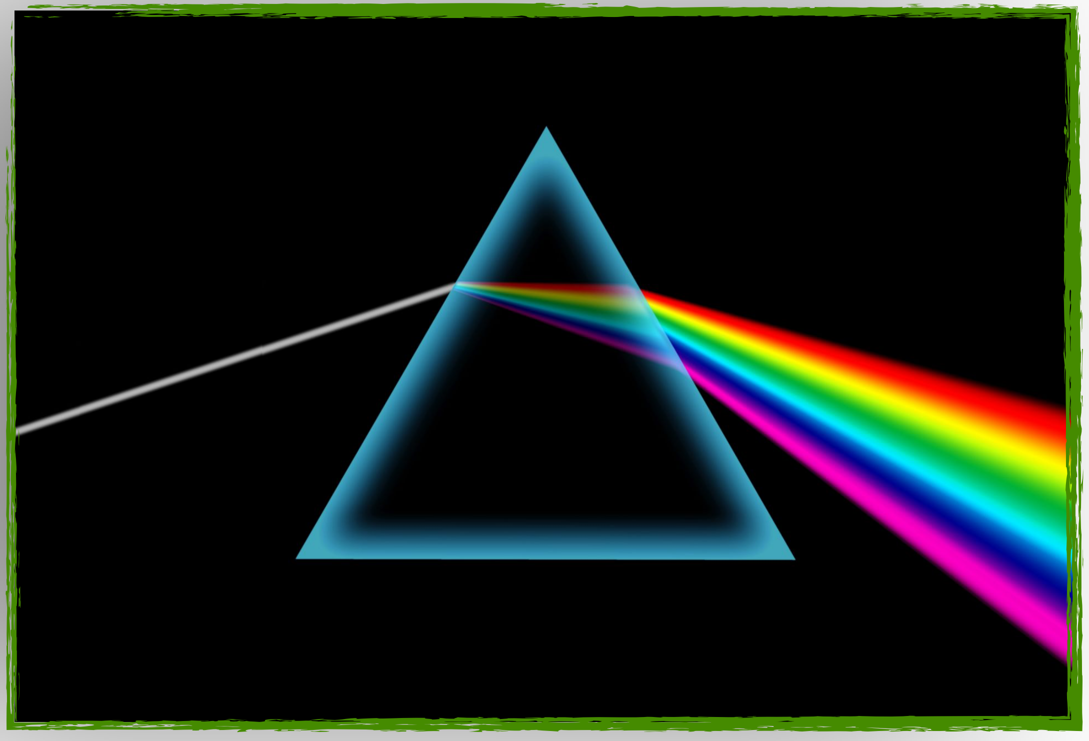
# Eletromagnetismo Avançado

1º ciclo
Aula de 22 setembro

# Ondas em meios lineares

$$\vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}} = 0 \qquad \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} = -\frac{\partial \vec{\mathbf{B}}}{\partial t}$$

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



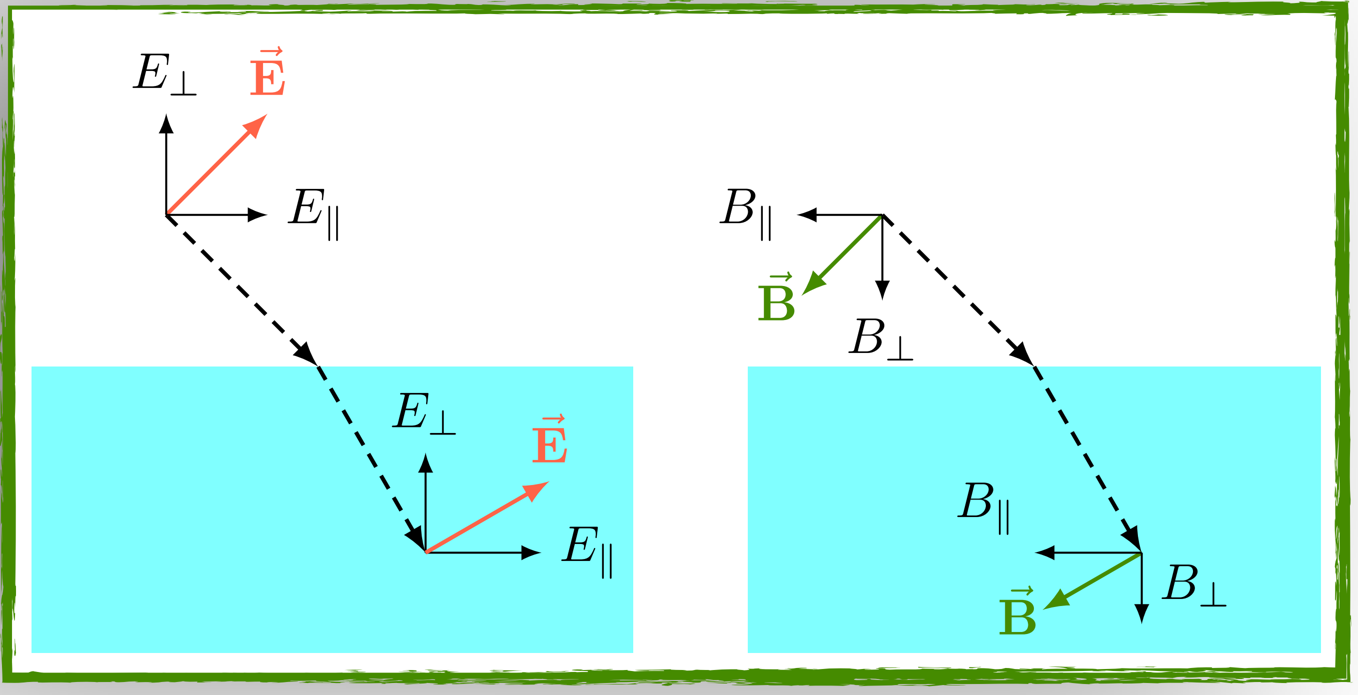
$$\nabla^2 \vec{\mathbf{E}} = \mu\epsilon\frac{\partial^2 \vec{\mathbf{E}}}{\partial t^2}$$

$$\nabla^2 \vec{\mathbf{B}} = \mu\epsilon\frac{\partial^2 \vec{\mathbf{B}}}{\partial t^2}$$

# Ondas em meios lineares

$$\vec{\nabla}\cdot\vec{\mathbf{D}}=0 \qquad \vec{\nabla}\times\vec{\mathbf{E}}=-\frac{\partial\vec{\mathbf{B}}}{\partial t}$$

$$\vec{\nabla}\cdot\vec{\mathbf{B}}=0 \qquad \vec{\nabla}\times\vec{\mathbf{H}}=\frac{\partial\vec{\mathbf{D}}}{\partial t}$$



# Ondas em meios lineares

$$\vec{\nabla} \cdot \vec{\mathbf{D}} = 0 \qquad \vec{\nabla} \times \vec{\mathbf{E}} = -\frac{\partial \vec{\mathbf{B}}}{\partial t}$$

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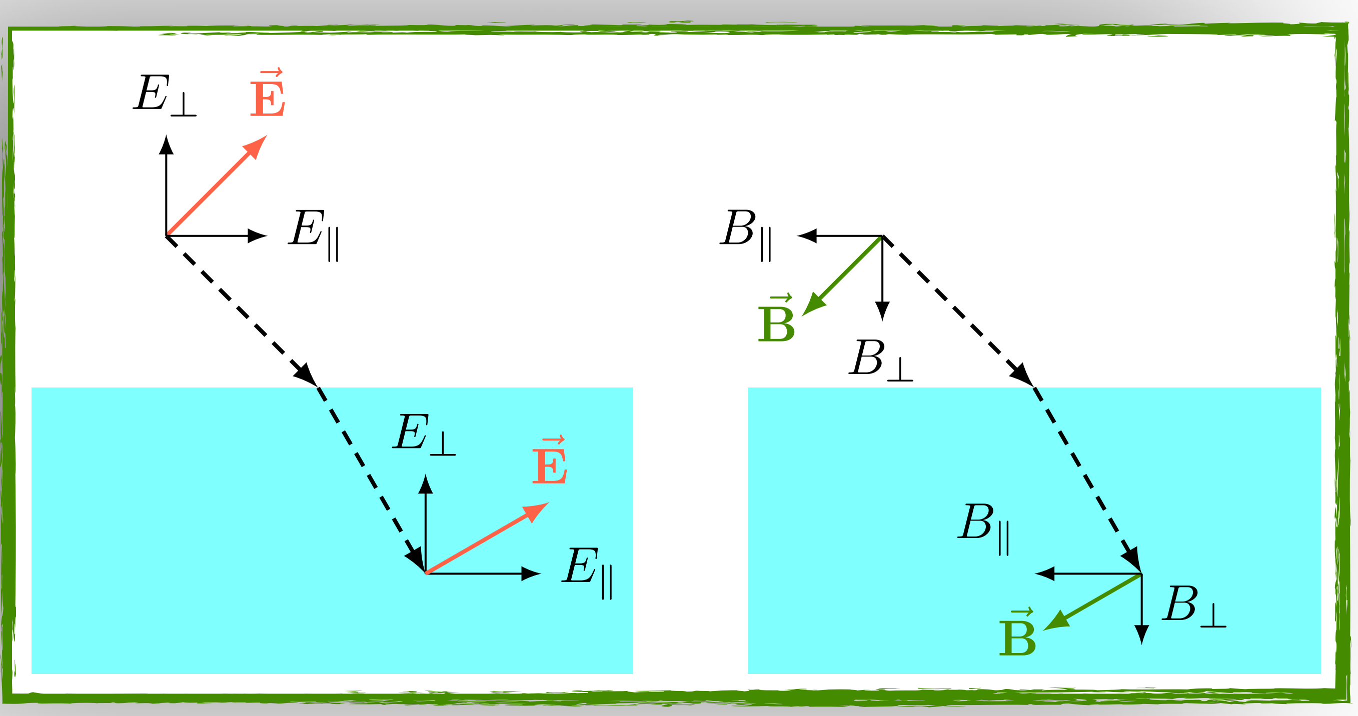


$$\epsilon_1 E_{1\perp} = \epsilon_2 E_{2\perp} \qquad B_{1\perp} = B_{2\perp}$$

$$E_{1\parallel} = E_{2\parallel} \qquad \frac{1}{\mu_1} B_{1\parallel} = \frac{1}{\mu_2} B_{2\parallel}$$

# Pratique o que aprendeu

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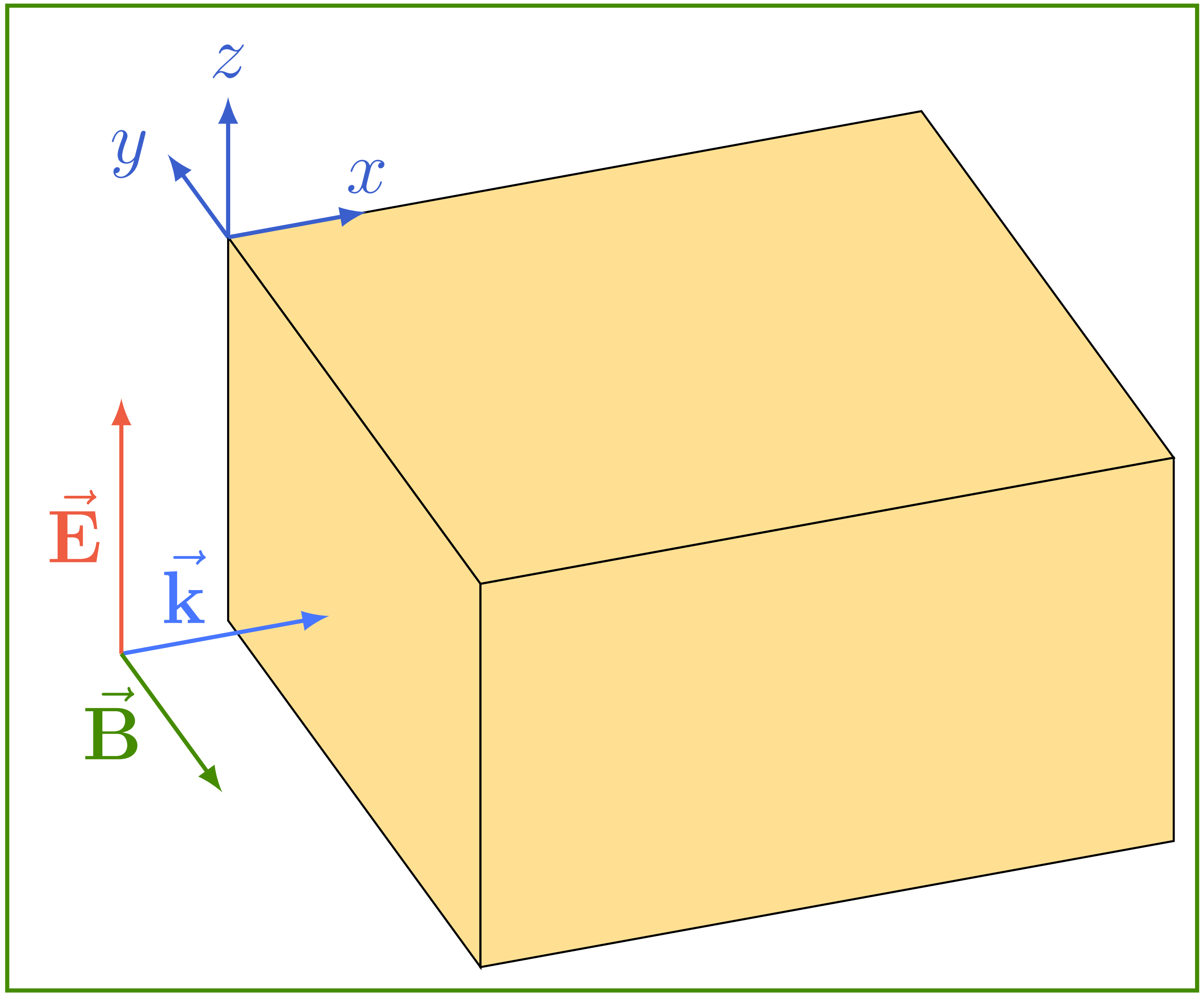

