = \cos^{-1}\frac{|\vec{E}_{N2}|}{|\vec{E}_2|} = \cos^{-1}\frac{31.25}{\sqrt{(-30)^2 + 31.25^2 + 70^2}}$$

$$= 67.69^\circ \quad \#$$