CODE: 4 6 8 X A U

$\vec{K} = K_x\hat{i} + K_y\hat{j} + K_z\hat{k}$

$\vec{r} = x\hat{i} + y\hat{j} + z\hat{k}$

$v_1 = \frac{\omega}{K_I} = \frac{\omega}{K_R}$ Reflection and Transmission from Normal Incidence:-

$\vec{K}\cdot\vec{r}$

✓ Incident $\vec{E}_I(z,t) = E_{0_I}\, e^{i[K_I z - \omega t]}\hat{x}$ $\quad K_I = K_R = K_1$

Plane, monochromatic $\rightarrow$

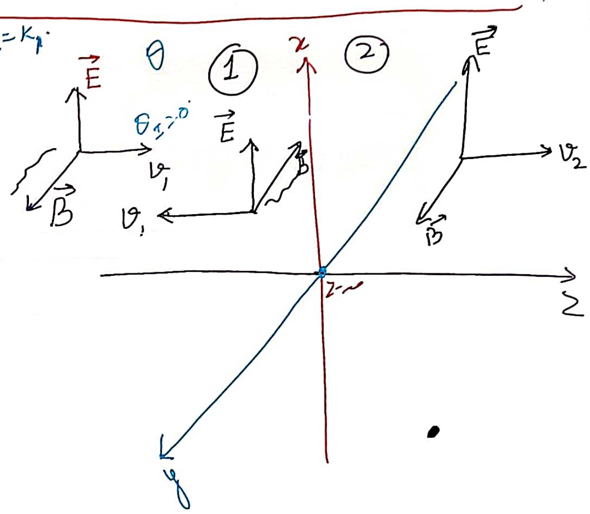
✓ $\vec{B}_I(z,t) = \frac{1}{v_1} E_{0_I}\, e^{i[K_I z - \omega t]}\hat{y}$

✓ Reflected $\vec{E}_R(z,t) = E_{0_R}\, e^{i[-K_R z - \omega t]}\hat{x}$

✓ $\vec{B}_R(z,t) = -\frac{1}{v_1} E_{0R}\, e^{i[-K_R z - \omega t]}\hat{y}$

✓ Transmitted $\vec{E}_T(z,t) = E_{0_T}\, e^{i[K_2 z - \omega t]}\hat{x}$

$\vec{B}_R(z,t) = \frac{1}{v_2} E_{0_T}\, e^{i[K_2 z - \omega t]}\hat{y}$



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At $z=0$: , $\sigma_f=0$, $J_f=0$

① $\nabla\cdot D=0 \Rightarrow \oint \vec{D}\cdot d\vec{a}=0$, $\epsilon_1 E_1^{\perp}=\epsilon_2 E_2^{\perp}$ — (1)

$B_1^{\perp}=B_2^{\perp}$ — (2)

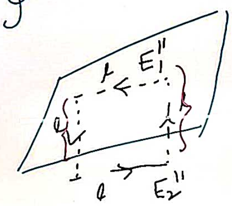
② $\nabla\cdot B=0$

③ $\boxed{\nabla\times E=-\frac{\partial B}{\partial t} \Rightarrow \oint \vec{E}\cdot d\vec{l}=-\frac{\partial}{\partial t}\underbrace{\int \vec{B}\cdot d\vec{a}}_{=0}} \Rightarrow E_1^{\parallel}=E_2^{\parallel}$ —(3) ✓

④ $\nabla\times H=\epsilon_0\frac{\partial \vec{D}}{\partial t} \Rightarrow \int \vec{H}\cdot d\vec{l}=\epsilon_0\frac{\partial}{\partial t}\underbrace{\int \vec{D}\cdot d\vec{a}}_{=0} \Rightarrow \frac{1}{\mu_1}B_{\parallel}^{1}=\frac{1}{\mu_2}B_2^{\parallel}$ —(4) ✓

$\vec{H}=\frac{\vec{B}}{\mu}-\vec{M}$

$\oint \vec{E}\cdot d\vec{l}=0$.