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$$\tilde{E}_I = \tilde{E}_0 e^{i(kx-\omega t)}$$

$$\tilde{E}_T = \tilde{E}_{0T} e^{i(qx-\omega t)}$$

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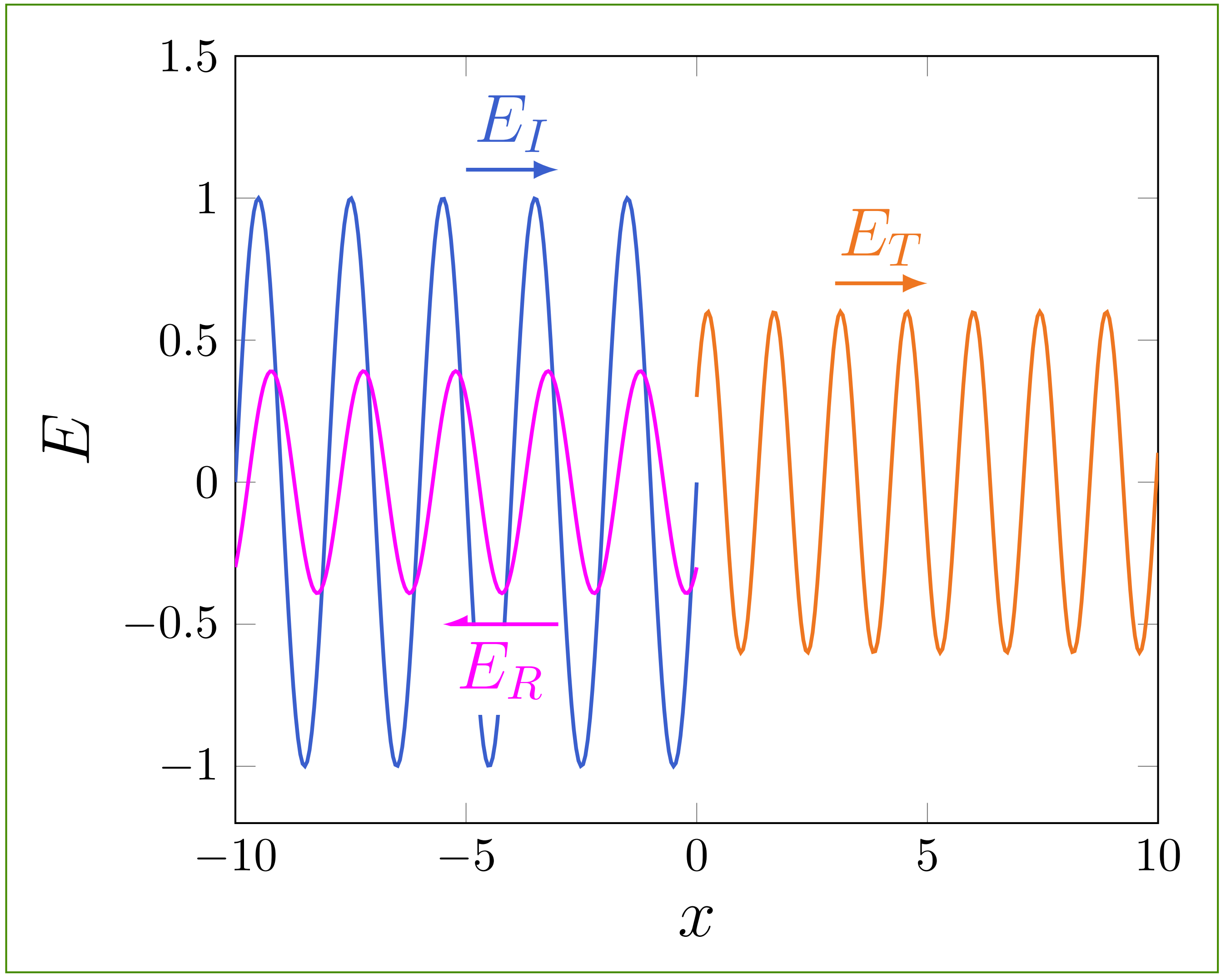

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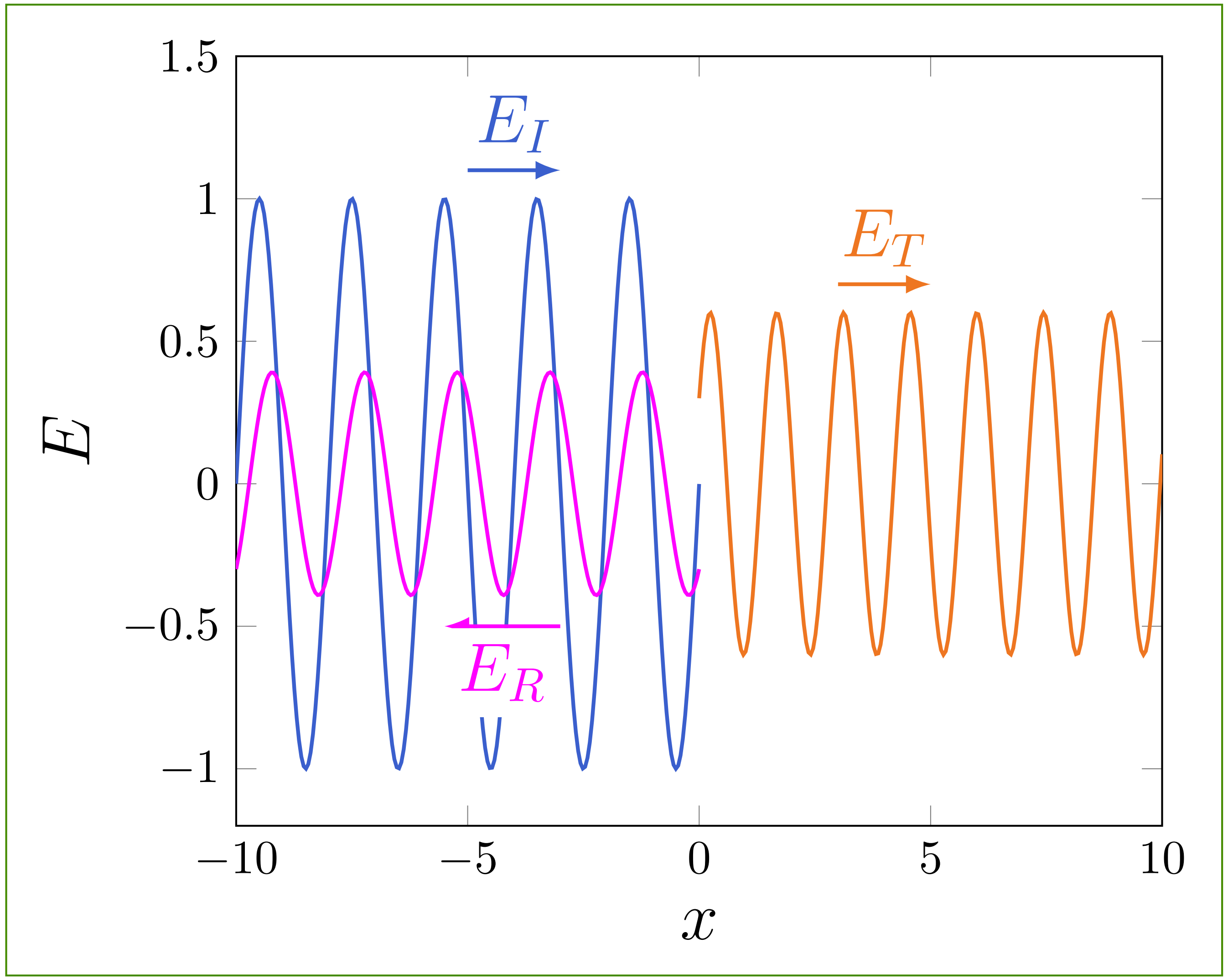


$$\tilde{E}_0 + \tilde{E}_{0R} = \tilde{E}_{0T}$$

# Pratique o que aprendeu

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$$\tilde{B}_T = \frac{n\tilde{E}_{0T}}{c} e^{i(qx-\omega t)}$$

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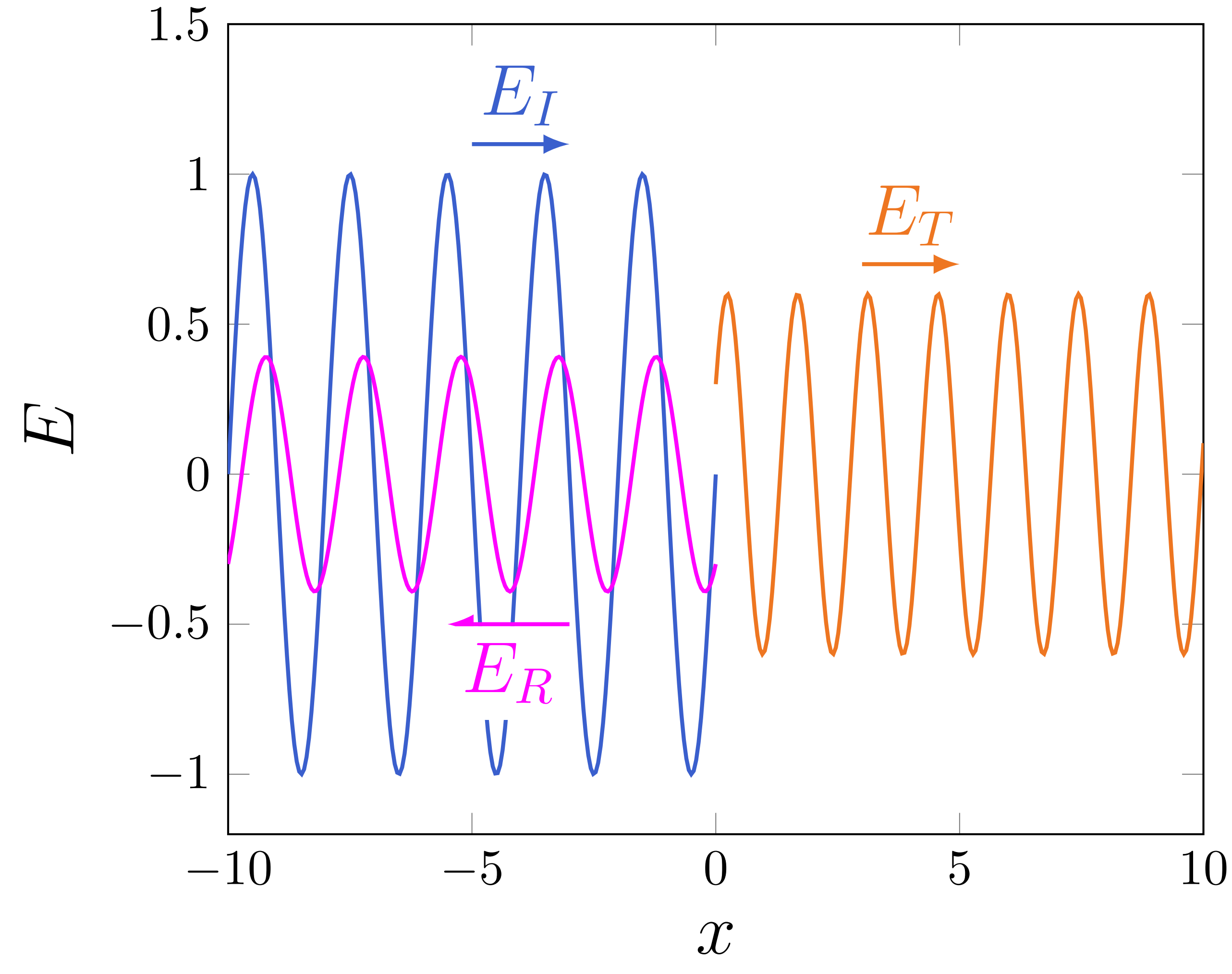


