1. Elektromagnetische Welle im Vakuum

$$E_x = 0;$$
 $E_y = 30\cos(2\pi * 10^8 t - \frac{2\pi}{3}x);$ $E_z = 0$

(a)
$$\omega = 2\pi * 10^8 \text{ 1/s}$$

$$f = \frac{\omega}{2\pi} = \underline{10^8 \text{ 1/s}}$$

(b)
$$k = \frac{2\pi}{3}$$

$$\lambda = \frac{2\pi}{k} = 3 \text{ m}$$

(c)

Direction: $\hat{\underline{x}}$

(d)
$$B_0 = \frac{E_0}{c}$$

$$\vec{B} = \frac{10^7 \cos(2\pi * 10^8 t - \frac{2\pi}{3} x)\hat{z}}{}$$

2. Photonen-Ping-Pong

(a)
$$w_{rms} = \frac{\epsilon_0 E_0^2}{2}$$

$$I_{rms} = \frac{c\epsilon_0 E_0^2}{2}$$

Linear Polarization

$$\vec{E}_2(t) = E_0 \begin{pmatrix} \cos(\omega t) \\ \sin(\omega t) \\ 0 \end{pmatrix}$$

$$w_{rms} = \epsilon_0 E_0^2$$

$$I_{rms} = c\epsilon_0 E_0^2$$

Circular Polarization

$$\vec{E}_1(t) = E_0 \begin{pmatrix} \cos(\omega t) \\ 0 \\ 0 \end{pmatrix} \begin{vmatrix} \vec{E}_2(t) = E_0 \begin{pmatrix} \cos(\omega t) \\ \sin(\omega t) \\ 0 \end{vmatrix} \begin{vmatrix} \vec{E}_3(t) = E_0 \begin{pmatrix} a\cos(\omega t) \\ b\sin(\omega t) \\ 0 \end{vmatrix}$$

$$w_{rms} = \frac{\epsilon_0 E_0^2 (a^2 + b^2)}{2}$$

$$I_{rms} = c\epsilon_0 E_0^2$$
 $I_{rms} = \frac{c\epsilon_0 E_0^2 (a^2 + b^2)}{2}$

Elliptical Polarization

(b)
$$\vec{F} = \frac{\mathrm{d}\vec{p}}{\mathrm{d}t} = \frac{P}{c} = \epsilon_0 E_{\mathrm{rms}}^2 A$$

$$F_1 = \epsilon_0 E_{\rm rms}^2 A$$

$$F_2 = 2F_1 = 2\epsilon_0 E_{\rm rms}^2 A$$

$$F_3 = \frac{F_1 + F_2}{2} = \frac{3}{2} \epsilon_0 E_{\text{rms}}^2 A$$

(c) pair Wave with largest $E_{\rm rms}$ with F_2

 $\Rightarrow \underline{F_2 + \vec{E}_2}$ generate the highest mean Force \overline{F}

3. Stehende Wellen

$$\vec{E}(\vec{r},t) = \operatorname{Re}\left(\vec{E}_0 e^{i\vec{k}\vec{r} - i\omega t}\right)$$

(a)

$$\vec{E}_1(x\hat{x},t) = \operatorname{Re}\left(\vec{E}_0 e^{ik_x x - i\omega t}\right)$$

$$\vec{E}_2(-x\hat{x},t) = \operatorname{Re}\left(\vec{E}_0 e^{-ik_x x - i\omega t}\right)$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = \operatorname{Re}\left(\vec{E}_0 \left[e^{ik_x x - i\omega t} + e^{-ik_x x - i\omega t}\right]\right) =$$

$$= \operatorname{Re}\left(\vec{E}_0 e^{-i\omega t}\right) * 2\cos(k_x x)$$

For
$$x = (2n+1)\frac{\pi}{2k_x}$$
, $n \in \mathbb{N}$: $\cos(k_x x) = 0 \implies \vec{E} = 0$

 \Rightarrow \vec{E} describes a standing Wave with $\lambda = \pi$

(b)

$$\vec{E}_1(x\hat{x},t) = \operatorname{Re}\left(\vec{E}_0 e^{ik_x x - i\omega t}\right)$$

$$\vec{E}_2(y\hat{y},t) = \operatorname{Re}\left(\vec{E}_0 \operatorname{e}^{ik_y y - i\omega t}\right)$$

$$\begin{split} \vec{E} &= \vec{E}_1 + \vec{E}_2 = \operatorname{Re} \left(\vec{E}_0 \left[\operatorname{e}^{i k_x x - i \omega t} + \operatorname{e}^{i k_y y - i \omega t} \right] \right) = \\ &= \operatorname{Re} \left(\vec{E}_0 \operatorname{e}^{-i \omega t} \underbrace{\left[\operatorname{e}^{i k_x x} + \operatorname{e}^{i k_y y} \right] \right)}_{>0 \implies \text{no Root}} \end{split}$$

 $\Rightarrow \vec{E}$ does not describe a standing Wave

(c)
$$\vec{r}_1 = \cos\left(\frac{\pi}{10}\right)\hat{x} + \sin\left(\frac{\pi}{10}\right)\hat{y}$$

$$\vec{E}_1(x\hat{x},t) = \operatorname{Re}\left(\vec{E}_0 e^{ik_x x - i\omega t}\right)$$

$$\vec{E}_2(\vec{r}_1,t) = \operatorname{Re}\left(\vec{E}_0 e^{i\vec{k}\vec{r}_1 - i\omega t}\right)$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = \operatorname{Re}\left(\vec{E}_0 \left[e^{ik_x x - i\omega t} + e^{i\vec{k}\vec{r}_1 - i\omega t} \right] \right) =$$

$$= \operatorname{Re}\left(\vec{E}_0 e^{-i\omega t} \left[e^{ik_x x} + e^{i\vec{k}\vec{r}_1} \right] \right)$$

$$> 0 \Rightarrow \operatorname{no} \operatorname{Root}$$

 $\Rightarrow \vec{E}$ does not describe a standing Wave

(d)
$$\omega_1 = 2\omega_2$$

$$\vec{E}_1(\hat{x},t) = \operatorname{Re}\left(\vec{E}_0 e^{i\vec{k}\hat{x} - i\omega_1 t}\right)$$
$$\vec{E}_2(-\hat{x},t) = \operatorname{Re}\left(\vec{E}_0 e^{-i\vec{k}\hat{x} - i\omega_2 t}\right)$$

$$\vec{E} = \vec{E}_1 + \vec{E}_2 = \operatorname{Re}\left(\vec{E}_0 \left[e^{ik_x x - i2\omega_2 t} + e^{-ik_x x - i\omega_2 t} \right] \right) =$$

$$= \operatorname{Re}\left(\vec{E}_0 e^{-i\omega_2 t} \left[e^{ik_x x - i\omega_2 t} + e^{ik_x x} \right] \right)$$
time dependent Root

 $\Rightarrow \vec{E}$ does not describe a standing Wave