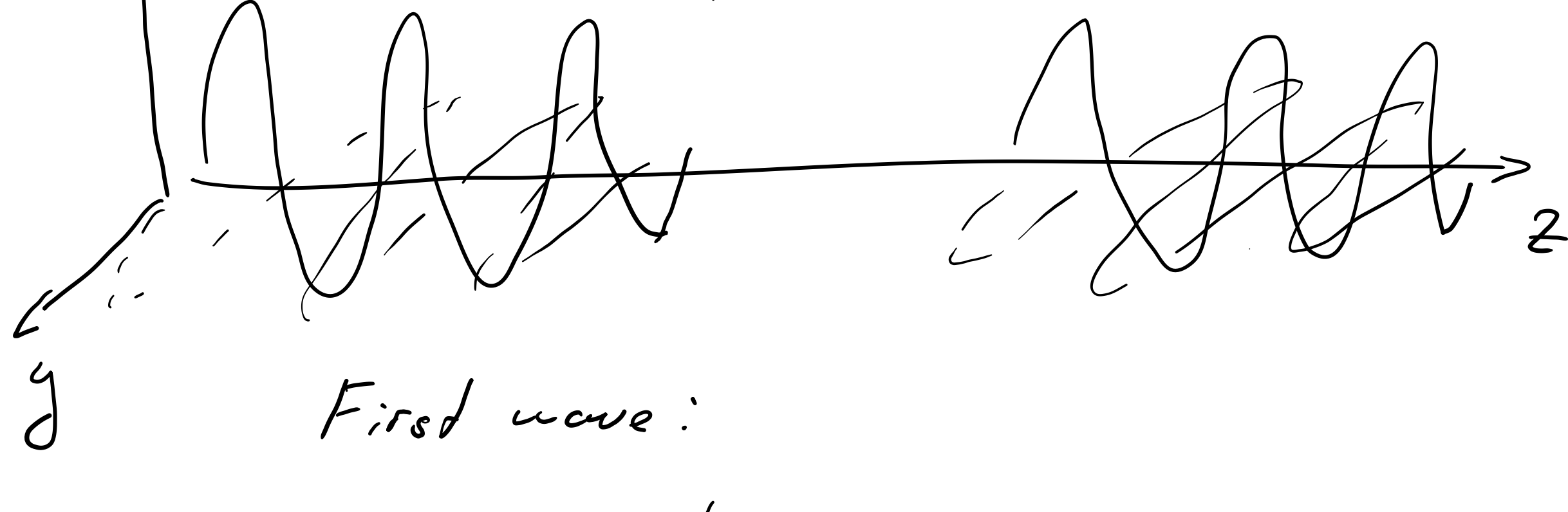


Very special case is actually standing waves. Such waves are possible when two counter propagating waves of same frequency, amplitude and polarization are adding up.

Let's imagine two waves:



First wave:

$$\begin{cases} \vec{E}_1 (E_0 e^{-i(\omega t - kz)}, 0, 0) \\ \vec{B}_1 (0, B_0 e^{-i(\omega t - kz)}, 0) \end{cases}$$

Second wave:

$$\begin{cases} \vec{E}_2 (E_0 e^{-i(\omega t + kz)}, 0, 0) \\ \vec{B}_2 (0, -B_0 e^{-i(\omega t + kz)}, 0) \end{cases}$$

$$[\vec{k} \vec{B}] = \frac{\omega}{c^2} \vec{E}$$

Ask to explain

Based on superposition principle:

$$\begin{cases} \vec{E} = \vec{E}_1 + \vec{E}_2 \\ \vec{B} = \vec{B}_1 + \vec{B}_2 \end{cases}$$

$$E_x = E_0 e^{-i(\omega t - kz)} + E_0 e^{-i(\omega t + kz)} = 2 E_0 e^{-i\omega t} \left(\frac{e^{-ikz} + e^{ikz}}{2} \right)$$

1) We will take only Re part.

$$2) \frac{e^{-ikz} + e^{ikz}}{2} = \cos(kz)$$

That means:

$$E_x = 2 E_0 \cos kz \cos \omega t$$

Amplitude is z dependent

Maxima will be at:

$$kz_n = \pi n \rightarrow \frac{2\pi}{\lambda} z_n = \pi n \quad \left| \begin{array}{l} z_n = n \frac{\lambda}{2} \end{array} \right|$$

Minima will be at:

$$kz_n = \frac{\pi}{2} + \pi n \rightarrow z_n = \frac{\lambda}{4} + n \frac{\lambda}{2}$$



It is clear that $\lambda_{\text{standing}} = \lambda_{\text{running}}$

Let's see what happens with magnetic component:

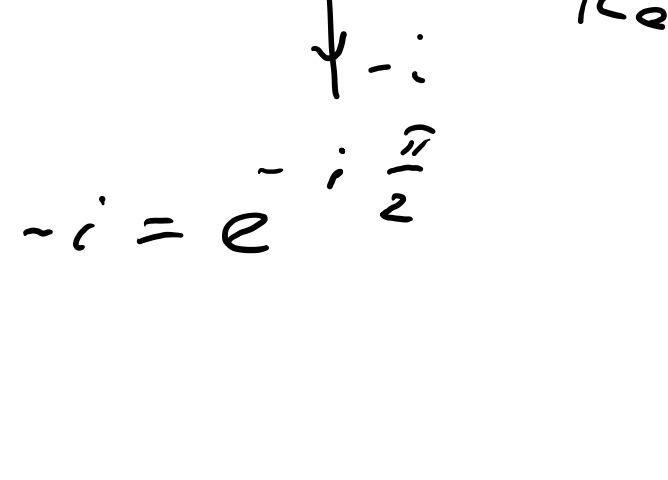
$$B_y = B_0 e^{i(\omega t - kz)} - B_0 e^{i(\omega t + kz)} = B_0 e^{i\omega t} \frac{e^{ikz} - e^{-ikz}}{-2i}$$

$$B_y = 2(-i) B_0 e^{i\omega t} \sin kz$$

$$B_y = 2 B_0 e^{i(\omega t - \frac{\pi}{2})} \sin kz$$

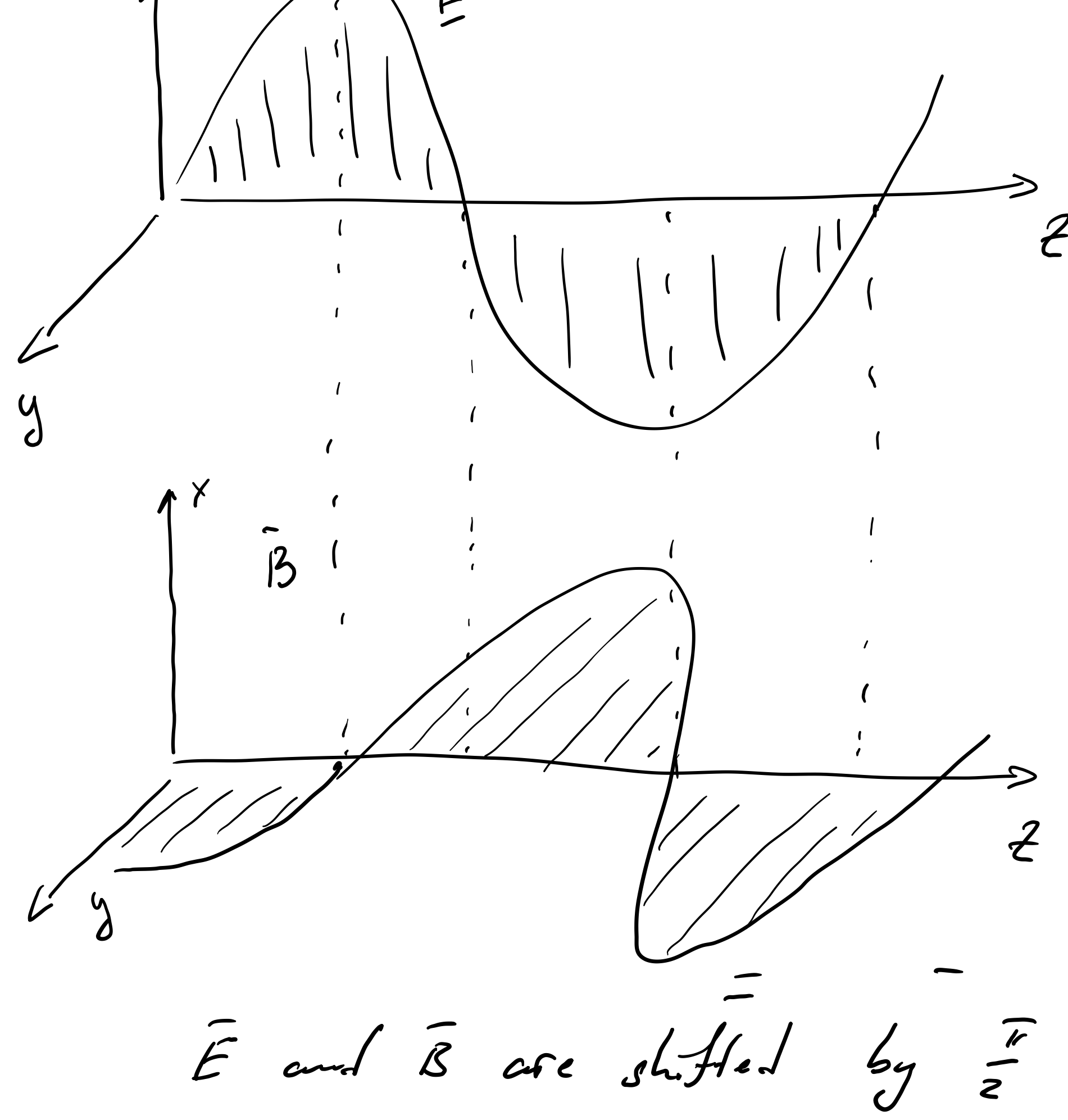
$$B_y = 2 B_0 \cos(\omega t - \frac{\pi}{2}) \sin kz$$