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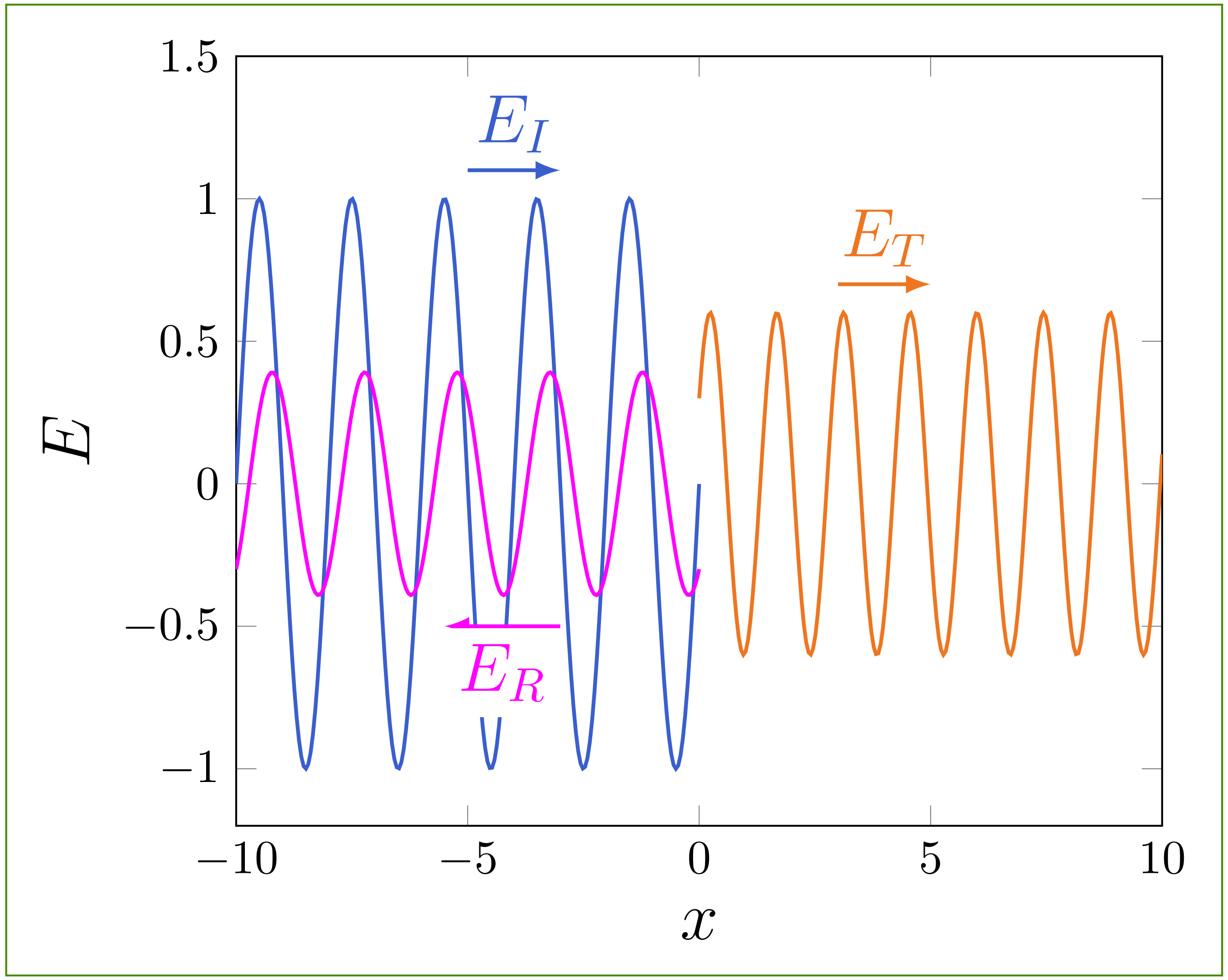


$$\tilde{E}_0 + \tilde{E}_{0R} = \tilde{E}_{0T}$$

$$\tilde{E}_0 - \tilde{E}_{0R} = \frac{n\mu_0}{\mu} \tilde{E}_{0T}$$

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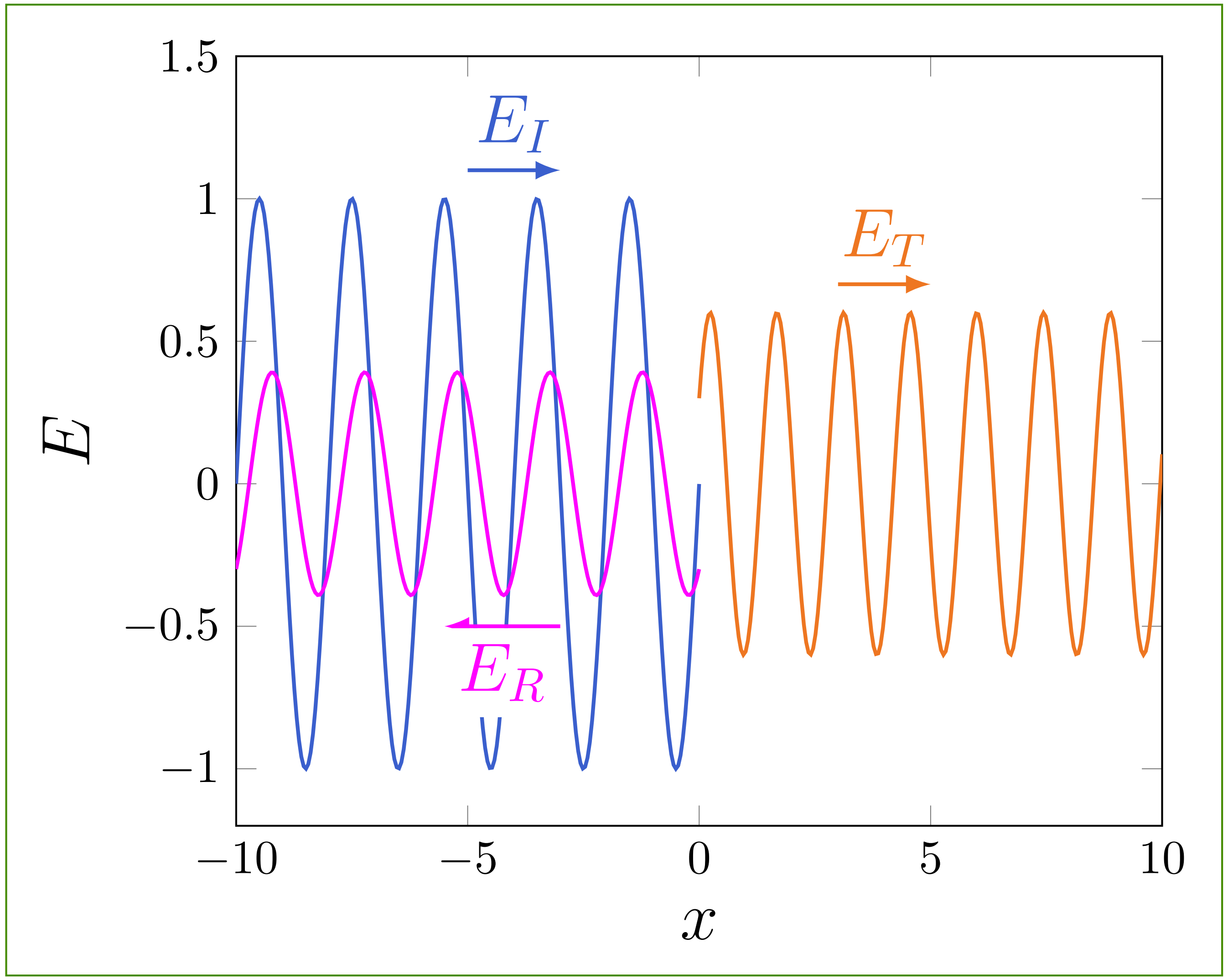


$$\tilde{E}_0 + \tilde{E}_{0R} = \tilde{E}_{0T}$$

$$\tilde{E}_0 - \tilde{E}_{0R} = n\tilde{E}_{0T}$$

$$n \approx \sqrt{\frac{\epsilon}{\epsilon_0}}$$

# Pratique o que aprendeu

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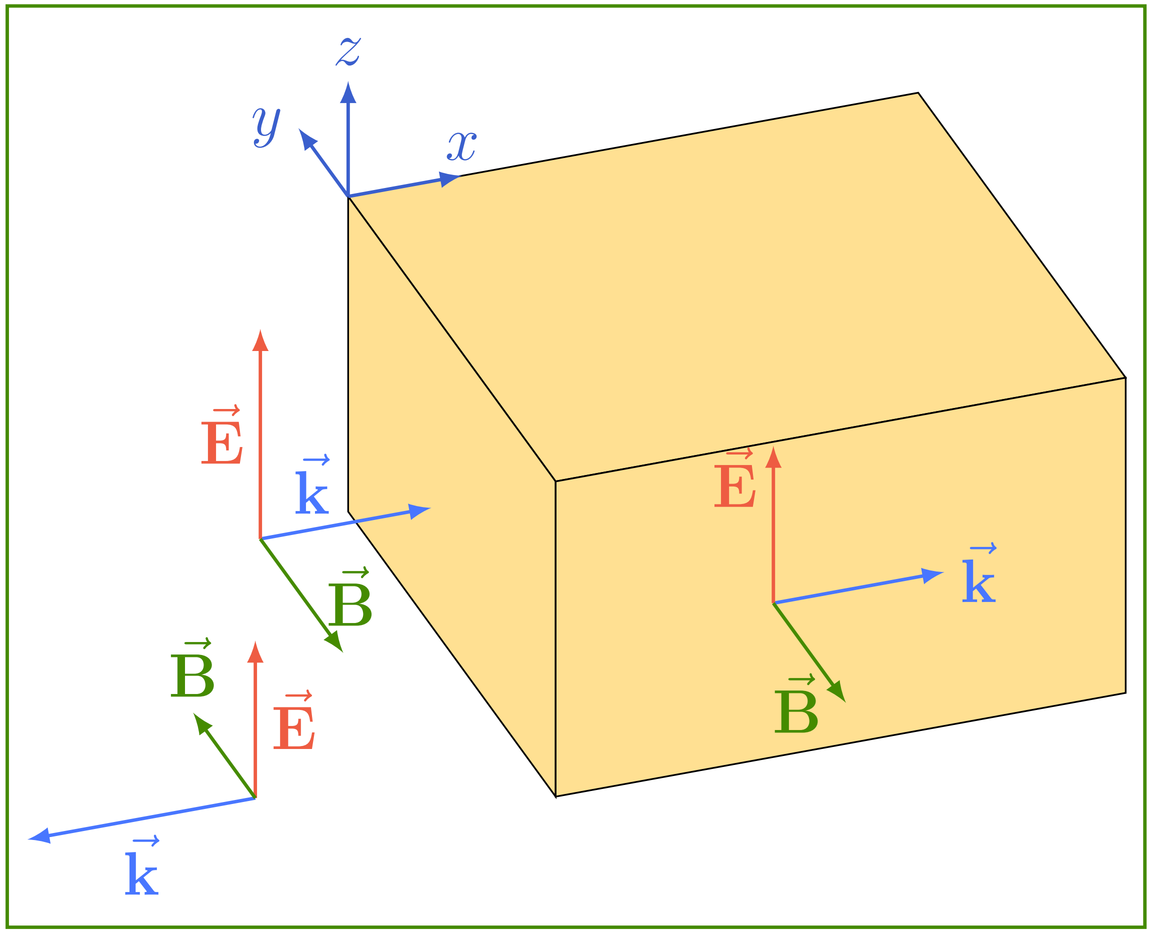

