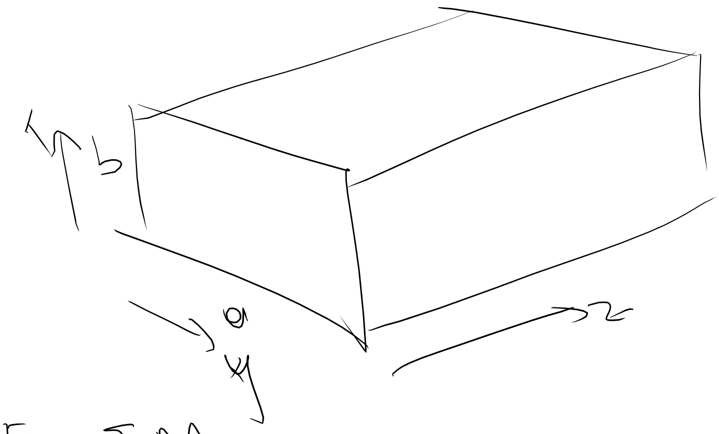


TE, TM

TE

$$E_{z0} = A\cos\left(\frac{n\pi}{b}x\right)\cos\left(\frac{m\pi}{a}y\right) \qquad n,m = 0,1,\dots \quad nm \neq 0$$

$$k = \frac{1}{c}\sqrt{\omega^2 - \omega_{mn}^2}$$

$$\omega_{mn}^2 = \left(\frac{n\pi}{b}\right)^2 + \left(\frac{m\pi}{a}\right)^2$$

$$\frac{\omega}{k} = v_p = \frac{c}{\sqrt{1 - \frac{\omega_{mn}^2}{\omega^2}}} > c$$

$$v_g = \frac{\partial \omega}{\partial k} = \frac{1}{\frac{\partial k}{\partial \omega}} = \frac{1}{\frac{1}{c}\frac{\omega}{\sqrt{\omega^2 - \omega_{mn}^2}}} = c\sqrt{1 - \frac{\omega_{mn}^2}{\omega^2}}$$

$$v_g < c$$

$$E_{z0} = A\cos\left(\frac{n\pi}{b}x\right)\cos\left(\frac{m\pi}{a}y\right)$$

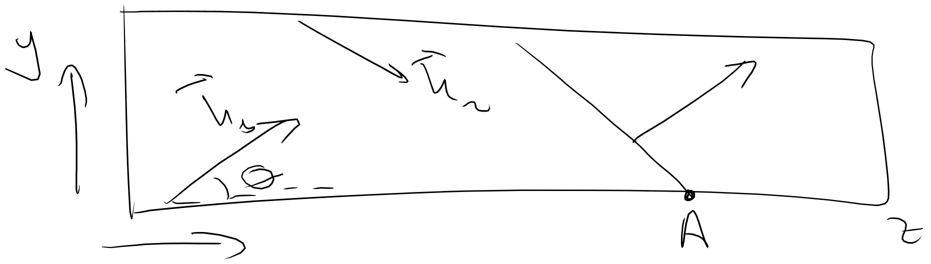
$$E_z = E_{z0}e^{i(kz-\omega t)} = \frac{A}{4}\left[e^{i\frac{n\pi}{b}x} + e^{-i\frac{n\pi}{b}x}\right]\left[e^{i\frac{m\pi}{a}y} + e^{-i\frac{m\pi}{a}y}\right]e^{i(kz-\omega t)}$$

$$= \frac{A}{4}e^{i\left(\frac{n\pi}{b}x + \frac{m\pi}{a}y + kz - \omega t\right)} + \frac{A}{4}e^{i\left(\frac{n\pi}{b}x - \frac{m\pi}{a}y + kz - \omega t\right)} + \dots$$

$$\vec{k}_1 = \frac{n\pi}{b}\hat{x} + \frac{m\pi}{a}\hat{y} + k\hat{z}$$

$$\frac{1}{v} = \frac{k_1}{w} = \frac{\sqrt{\left(\frac{n\pi}{b}\right)^2 + \left(\frac{m\pi}{a}\right)^2 + k^2}}{w} = \frac{\sqrt{\frac{1}{c^2}w_{mn}^2 + k^2}}{w} = \frac{1}{c}$$