$E_1^{\parallel}l-E_2^{\parallel}l=0$

$f_{0^-}=f_{0^+}$

$\left.\frac{\partial f}{\partial z}\right|_{0^-}=\left.\frac{\partial f}{\partial z}\right|_{0^+}$

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CODE: 4 6 8 X A U

$E_1'' = E_2''$, At $z=0$

$$E_{0I}\, e^{\cancel{-i\omega t}} + E_{0R}\, e^{\cancel{-i\omega t}} = E_{0T}\, \cancel{e^{-i\omega t}} \Rightarrow E_{0I} + E_{0R} = E_{0T}$$

$$\frac{1}{\mu_1} B_1'' = \frac{1}{\mu_2} B_2'' \Rightarrow \frac{1}{\mu_1}\left[\frac{1}{v_1} E_{0T} - \frac{1}{v_1} E_{0R}\right] e^{\cancel{-i\omega t}} = \frac{1}{\mu_2}\,\frac{1}{v_2}\, E_{0T}\, e^{\cancel{-i\omega t}} \Rightarrow E_{0I} - E_{0R} = \underbrace{\frac{\mu_1}{\mu_2}\cdot\frac{v_1}{v_2}}_{\beta}\cdot E_{0T}$$

$$\boxed{\begin{aligned} f_{0I} + f_{0R} &= f_{0T} \\ f_{0I} - f_{0R} &= \frac{k_2}{k_1}\cdot f_{0T} \end{aligned}}$$

$$\beta = \frac{\mu_1}{\mu_2}\cdot\frac{v_1}{v_2}.$$

$$E_{0T} = \frac{2}{1+\beta} E_{0I} \Rightarrow \frac{E_{0T}}{E_{0I}} = \frac{2}{1+\beta}.$$

$$E_{0R} = \frac{1-\beta}{1+\beta}\cdot E_{0I} \Rightarrow \frac{E_{0R}}{E_{0I}} = \frac{1-\beta}{1+\beta}.$$

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CODE: 468XAU

$$\langle \vec{S} \rangle = \frac{\vec{E}\times\vec{B}}{\mu_0} = \frac{c^2\epsilon_0 E^2}{c} = c\epsilon_0 E_0^2 \langle \cos^2(kz-\omega t)\rangle$$

$\vec{E} = E_0 \cos(kz-\omega t)$

$c = \frac{1}{\sqrt{\mu_0\epsilon_0}}$

$$\boxed{I = \left\langle \frac{\text{Power}}{\text{Area}} \right\rangle = \frac{1}{2} c\epsilon_0 E_0^2}$$

$c^2\epsilon_0 = \frac{1}{\mu_0}$

$n_1 >> n_2$

$R + T = 1.$

$\frac{\mu_1}{\mu_2} \cdot \frac{n_2}{n_1} \approx \frac{n_2}{n_1}$

$$R = \frac{I_R}{I_I} = \frac{\frac{1}{2}\epsilon_1 v_1 E_{0R}^2}{\frac{1}{2}\epsilon_1 v_1 E_{0I}^2} = \left(\frac{E_{0R}}{E_{0I}}\right)^2$$

$$\boxed{\frac{n_1-n_2}{n_1+n_2}} = \boxed{\frac{E_{0R}}{E_{0I}} = \frac{1-\beta}{1+\beta}}$$

$$\boxed{\beta = \frac{\mu_1}{\mu_2}\frac{v_1}{v_2}}$$

$$T = \frac{I_T}{I_I} = \frac{\frac{1}{2}\epsilon_2 v_2 E_{0T}^2}{\frac{1}{2}\epsilon_1 v_1 E_{0I}^2} = \frac{\epsilon_2 v_2}{\epsilon_1 v_1}\left(\frac{E_{0T}}{E_{0I}}\right)^2$$

$$\boxed{\frac{E_{0T}}{E_{0I}} = \frac{2}{1+\beta}}$$

$$= \frac{2n_1}{n_1+n_2}$$

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CODE: 4 6 8 X A U

$$\frac{E_{0R}}{E_{0I}} = \left(\frac{n_1 - n_2}{n_1 + n_2}\right)$$,

(i) if $n_1 > n_2$ E_{0R} is in same phase with E_{0I}

(ii) $n_1 < n_2$. E_{0R} is not in same phase of E_{0I}

$$\frac{E_{0T}}{E_{0I}} = \frac{2n_1}{n_1 + n_2}.$$

Q. $\theta_I = 0$

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R +

$$T = \beta \left(\frac{E_{0T}}{E_{0I}}\right)^2 , \quad R = \left(\frac{E_{0R}}{E_{0I}}\right)^2$$