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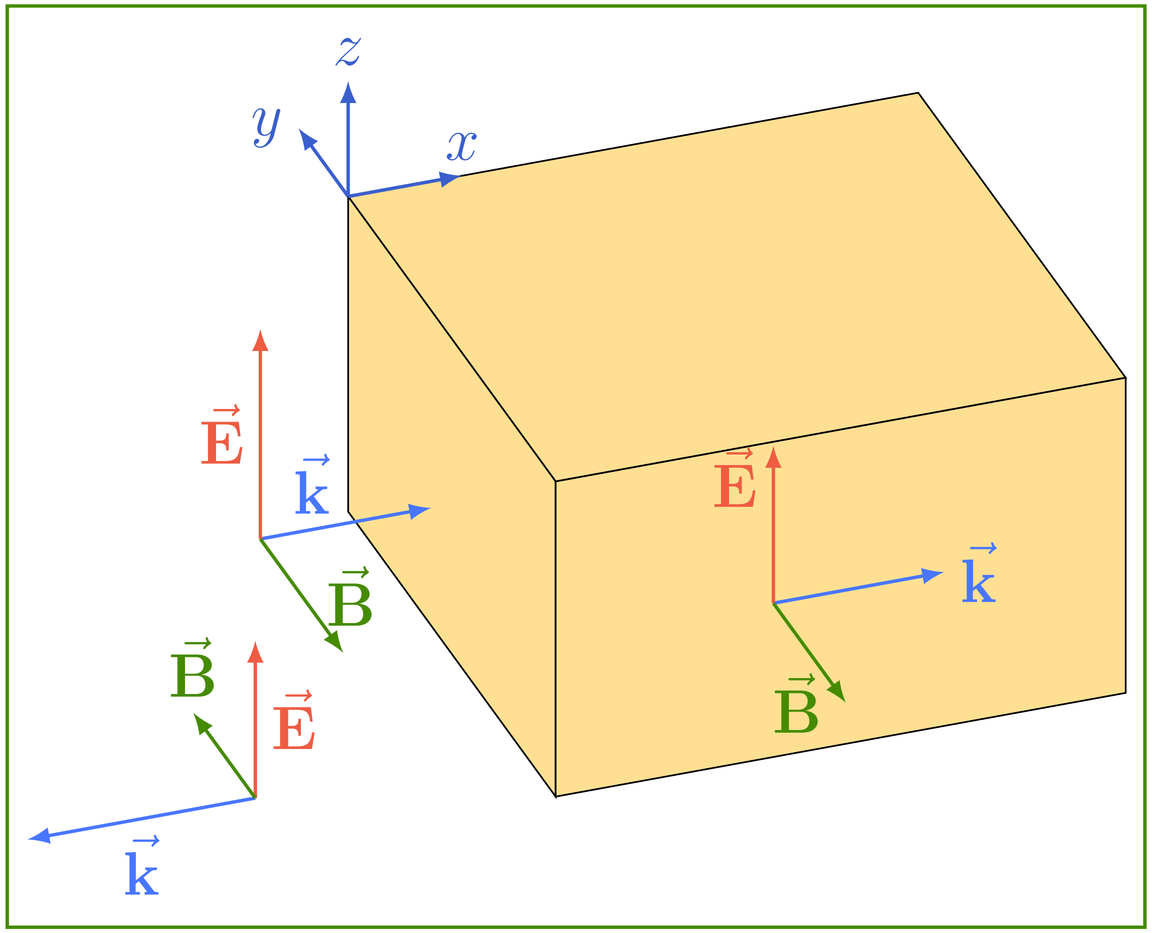
$$\tilde{E}_0 + \tilde{E}_{0R} = \tilde{E}_{0T}$$

$$\tilde{E}_0 - \tilde{E}_{0R} = n\tilde{E}_{0T}$$

$$\tilde{E}_{0T} = \frac{2}{1+n}\tilde{E}_0$$



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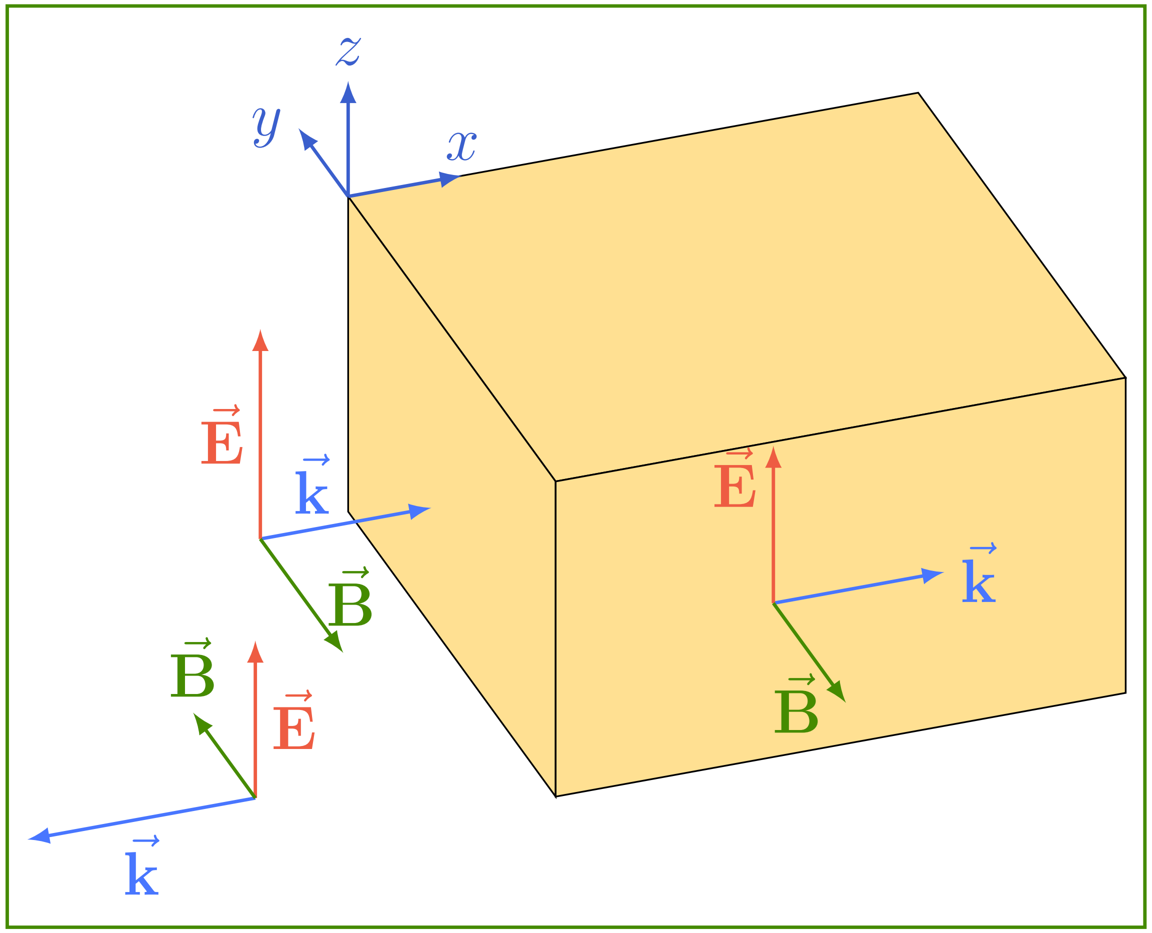


$$\tilde{E}_{0T} = \frac{2}{1+n}\tilde{E}_0$$

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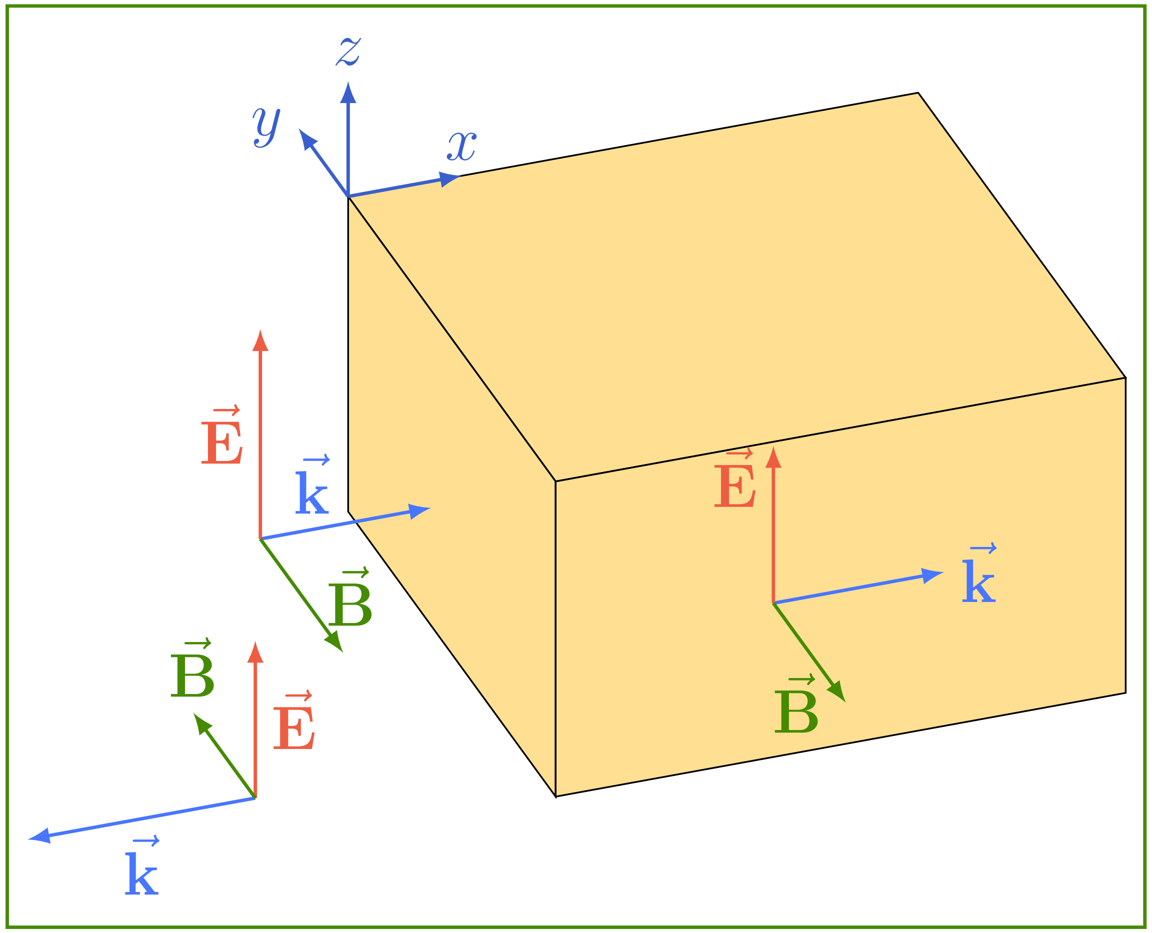
$$I = \frac{1}{2} v \epsilon E_0^2$$



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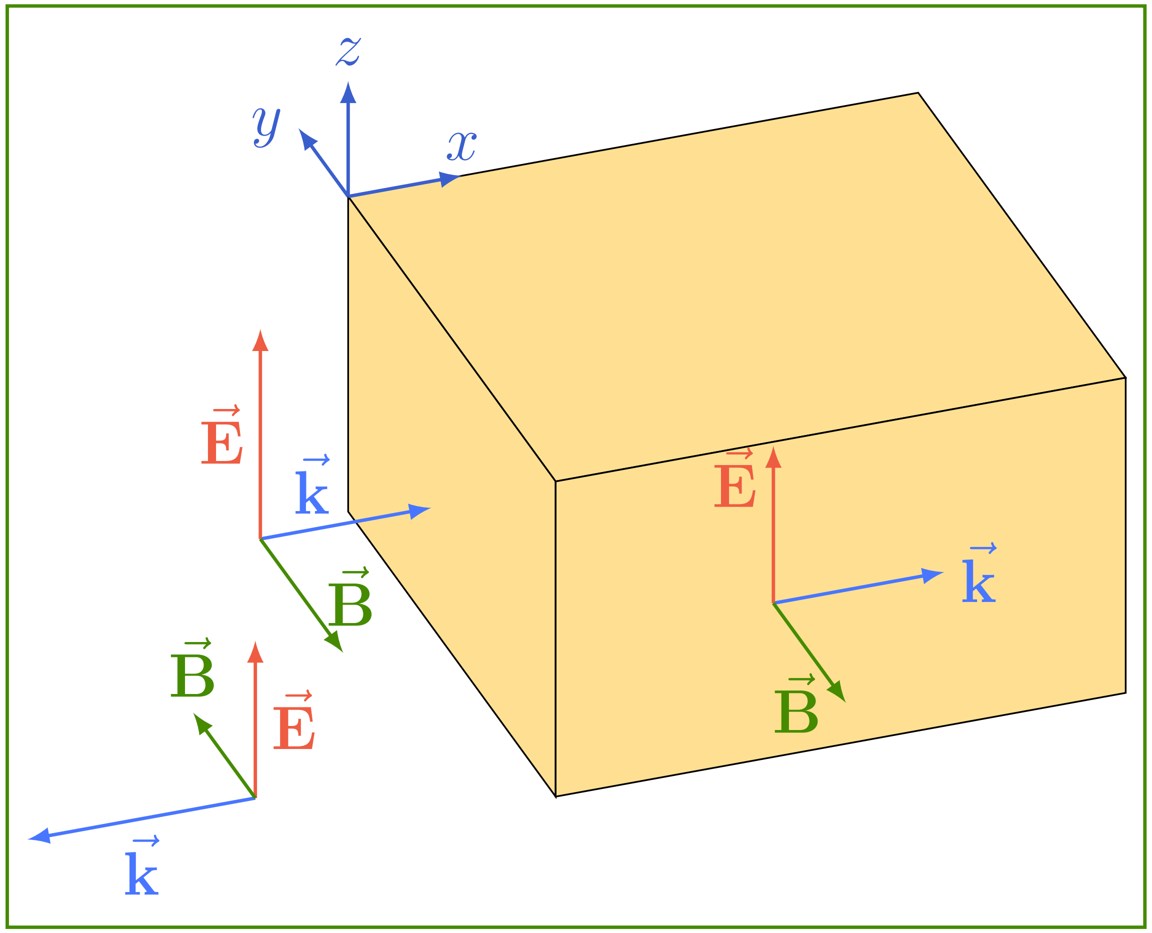