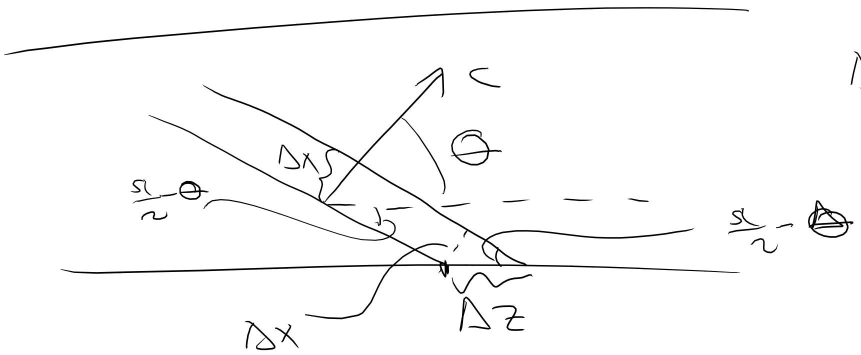
$$k^2 = \frac{1}{c^2}\left(w^2 - w_{mn}^2\right)$$



$$|\vec{k}_1| = |\vec{k}_2|$$

$$v_{\parallel} = c\cos\theta = c\,\frac{k_{1z}}{\sqrt{k_{1x}^2 + k_{1y}^2 + k^2}}$$

$$v_A = \frac{c}{\cos\theta} > c$$



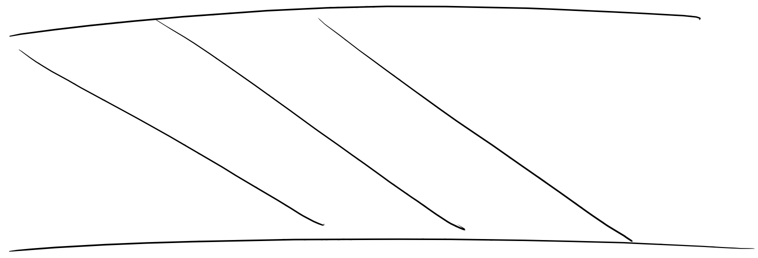
Δt

$\Delta x = c\Delta t$

$$\frac{\Delta x}{\Delta z} = \sin\left(\frac{\pi}{2} - \theta\right) = \cos\theta \Rightarrow \Delta z = \frac{\Delta x}{\cos\theta}$$

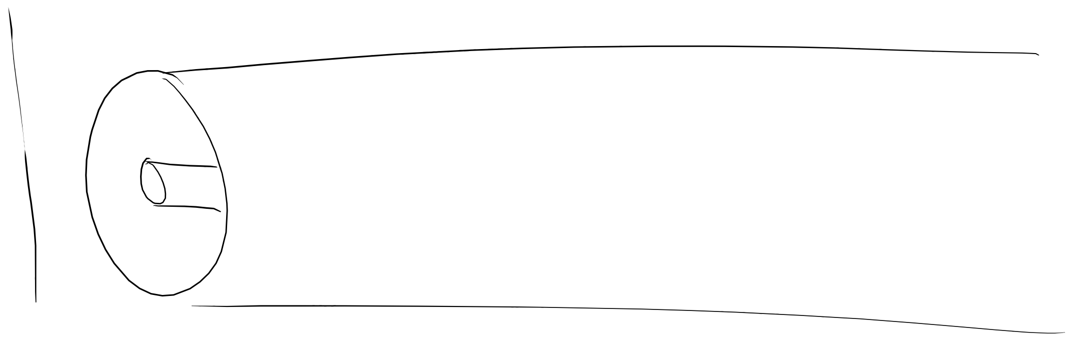
$$\Delta z = \frac{c\Delta t}{\cos\theta} \Rightarrow \frac{\Delta z}{\Delta t} = \frac{c}{\cos\theta}$$