$$v_1 = \frac{1}{\sqrt{\mu_1 \varepsilon_1}}$$

$$\varepsilon_1 = \frac{1}{v_1^2 \mu_1} \; ; \; \varepsilon_2 = \frac{1}{v_2^2 \mu_2}$$

$$\to T = \frac{\frac{1}{2} \varepsilon_2 v_2 E_{0T}^2}{\frac{1}{2} \varepsilon_1 v_1 E_{0I}^2}$$

$$= \frac{\left(\frac{1}{v_2^2 \mu_2}\right) v_2 E_{0T}^2}{\frac{1}{(v_1^2 \mu_1)} \cdot v_1 E_{0I}^2} = \left(\frac{v_1 \mu_1}{v_2 \mu_2}\right) \frac{E_{0T}^2}{E_{0I}^2} = \frac{\beta E_{0T}^2}{E_{0I}^2}$$

$$R + T = \frac{(E_{0R})^2 + \beta (E_{0T})^2}{(E_{0I})^2}$$

$$= \left(\frac{1-\beta}{1+\beta}\right)^2 + \beta \cdot \left(\frac{2}{1+\beta}\right)^2$$

$$= 1$$

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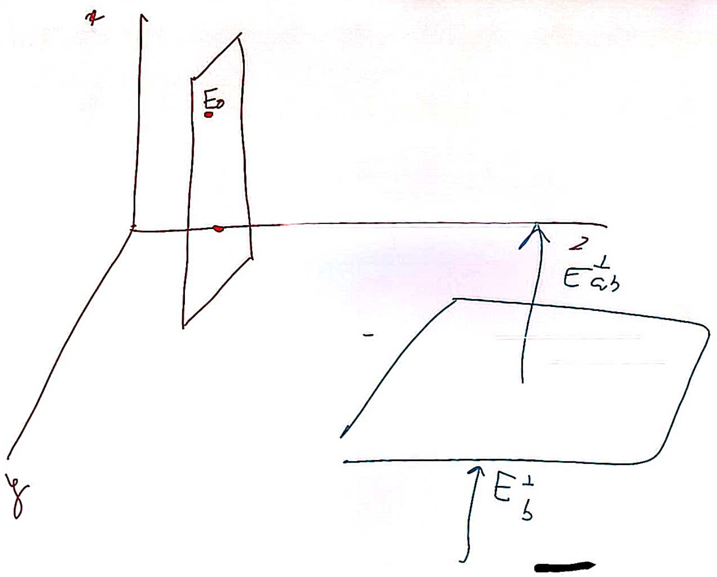

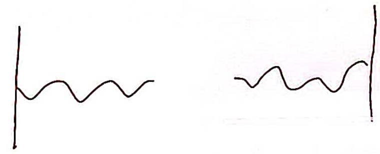

$$\sin(Kx - \omega t)$$

$$\sin[(k+\Delta k)x - (\omega+\Delta\omega)t]$$

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CODE: 468XAU

Free space : $\rho_f = 0$, $J_f = 0$

$$\vec{E}(z,t) = E_0 e^{i(kz-\omega t)}$$

$k = \frac{2\pi}{\lambda}$

$k_1 + ik_2$

Free space.

$\nabla \cdot E = 0$ $\nabla \times E = -\frac{\partial B}{\partial t}$

$\nabla \cdot B = 0$ $\nabla \times B = \mu\epsilon \frac{\partial E}{\partial t}$

Maxwell eqn

Conductor :→ $R = \rho \frac{l}{A}$ Resistivity

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

$\nabla \times (\nabla \times E) = -\cancel{\mu\epsilon}\frac{\partial}{\partial t}(\nabla \times B)$

$\vec{E} \perp \vec{B}$ ← $\nabla(\nabla \cdot E) - \nabla^2 E =$

$-\nabla^2 E = -\mu\epsilon \frac{\partial^2 E}{\partial t^2}$

$\nabla \cdot D = \rho_f$ ⇒ $\epsilon \nabla \cdot E = \rho_f$

→ $\nabla \cdot E = 0$

$\nabla \cdot B = 0$

$\nabla \times E = -\frac{\partial B}{\partial t}$

$J_f = \sigma \vec{E}$

$\nabla \times H = J_f + \frac{\partial D}{\partial t}$

$v = \frac{1}{\sqrt{\mu\epsilon}}$

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CODE: 4 6 8 X A U

$$\nabla\cdot E = 0, \quad \nabla\cdot B = 0, \quad \nabla\times E = -\frac{\partial B}{\partial t} \qquad \vec{E}\perp\vec{B}, \quad \frac{\vec{E}}{c} = \vec{B}$$