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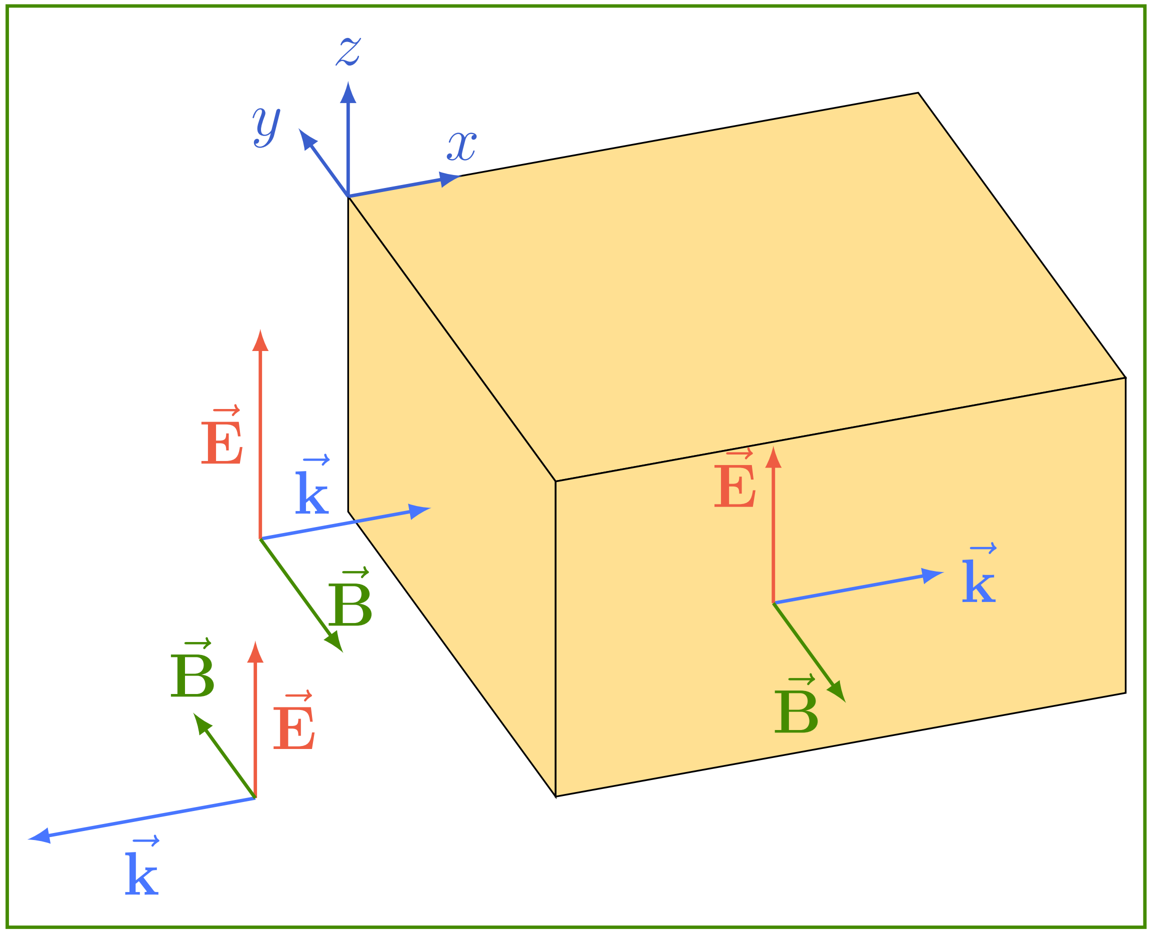
$$I_R = \left(\frac{1-n}{1+n}\right)^2 I_0$$



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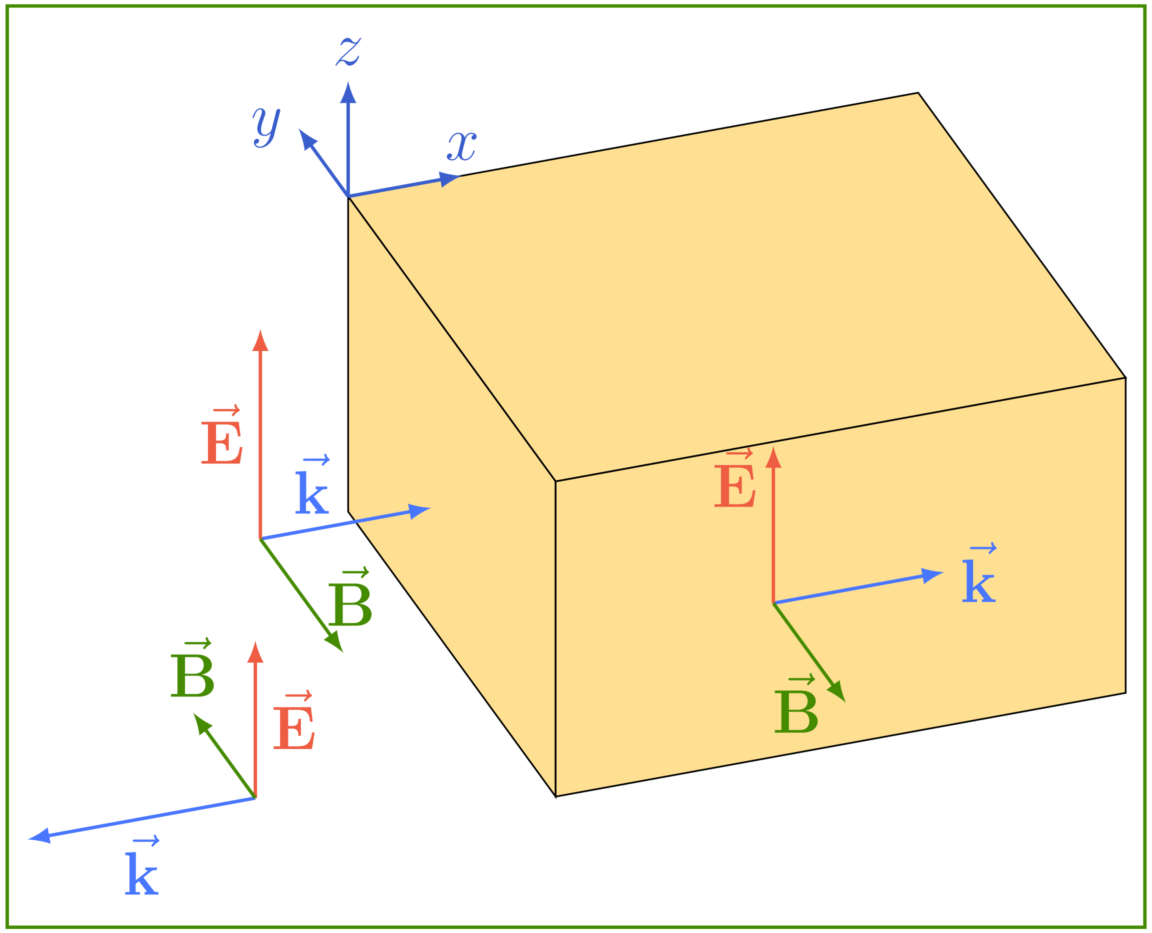


$$I = \frac{1}{2} v \epsilon E_0^2 = n \frac{1}{2} c \epsilon_0 E_0^2$$

$$I_R = \left(\frac{1-n}{1+n}\right)^2 I_0$$

$$I_T = \frac{4n}{(1+n)^2} I_0$$

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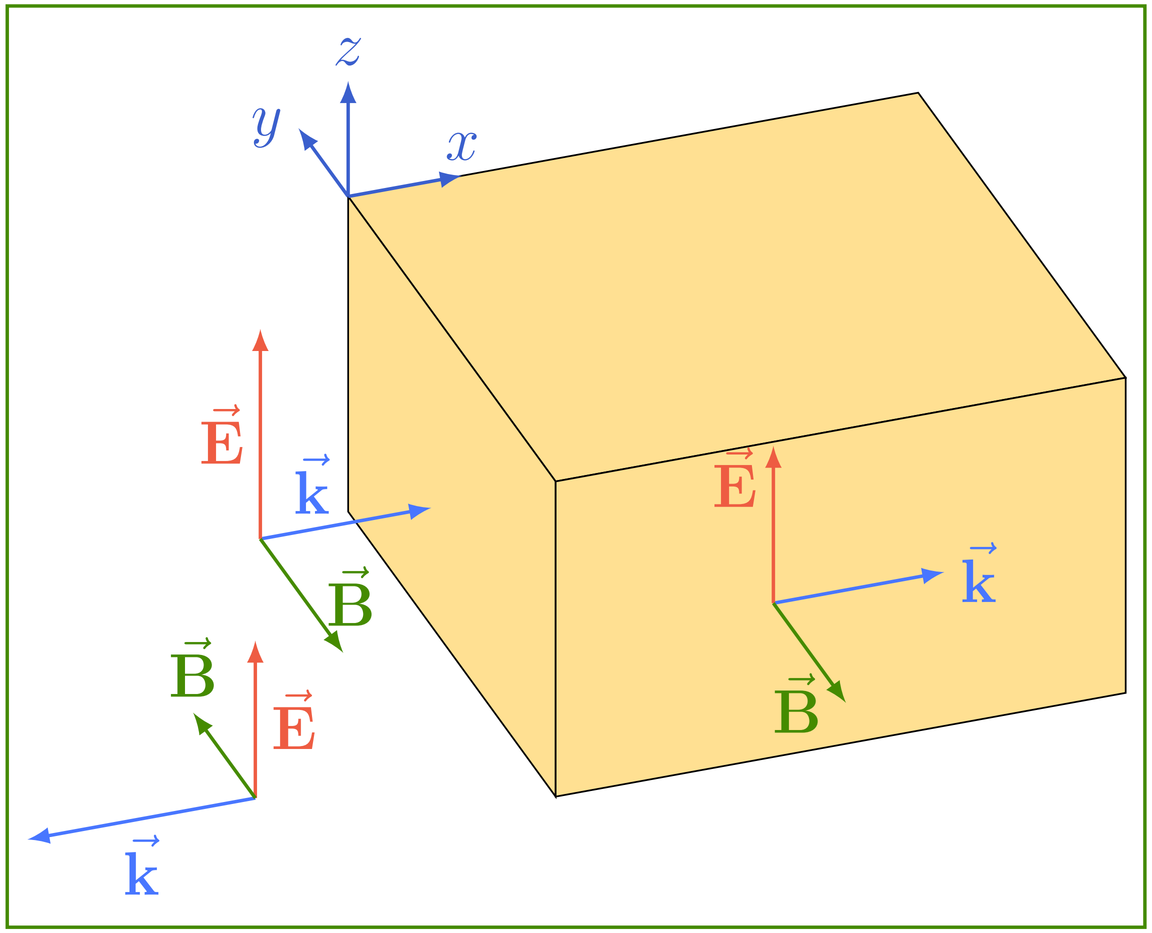
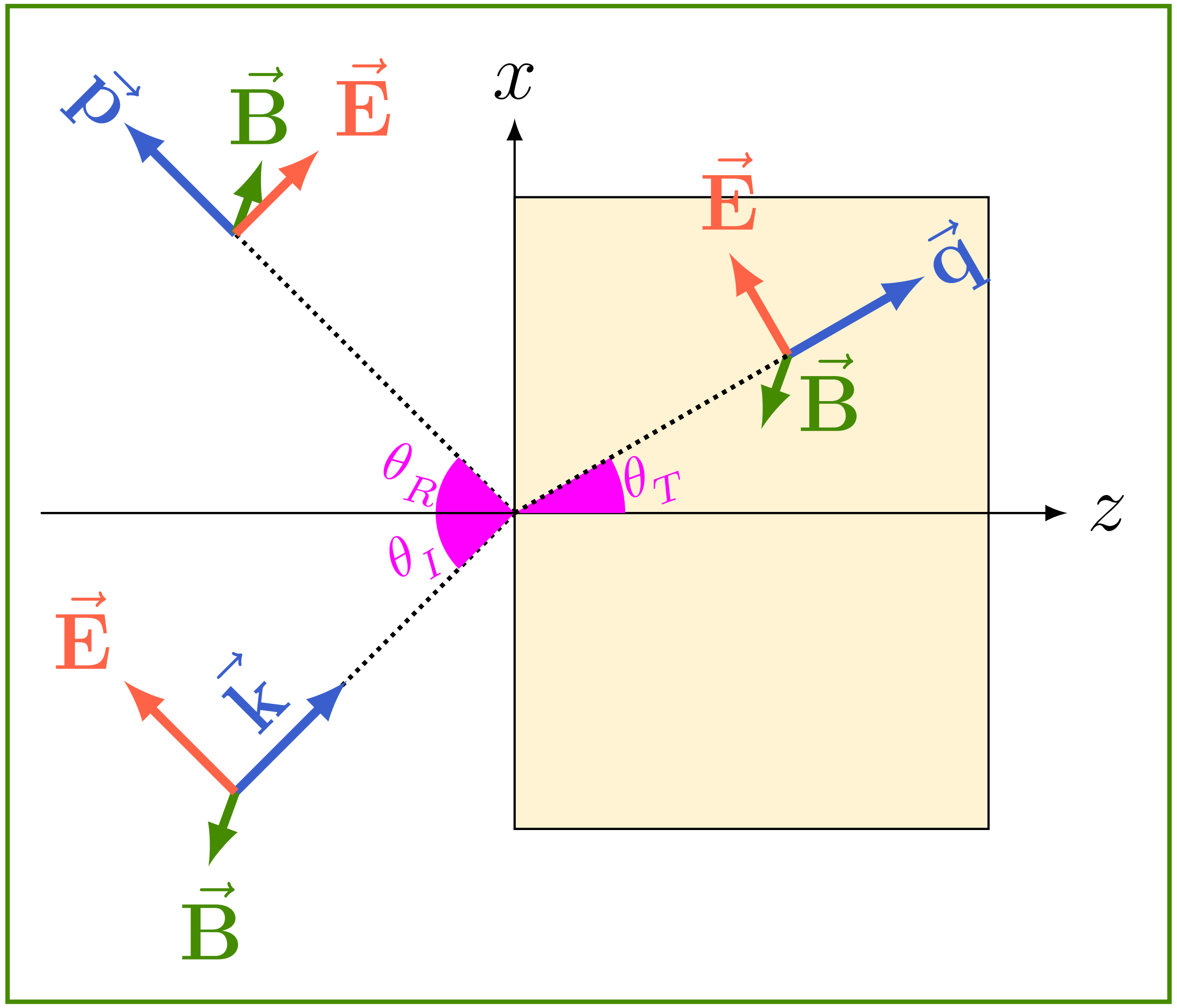
$$I_T + I_R = I_0$$