$$v_A = \frac{\Delta z}{\Delta t} = \frac{c}{\cos\theta}$$



TE , TM , TEM

TEM



$$\vec{\nabla}\cdot\vec{B} = 0 \Rightarrow \frac{\partial B_{0x}}{\partial x} + \frac{\partial B_{0y}}{\partial y} = 0$$

$$\vec{B} = \vec{B}_0 e^{i(kz-wt)}$$

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

$$k = \frac{1}{c}\sqrt{w^2 - w_{mn}^2}$$

$$w_{mn}^2 = \left(\frac{m\pi}{b}\right)^2 + \left(\frac{n\pi}{a}\right)^2$$

$$E_z = \sum_{mn} A_{mn}\cos\left(\frac{m\pi}{b}y\right)\cos\left(\frac{n\pi}{a}x\right)e^{i(kz-wt)}$$

$$w > w_{mn}$$

Chapter 12 Electromagnetic Potentials

$$\vec{\nabla}\cdot\vec{B} = 0 \Rightarrow \vec{B} = \vec{\nabla}\times\vec{A}$$

$$\vec{\nabla}\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} \Rightarrow \vec{E} \neq -\nabla\phi$$

$$\vec{\nabla}\times\vec{E} = -\frac{\partial}{\partial t}(\vec{\nabla}\times\vec{A}) = -\vec{\nabla}\times\left(\frac{\partial\vec{A}}{\partial t}\right)$$

$$\vec{\nabla}\times\left(\vec{E}+\frac{\partial\vec{A}}{\partial t}\right) = 0 \Rightarrow \vec{E}+\frac{\partial\vec{A}}{\partial t} = -\nabla\phi$$

$$\boxed{\Rightarrow \vec{E} = -\nabla\phi - \frac{\partial\vec{A}}{\partial t}}$$

$$\boxed{\vec{B} = \vec{\nabla}\times\vec{A}}$$

$$\vec{\nabla}\cdot\vec{E} = \rho/\varepsilon$$

$$\boxed{-\nabla^2\phi - \frac{\partial}{\partial t}\vec{\nabla}\cdot\vec{A} = \frac{\rho}{\varepsilon}}$$

$$\vec{\nabla}\times\vec{B} = \mu\vec{J} + \mu\varepsilon\frac{\partial\vec{E}}{\partial t}$$

$$\vec{\nabla}\times(\vec{\nabla}\times\vec{A}) = \mu\vec{J} + \mu\varepsilon\frac{\partial}{\partial t}\left(-\vec{\nabla}\phi - \frac{\partial\vec{A}}{\partial t}\right)$$

$$\vec{\nabla}(\vec{\nabla}\cdot\vec{A}) - \nabla^2\vec{A}$$

$$\left(\mu\varepsilon\frac{\partial^2\vec{A}}{\partial t^2} - \nabla^2\vec{A}\right) + \vec{\nabla}\left(\vec{\nabla}\cdot\vec{A} + \mu\varepsilon\frac{\partial\phi}{\partial t}\right) = \mu\vec{J}$$

$$\left(\mu\varepsilon\frac{\partial^2\phi}{\partial t^2}-\nabla^2\phi\right)-\frac{\partial}{\partial t}\left(\vec{\nabla}\cdot\vec{A}+\mu\varepsilon\frac{\partial\phi}{\partial t}\right)=\frac{\rho}{\varepsilon}$$

$$\vec{E}=-\nabla\phi-\frac{\partial\vec{A}}{\partial t}$$

$$\vec{B}=\vec{\nabla}\times\vec{A}$$

$$\vec{A}\to\vec{A}+\vec{\nabla}\Lambda$$

$$\vec{B}=\vec{\nabla}\times\vec{A}\to\vec{\nabla}\times(\vec{A}+\vec{\nabla}\Lambda)=\vec{\nabla}\times\vec{A}+\underbrace{\vec{\nabla}\times(\vec{\nabla}\Lambda)}_{0}=\underbrace{\vec{\nabla}\times\vec{A}}_{\vec{B}}$$

$$\vec{B}\to\vec{B}$$

$$\vec{E}=-\vec{\nabla}\phi-\frac{\partial\vec{A}}{\partial t}$$