$$\nabla\times B = \mu\sigma E + \mu\epsilon\frac{\partial E}{\partial t}$$

Plane wave:

$$\vec{E}(z,t) = \tilde{E}_0 e^{i[\tilde{k}z-\omega t]}$$

$$\vec{B}(z,t) = \tilde{B}_0 e^{i[\tilde{k}z-\omega t]}$$

$$\nabla\times(\nabla\times E) = -\frac{\partial}{\partial t}(\nabla\times B)$$

$$-\nabla^2 E = -\left[\mu\epsilon\frac{\partial^2 E}{\partial t^2} + \mu\sigma\frac{\partial E}{\partial t}\right]$$

$$\frac{\partial^2 E}{\partial z^2} = \boxed{\nabla^2 E = \mu\epsilon\frac{\partial^2 E}{\partial t^2} + \mu\sigma\frac{\partial E}{\partial t}} \rightarrow (A)$$

Modified wave Eqn

$$\nabla^2 B = \mu\epsilon\frac{\partial^2 B}{\partial t^2} + \mu\sigma\frac{\partial B}{\partial t}$$

From (A):

$$(i\tilde{k})^2 E_0 \cancel{e^{i(\tilde{k}z-\omega t)}} = \mu\epsilon\cdot(-i\omega)^2 E_0 \cancel{e^{i(\tilde{k}z-\omega t)}} + \mu\sigma(-i\omega) E_0 \cancel{e^{i(\tilde{k}z-\omega t)}}$$

$$\boxed{\tilde{k}^2 = \mu\epsilon\omega^2 + i\mu\sigma\omega}$$

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CODE: 4 6 8 X A U

$$\tilde{K}^2 = \mu\epsilon\omega^2 + i\omega\mu\sigma.$$

$$\boxed{\tilde{K} = K_1 + iK_2.} = Ke^{i\phi}$$

$$K_1 = \omega\sqrt{\frac{\epsilon\mu}{2}}\left[\sqrt{1+\left(\frac{\sigma}{\epsilon\omega}\right)^2} + 1\right]^{1/2}$$

$$\boxed{K_2 = \omega\sqrt{\frac{\epsilon\mu}{2}}\left[\sqrt{1+\left(\frac{\sigma}{\epsilon\omega}\right)^2} - 1\right]^{1/2}}$$

$$K = \sqrt{K_1^2 + K_2^2}$$

$$\tan\phi = \frac{K_2}{K_1},$$

$$\vec{E}(z,t) = E_0\, e^{i[\tilde{K}z-\omega t]}$$

$$= E_0\, e^{-K_2 z}\, e^{i[K_1 z-\omega t]} \quad \text{— (A)}$$

$\frac{1}{e}$ → Skin Depth

$$z = \frac{1}{K_2} \Rightarrow \vec{E} = \frac{1}{e} E_0\, e^{i[Kz-\omega t]}$$

$$\vec{B}(z,t) = B_0\, e^{-K_2 z}\, e^{i[K_1 z-\omega t]} \quad \text{— (B)}$$

$$\delta_E - \delta_B \neq 0$$

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$$\vec{E}(z,t) = \underline{E_0^{(z,t)}} e^{-K_2 z} e^{i(K_1 z - \omega t)}$$

$$\vec{B}(z,t) = \underline{B_0^{(z,t)}} e^{-K_2 z} e^{i(K_1 z - \omega t)}$$

$$k_1 = \frac{2\pi}{\lambda_1}, \quad v = \frac{\lambda}{T}, \quad \omega.$$

$$E_0(z,t) = E_{0_1} e^{i\delta_E}$$

$$B_0(z,t) = B_{0_1} e^{i\delta_B}.$$

$$v = \frac{\omega}{K}.$$

$$B_0 = \frac{E_0}{\omega}\tilde{K} \Rightarrow B_{0_1} e^{i\delta_B} = \frac{E_{0_1} e^{i\delta_E}}{\omega}\tilde{K}$$

$$= \frac{E_{01}}{\omega} e^{i\delta_E} . K e^{i\phi}$$

$$= \frac{E_{01} K}{\omega} e^{i(\delta_E + \phi)}$$

$$\delta_B = \delta_E + \phi.$$

$$\boxed{\delta_B - \delta_E = \phi}$$

Reflection at a Conducting Surface:

Absorption

Reflectance

Dispersion (ν)

E_I ① ② Conductor E_T

E_R K_1 $\tilde{K}_2$

① $E_1^{\parallel} - E_2^{\parallel} = 0$,

② $\frac{1}{\mu_1} B_1^{\parallel} - \frac{1}{\mu_2} B_2^{\parallel} = 0$

At z = 0

$E_{0I} + E_{0R} = E_{0T}$

$\frac{1}{\mu_1 v_1}\left[E_{0I} - E_{0R}\right] = \frac{\tilde{K}_2}{\mu_2 \cdot \omega} E_{0T}$

Transmitted $\vec{E}_T(z,t) = E_0 e^{i[\tilde{K}_2 z - \omega t]}$ Incidence

$\vec{B}_T(z,t) = \frac{\tilde{K}_2}{\omega} E_0 e^{i[\tilde{K}_2 z - \omega t]}$

$\vec{E}_I = E_{0I} e^{i[K_1 z - \omega t]} \hat{x}$

$\vec{B}_I = \frac{1}{v_1} E_{0I} e^{i[K_1 z - \omega t]} \hat{y}$

$\vec{E}_R = E_{0R} e^{i[-K_1 z - \omega t]} \hat{x}$

$\vec{B}_R = -\frac{1}{v_1} E_{0R} e^{i[-K_1 z - \omega t]} \hat{y}$

$\tilde{\beta} = \frac{\mu_1 v_1 \tilde{K}_2}{\mu_2 \omega}$

$\frac{E_{0R}}{E_{0I}} = \frac{1-\tilde{\beta}}{1+\tilde{\beta}}$

$\frac{E_{0T}}{E_{0I}} = \frac{2}{1+\tilde{\beta}}$

$\beta \to \infty$

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CODE: 4 6 8 X A U

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

$$\sigma \nabla \cdot E = -\frac{\partial \rho_f}{\partial t}$$

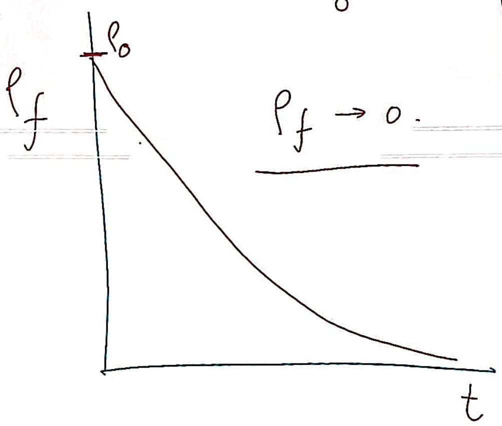
$$\frac{\sigma}{\epsilon} \rho_f = -\frac{\partial \rho_f}{\partial t}$$

$$\Rightarrow \boxed{\frac{\partial \rho_f}{\partial t} + \frac{\sigma}{\epsilon} \rho_f = 0}$$

$$-\frac{\sigma}{\epsilon} \rho_0 e^{-\sigma/\epsilon\, t} + \frac{\sigma}{\epsilon} \rho_0 e^{-\frac{\sigma}{\epsilon} t} = 0$$

$$\rho_f = \rho_0 e^{-\frac{\sigma}{\epsilon} t}$$

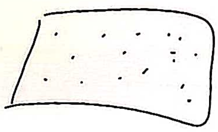
$$\tau = \frac{\epsilon}{\sigma}.$$



$$\rho_f \to 0.$$

$$R = \rho \frac{l}{A}.$$

$$\Rightarrow \frac{1}{\rho} = \frac{l}{RA}.$$



$$V = IR$$

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

$$\frac{I}{\cancel{A}} = \frac{1}{\rho} \cdot \frac{V}{l} = \frac{\cancel{l}}{R\cancel{A}} \cdot \frac{V}{\cancel{l}}$$

$$V = IR$$

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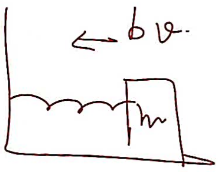
CODE: 468XAU