# Incidência oblíqua

$$\tilde{\mathbf{E}}_I = \tilde{\mathbf{E}}_{\mathbf{0I}} e^{i(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}}-\omega t)}$$



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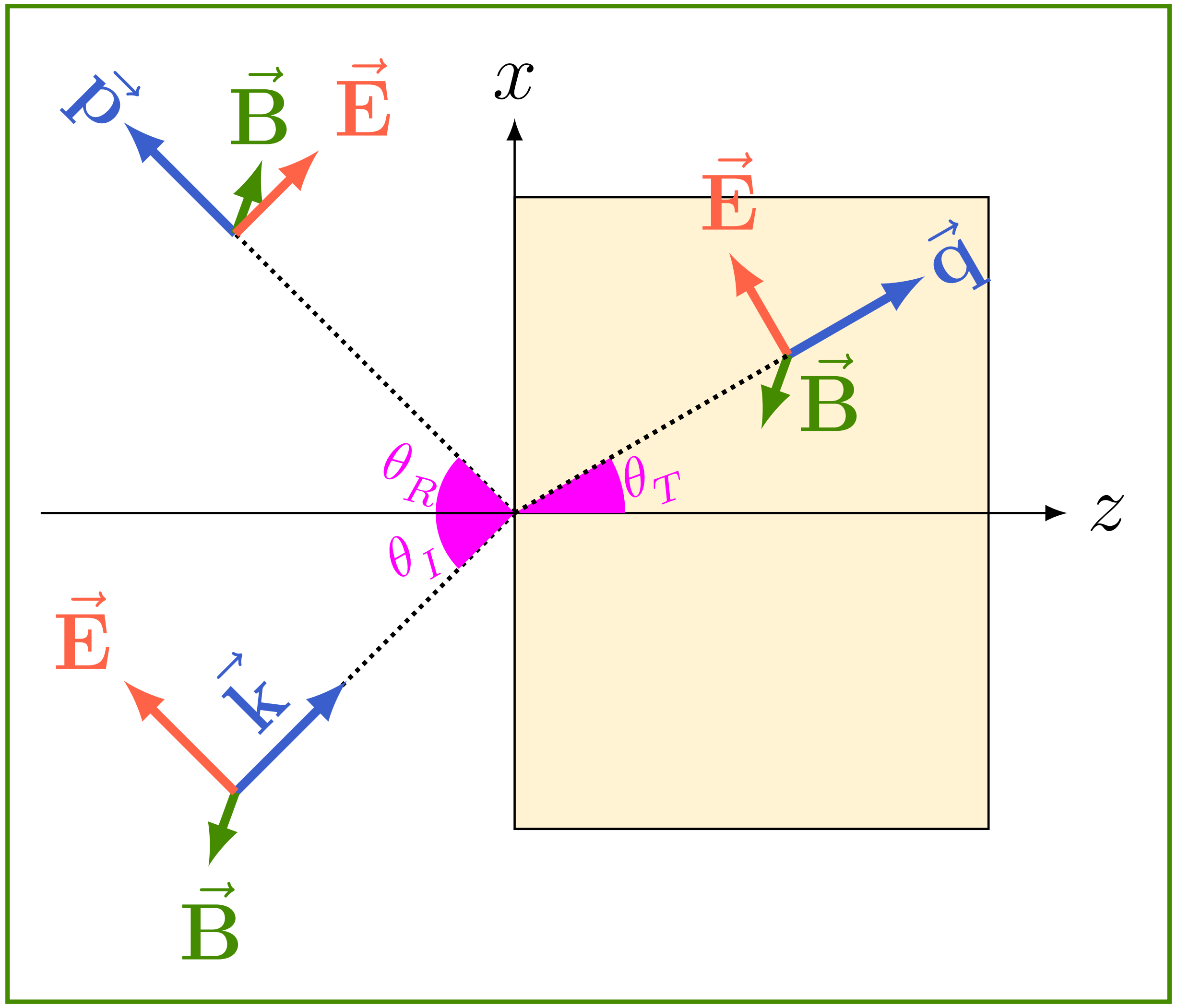

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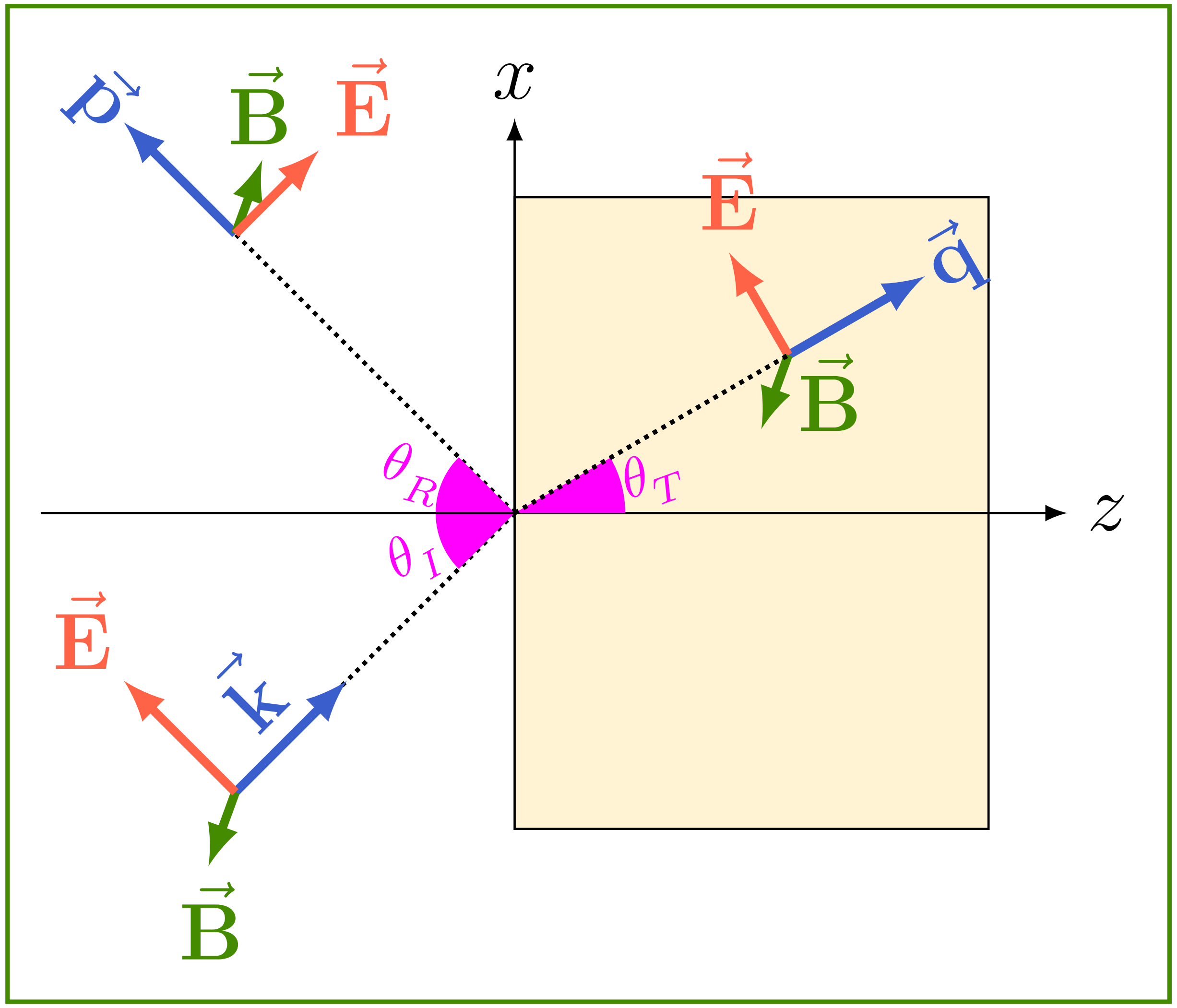
$$kc = pc = q\frac{c}{n}$$



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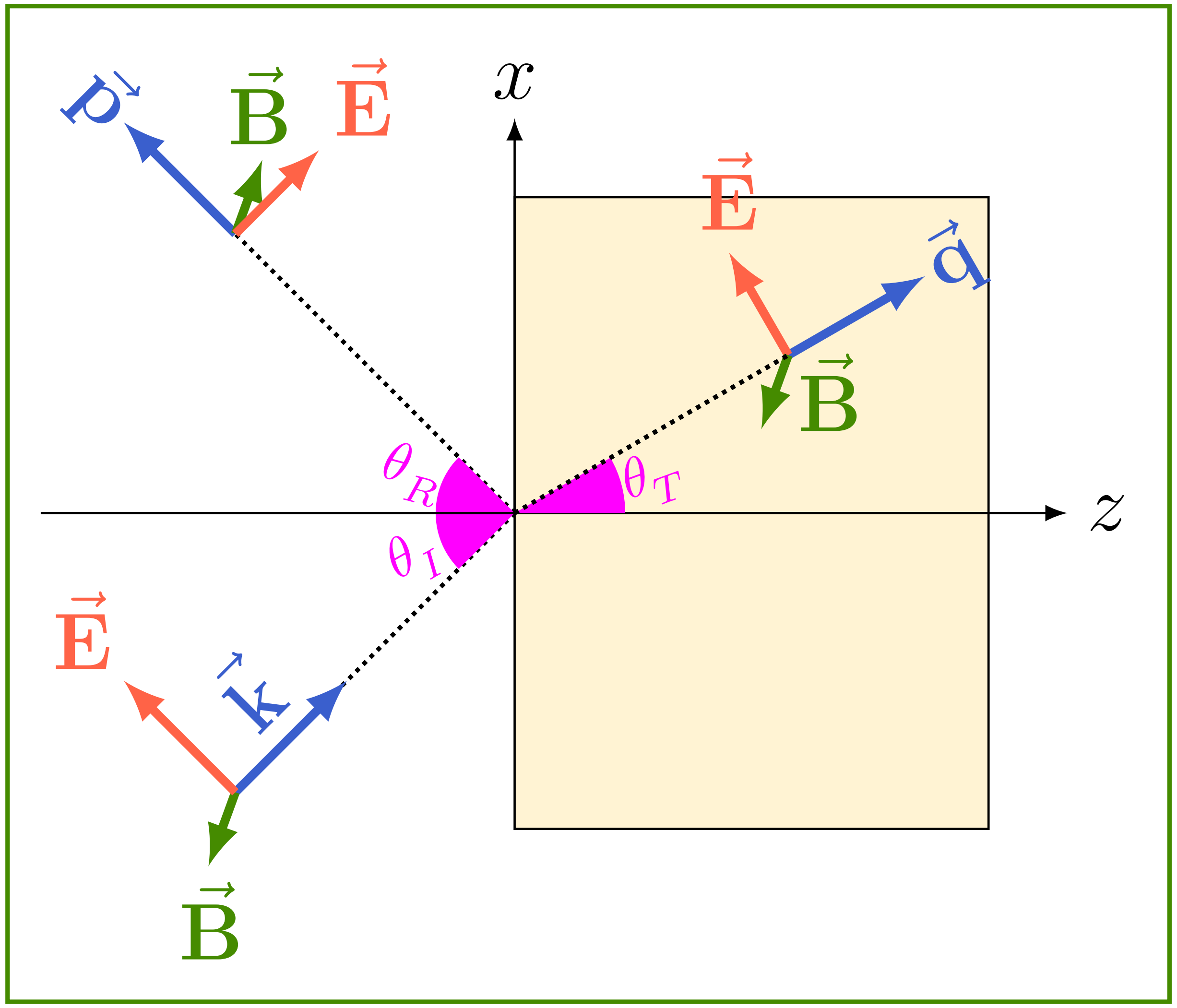