$$B_y = 2 B_0 \sin \omega t \sin kz$$



What does it mean?

$$\begin{cases} E_x = 2 E_0 \cos kz \cos \omega t \\ B_y = 2 B_0 \sin kz \sin \omega t \end{cases}$$



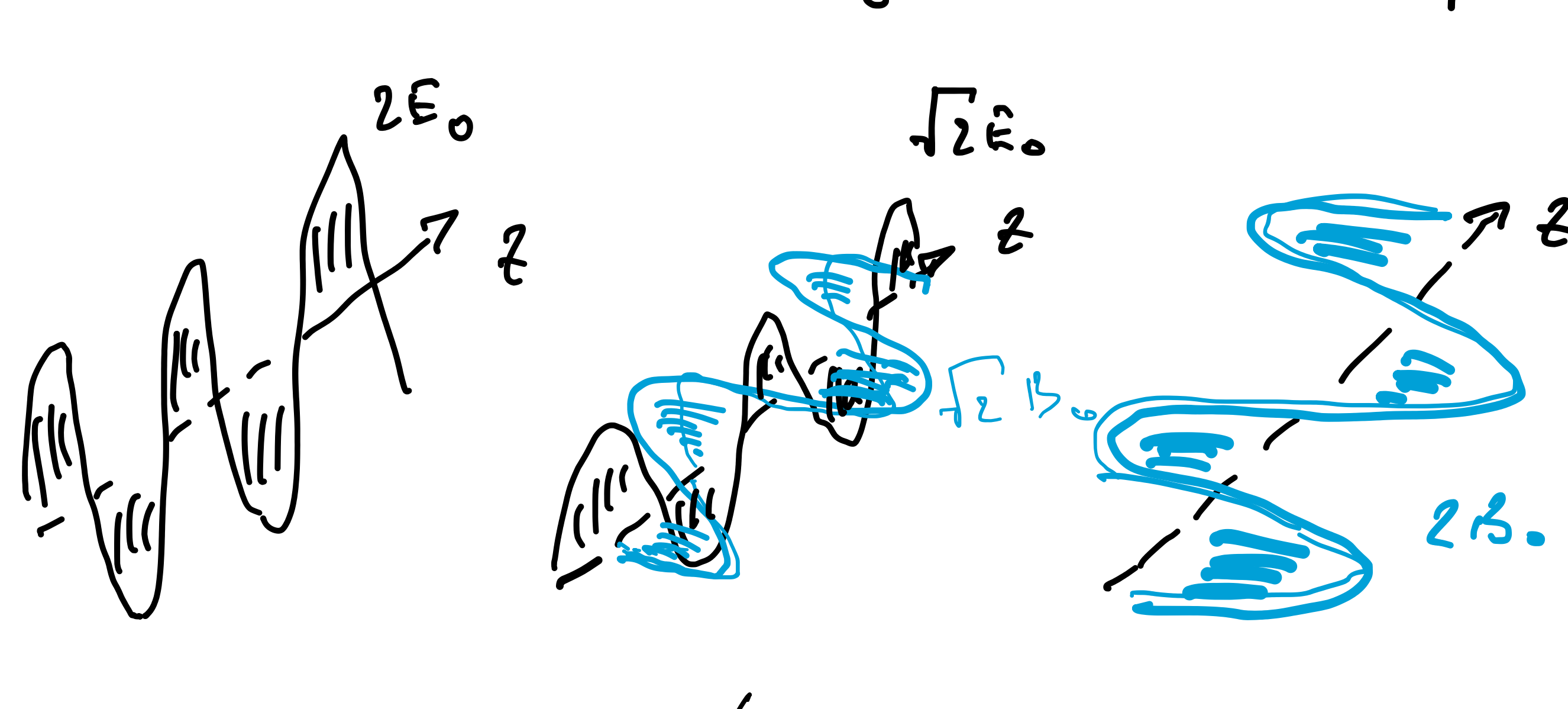
$\vec{E}$ and $\vec{B}$ are shifted by $\frac{\pi}{2}$ or $\frac{1}{4}$