$$F = -kx - bv$$

$$\Rightarrow \ddot{x} + \frac{k}{m}x + \frac{b}{m}\dot{x} = 0$$



$$\ddot{z} + \omega_0^2 z + \underbrace{\gamma \dot{z}}_{i\omega\gamma} = 0$$

$$z = z_0 e^{i\omega t}$$

$$F = -kx$$

$$x = x_0 \cos \omega_0 t$$

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CODE: 4 6 8 X A U

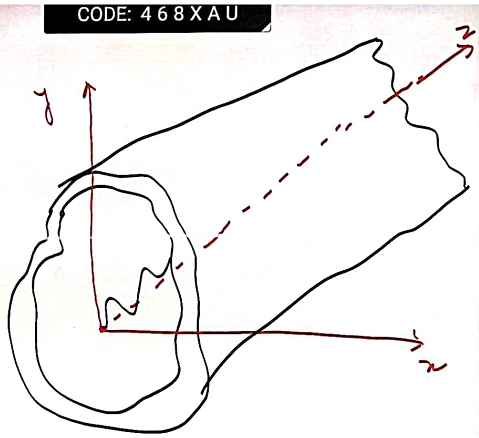
Guided Waves →

Inside Side of Conductor : $E^{\parallel} = 0$ — (1)

$B^{\perp} = 0$ — (2)

$$\left.\begin{array}{l} \vec{E}(x,y,z,t) = \vec{E}_0(x,y)\, e^{i(kz-\omega t)} \quad \text{— (A)} \\ \vec{B}(x,y,z,t) = \vec{B}_0(x,y)\, e^{i(kz-\omega t)} \quad \text{— (B)} \end{array}\right] \text{— (3)}$$

$$[B_{0x}\hat{x} + B_{0y}\hat{y} + B_{0z}\hat{z}]\, e^{i(kz-\omega t)}$$



$$\left.\begin{array}{ll} \boxed{\begin{array}{l} \nabla\cdot\vec{E} = 0 \quad \text{(I)} \\ \nabla\cdot\vec{B} = 0 \quad \text{(II)} \end{array}} & \begin{array}{l} \nabla\times\vec{E} = -\dfrac{\partial \vec{B}}{\partial t} \quad \text{(III)} \\ \nabla\times\vec{B} = \dfrac{1}{c^2}\dfrac{\partial \vec{E}}{\partial t} \quad \text{(IV)} \end{array} \end{array}\right] \text{— (4)}$$

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CODE: 4 6 8 X A U

$\vec{E}_0 = E_{0x}\hat{x} + E_{0y}\hat{y} + E_{0z}\hat{z}$, $\vec{B}_0 = B_{0x}\hat{x} + B_{0y}\hat{y} + B_{0z}\hat{z}$.

$E_x = E_{0x} e^{i(kz-\omega t)}\hat{x}$

$E_y = E_{0y} e^{i(kz-\omega t)}$

$E_z = E_{0z} e^{i(kz-\omega t)}$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} = -\frac{\partial}{\partial t}\left[B_0 e^{i(kz-\omega t)}\right] = i\omega B_0 e^{i(kz-\omega t)}$$

$$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial_x & \partial_y & \partial_z \\ E_x & E_y & E_z \end{vmatrix} = i\omega B_0 e^{i(kz-\omega t)}$$

x-Component: $\left[\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z}\right] = i\omega B_{0x} e^{i[kz-\omega t]}$

$$\Rightarrow \left[\frac{\partial E_{0z}}{\partial y} - ik E_{0y}\right] e^{i(kz-\omega t)} = i\omega B_x. \Rightarrow \boxed{\frac{\partial E_z}{\partial y} - ikE_y = i\omega B_x.}$$

CODE: 4 6 8 X A U

$$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ 1 & 2 & 3 \\ 4 & 5 & 6 \end{vmatrix}$$

y-component: $-\left[\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z}\right] = i\omega B_{0y} e^{i(kz-\omega t)}$

$$\boxed{-\left[\frac{\partial E_z}{\partial x} - ikE_x\right] = i\omega B_y} \Rightarrow ikE_x - \frac{\partial E_z}{\partial x} = i\omega B_y.$$

z-component:

$$\boxed{\frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x} = i\omega B_{0z} e^{i(kz-\omega t)} = i\omega B_z.}$$

$$\nabla \times B = \frac{1}{c^2}\frac{\partial E}{\partial t}.$$

$$\begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \partial_x & \partial_y & \partial_z \\ B_x & B_y & B_z \end{vmatrix} = \frac{-1}{c^2}(i\omega) E_0 e^{i(kz-\omega t)}$$

$$= -\left(\frac{i\omega}{c^2}\right) E_x$$

$$\frac{\partial B_z}{\partial y} - \frac{\partial B_y}{\partial z}.$$

$$\boxed{\frac{\partial B_z}{\partial y} - ikB_y = -\frac{i\omega}{c^2} E_x.}$$

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CODE: 468XAU

(1) $$\frac{\partial E_y}{\partial x} - \frac{\partial E_z}{\partial y} = i\omega B_z$$