$$k = p = \frac{q}{n}$$

$$k_x x = p_x x = q_x x$$

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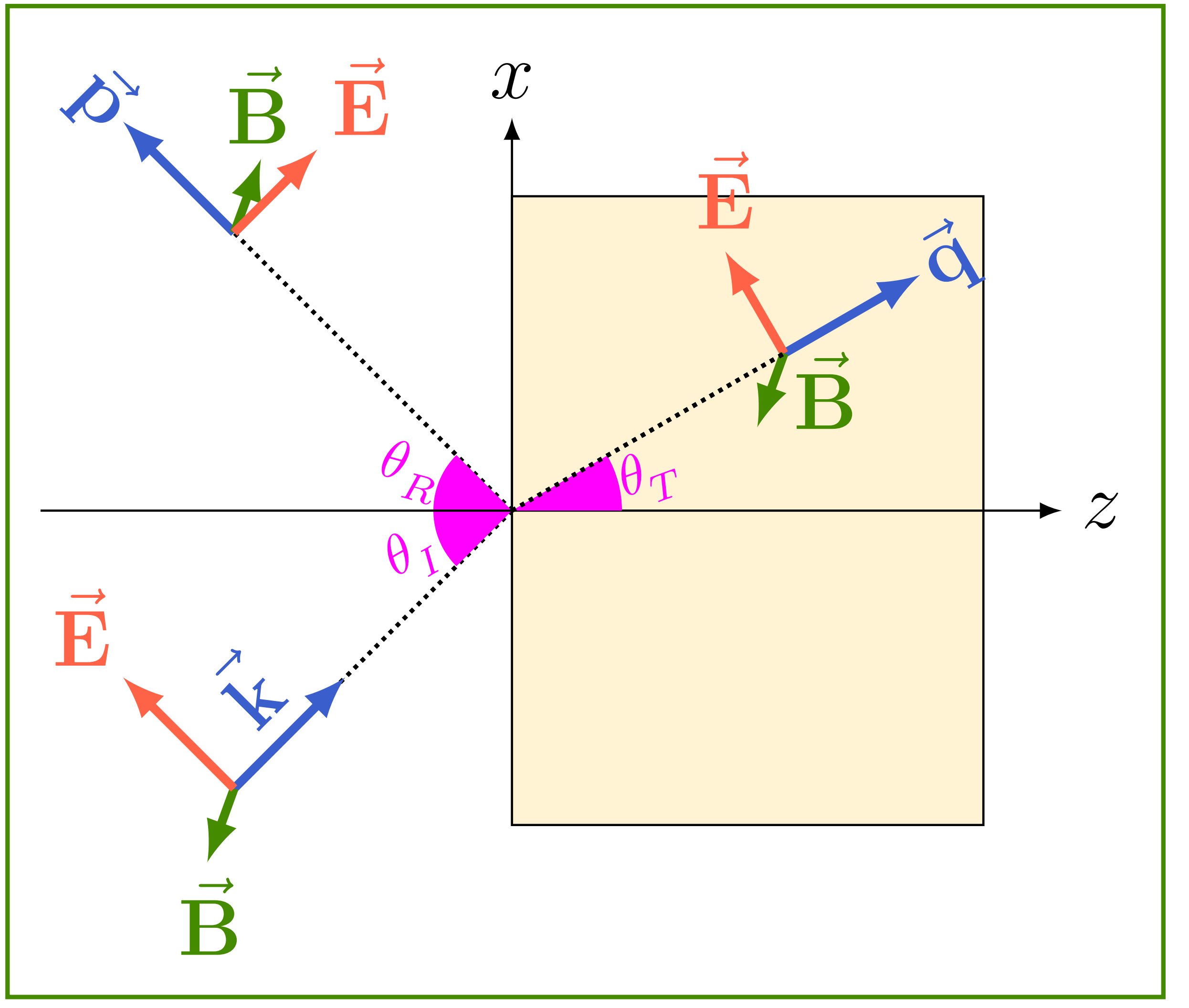


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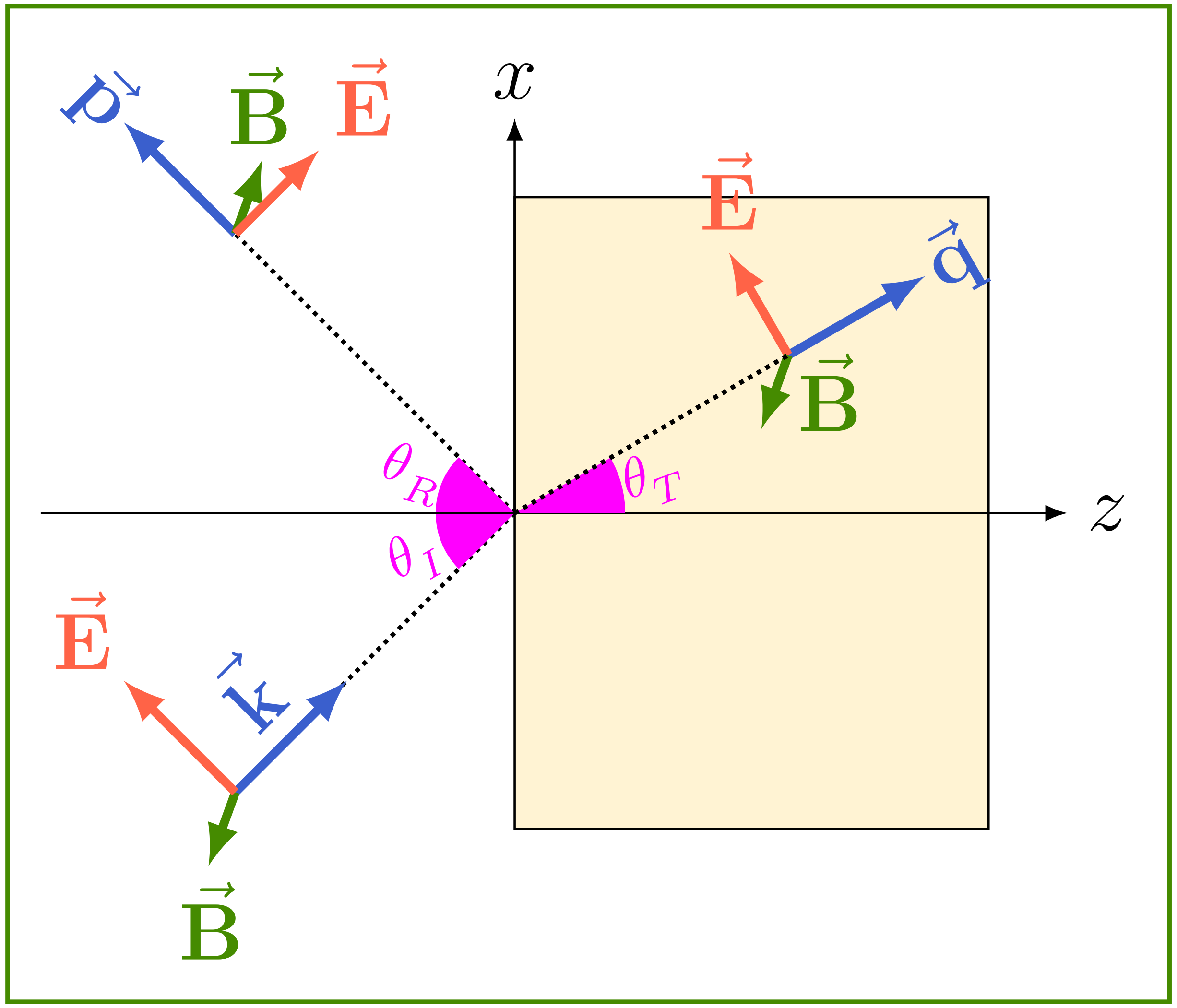
$$k = p = \frac{q}{n}$$

$$k_x = p_x = q_x$$

$$\theta_I = \theta_R$$

$$\sin\theta_I = n\sin\theta_T$$



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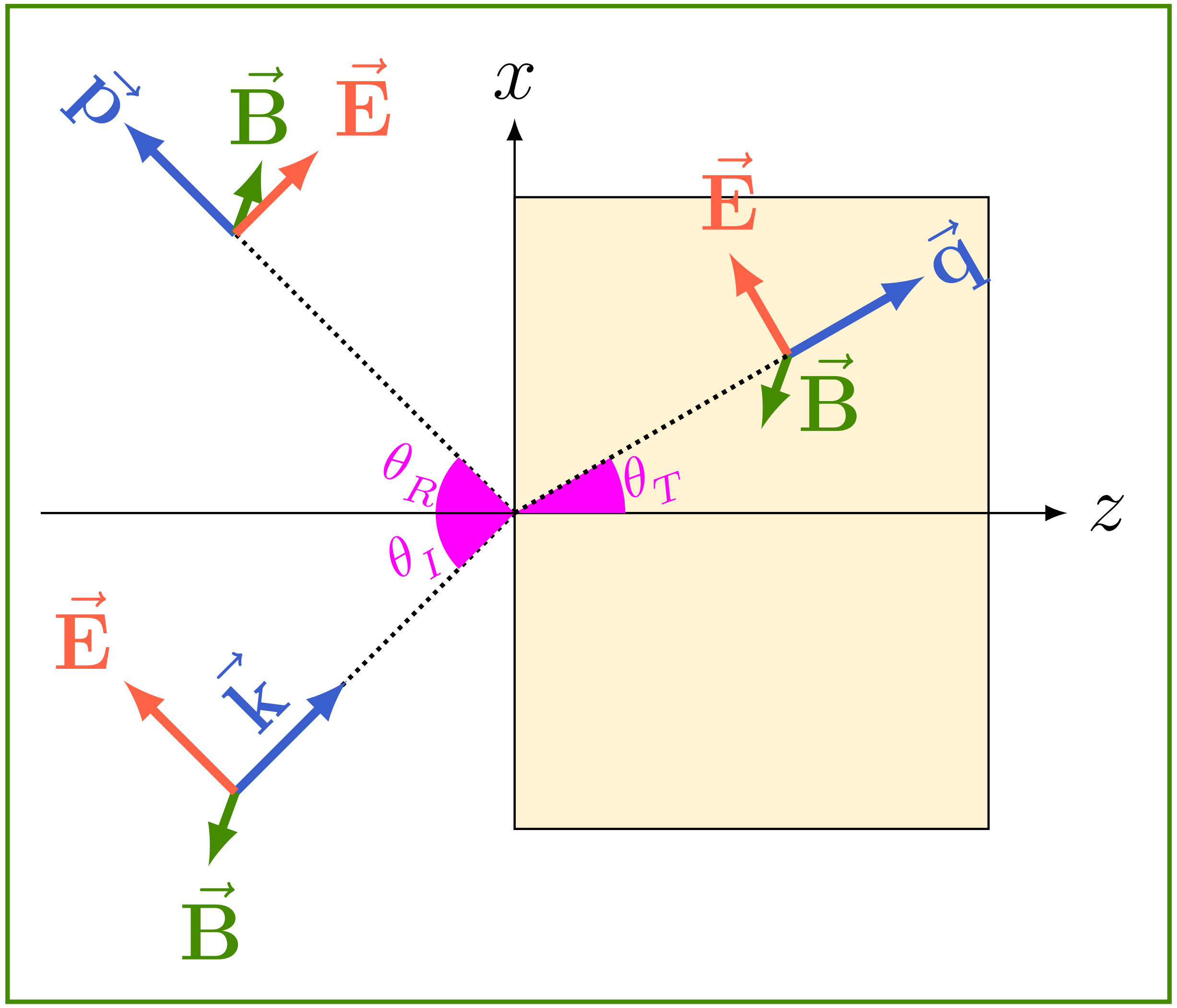