Why? What about energy conservation law?

$$t=0$$

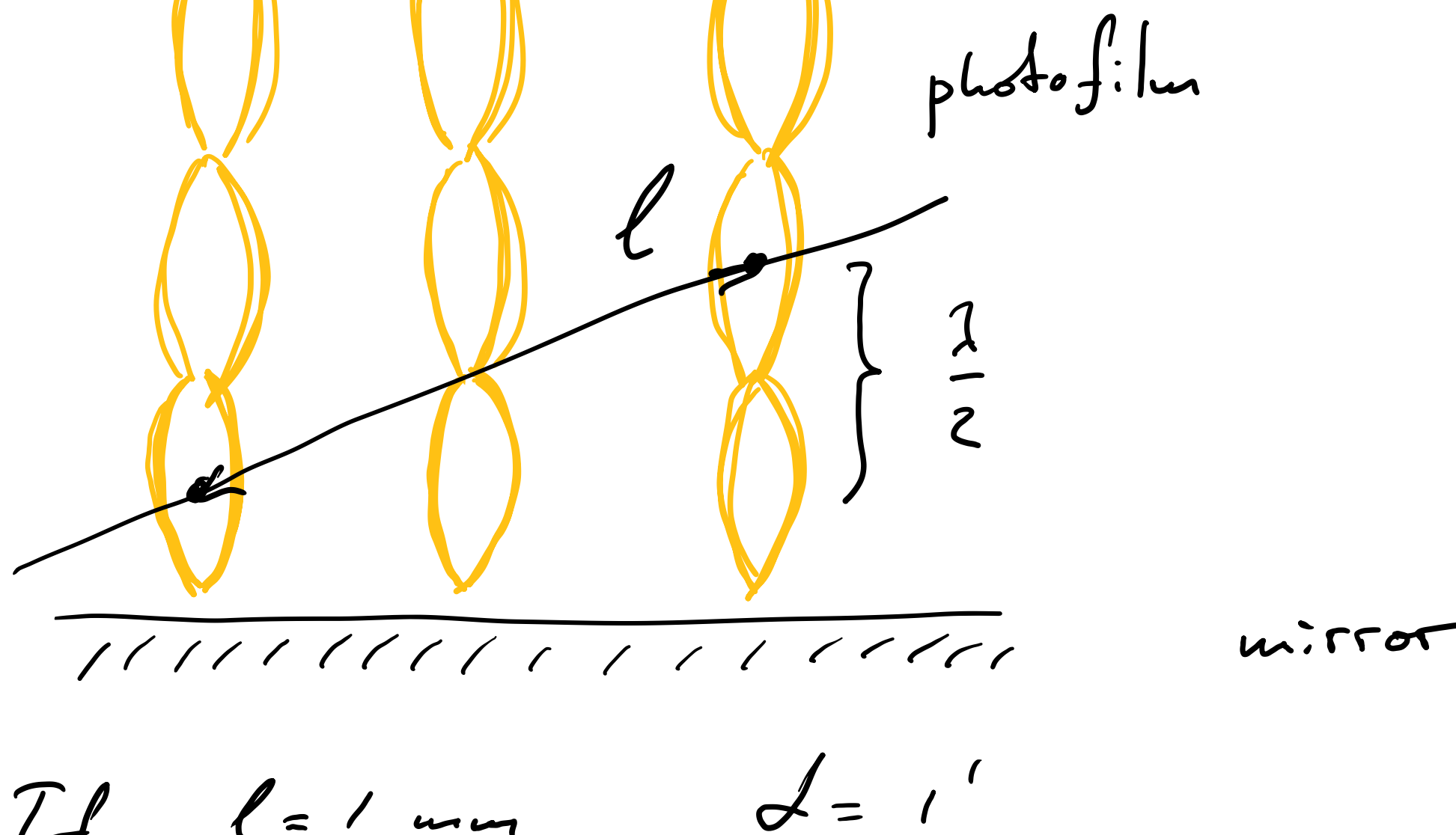
$$t = \frac{T}{8}$$

$$t = \frac{T}{4}$$



Weiner experiment (1890)

Light $\vec{k}$



If $l = 1 \text{ mm}$ $\Delta = 1'$

$$\Delta l = \frac{\lambda}{2}$$

Why?

$$\lambda = 2\Delta l = 2 \cdot \frac{10^{-3}}{60} \cdot \frac{1}{60} \text{ m} \approx \frac{1}{2} \cdot 10^{-6} = 500 \text{ nm}$$

degrees to radians

minutes to degrees

Demonstration

Lecher line

Ernst Lecher (1909)