(2) $$\frac{\partial E_z}{\partial y} - ikE_y = i\omega B_x$$

(3) $$\frac{\omega}{c^2}\cancel{ikE_x} - \frac{\omega}{c^2}\frac{\partial E_z}{\partial x} = i\frac{\omega^2}{c^2}B_y$$

(4) $$\frac{\partial B_y}{\partial x} - \frac{\partial B_x}{\partial y} = -\frac{i\omega}{c^2}E_z$$

(5) $$k\frac{\partial B_z}{\partial y} - ik^2B_y = -\cancel{\frac{i\omega k}{c^2}}E_x$$

(6) $$ikB_x - \frac{\partial B_z}{\partial x} = -\frac{i\omega}{c^2}E_y$$

✓ $$E_x = \frac{i}{\left[\frac{\omega^2}{c^2} - k^2\right]}\left[k\frac{\partial E_z}{\partial x} + \omega\frac{\partial B_z}{\partial y}\right] \quad - (6)$$

✓ $$E_y = \frac{i}{\frac{\omega^2}{c^2} - k^2}\left[k\frac{\partial E_z}{\partial y} - \omega\frac{\partial B_z}{\partial x}\right]$$

$$(2)\times\frac{\omega}{c^2} + k\times(6) \Rightarrow B_x = \frac{i}{\left(\frac{\omega}{c}\right)^2 - k^2}\left[k\frac{\partial B_z}{\partial x} - \frac{\omega}{c^2}\frac{\partial E_z}{\partial y}\right]$$

$$(3)\times\frac{\omega}{c^2} + (5)\times k \Rightarrow B_y = \frac{i}{(\omega/c)^2 - k^2}\left[k\frac{\partial B_z}{\partial y} + \frac{\omega}{c^2}\frac{\partial E_z}{\partial x}\right]$$

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$$\nabla \cdot \vec{E} = 0 \Rightarrow \frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z} = 0$$

$$\left[\frac{\partial E_{0x}}{\partial x} + \frac{\partial E_{0y}}{\partial y} + \frac{\partial E_{0z}}{\partial z}\right] e^{i[kz-\omega t]} = 0$$

$$\frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + ikE_z = 0$$

$$\frac{i}{\left(\omega/c\right)^2 - k^2}\left[k\frac{\partial^2 E_z}{\partial x^2} + \omega\cancel{\frac{\partial^2 B_z}{\partial x \partial y}} + k\frac{\partial^2 E_z}{\partial y^2} - \omega\cancel{\frac{\partial B_z}{\partial x \partial y}}\right] + ikE_z = 0$$

$$\nabla^2 V = -\rho/\epsilon_0 = 0$$

$$\Rightarrow \frac{\partial^2 E_z}{\partial x^2} + \frac{\partial^2 E_z}{\partial y^2} + \left[\frac{\omega^2}{c^2} - k^2\right] E_z = 0$$

B_z

$$\vec{E} = \vec{E}_0 e^{i(kz-\omega t)}$$

$$\vec{E}_0 = E_{0x}\hat{x} + E_{0y}\hat{y} + E_{0z}\hat{z}$$

$$E_z = E_{0z} e^{i(kz-\omega t)} \hat{z}$$

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$$\frac{\omega}{c^2}\frac{\partial E_z}{\partial y} - \frac{\omega}{c^2}\, i\cancel{k}\, E_y + \underline{i k^2}\, B_x - k\frac{\partial B_z}{\partial x} = \underline{i\frac{\omega^2}{c^2}}\, B_x - \frac{i\omega \cancel{k}}{\cancel{c^2}}\, E_y$$

$$i\left[k^2 - \frac{\omega^2}{c^2}\right] B_x = k\frac{\partial B_z}{\partial x} - \frac{\omega}{c^2}\frac{\partial E_z}{\partial y}$$

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