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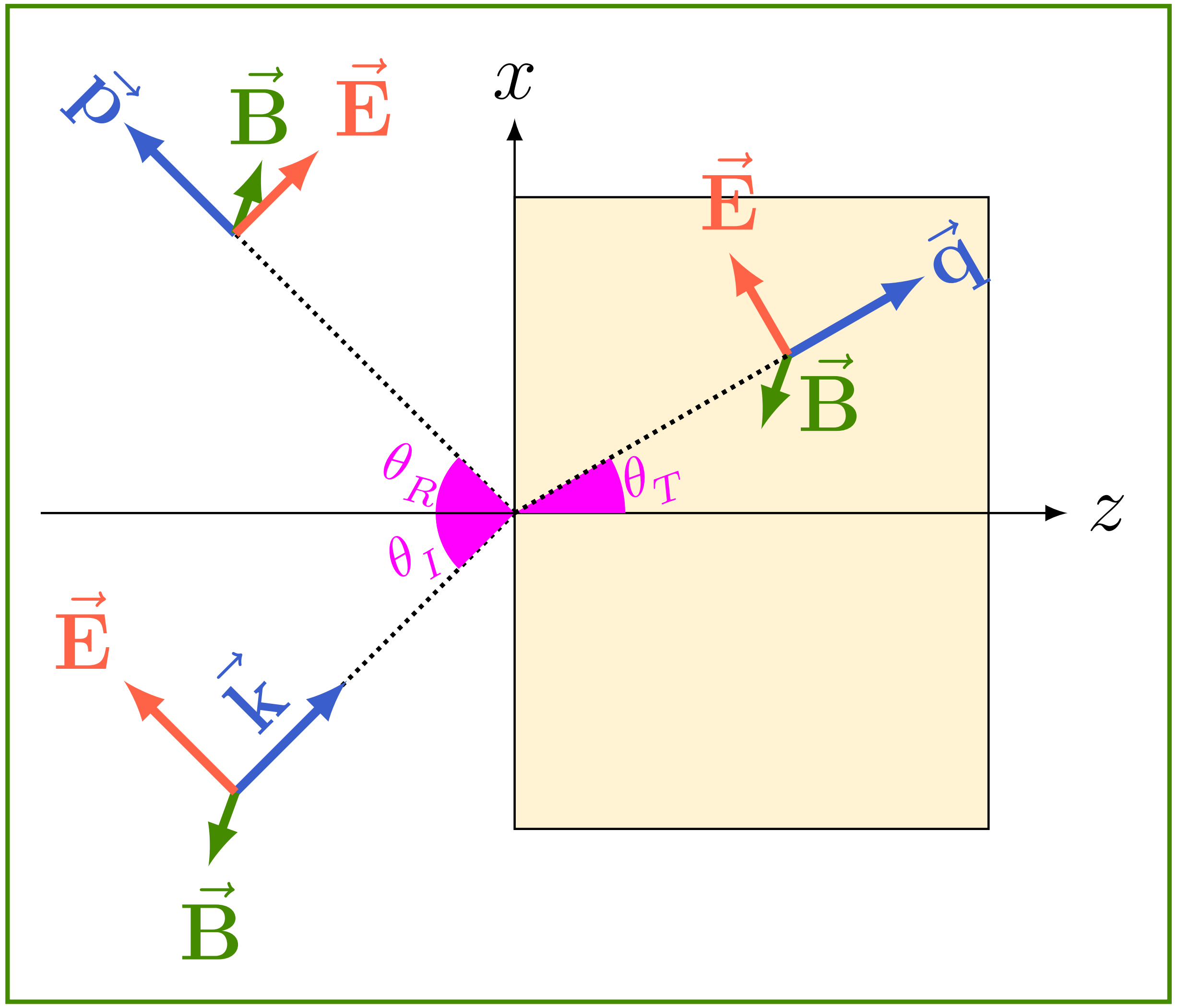
$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$

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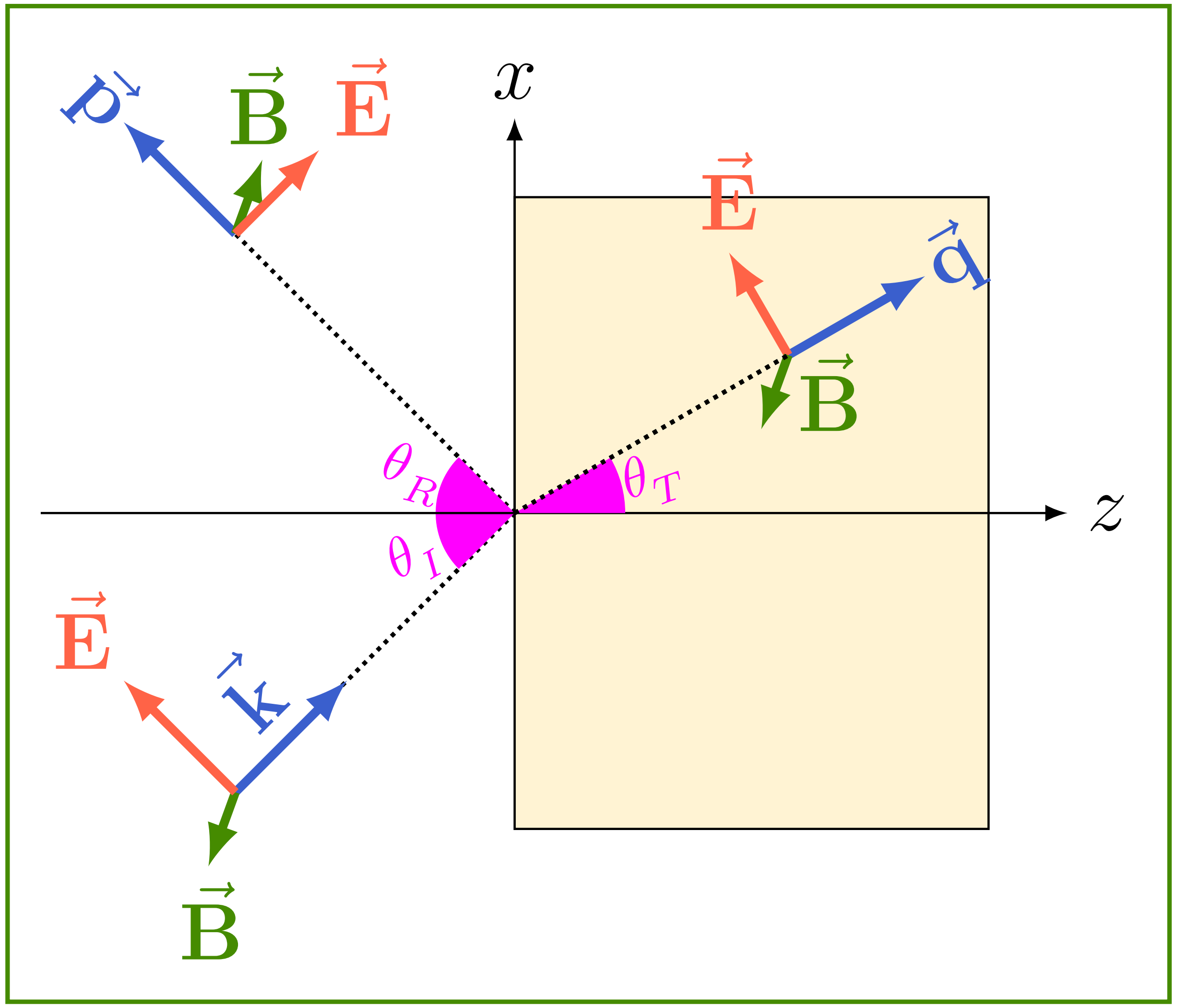


$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$

$$\tilde{E}_{0x} + \tilde{E}_{0Rx} = \tilde{E}_{0Tx}$$

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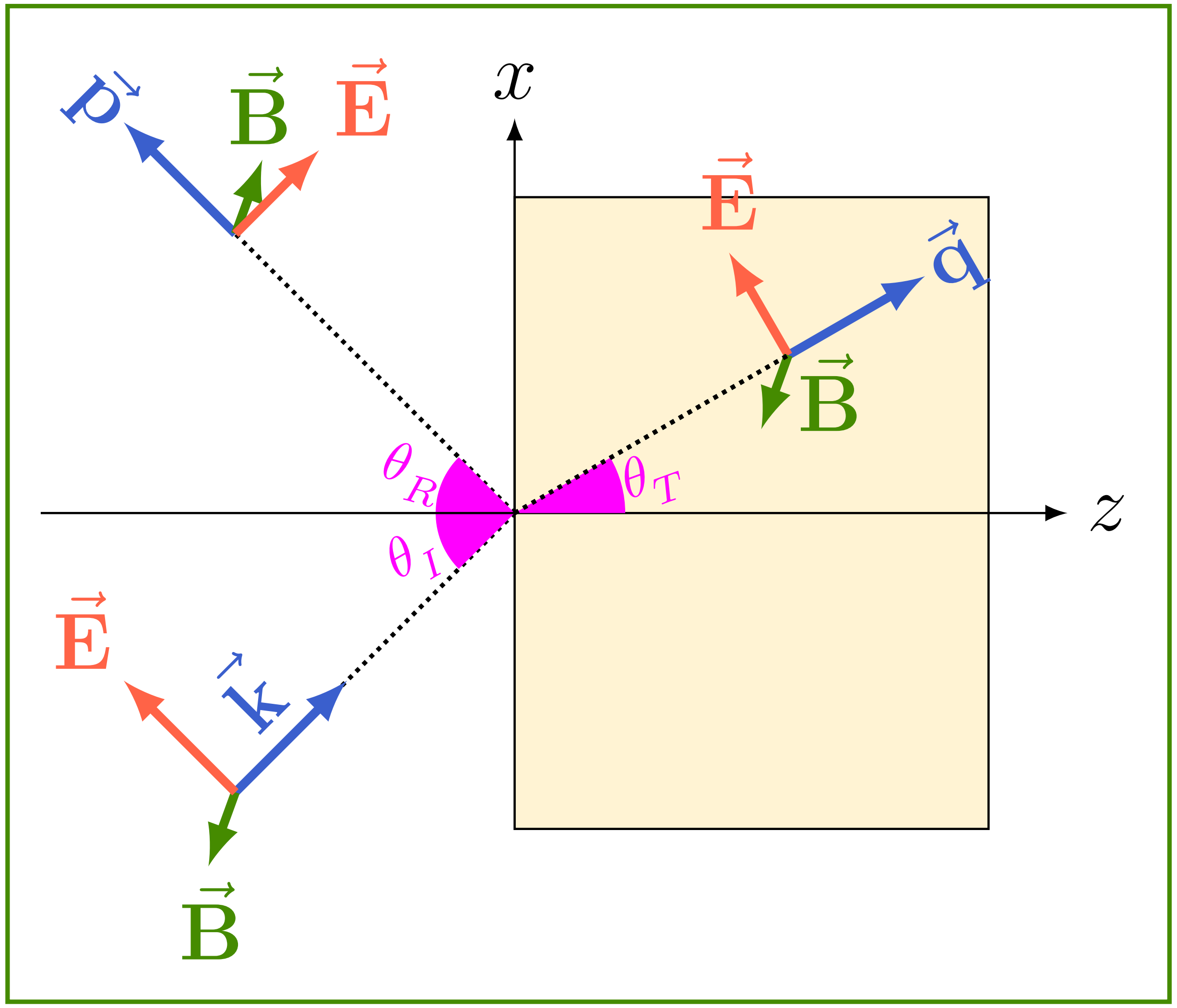
$$\tilde{\mathbf{E}}_T = \tilde{\mathbf{E}}_{\mathbf{0T}} e^{i(\vec{\mathbf{q}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_R = \tilde{\mathbf{E}}_{\mathbf{0R}} e^{i(\vec{\mathbf{p}}\cdot\vec{\mathbf{r}}-\omega t)}$$




$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$

$$\tilde{E}_{0x} + \tilde{E}_{0Rx} = \tilde{E}_{0Tx}$$

$$-E_0 \sin\theta + E_{0R} \sin\theta = n^2 E_{0T} \sin\theta_T$$

# Incidência oblíqua

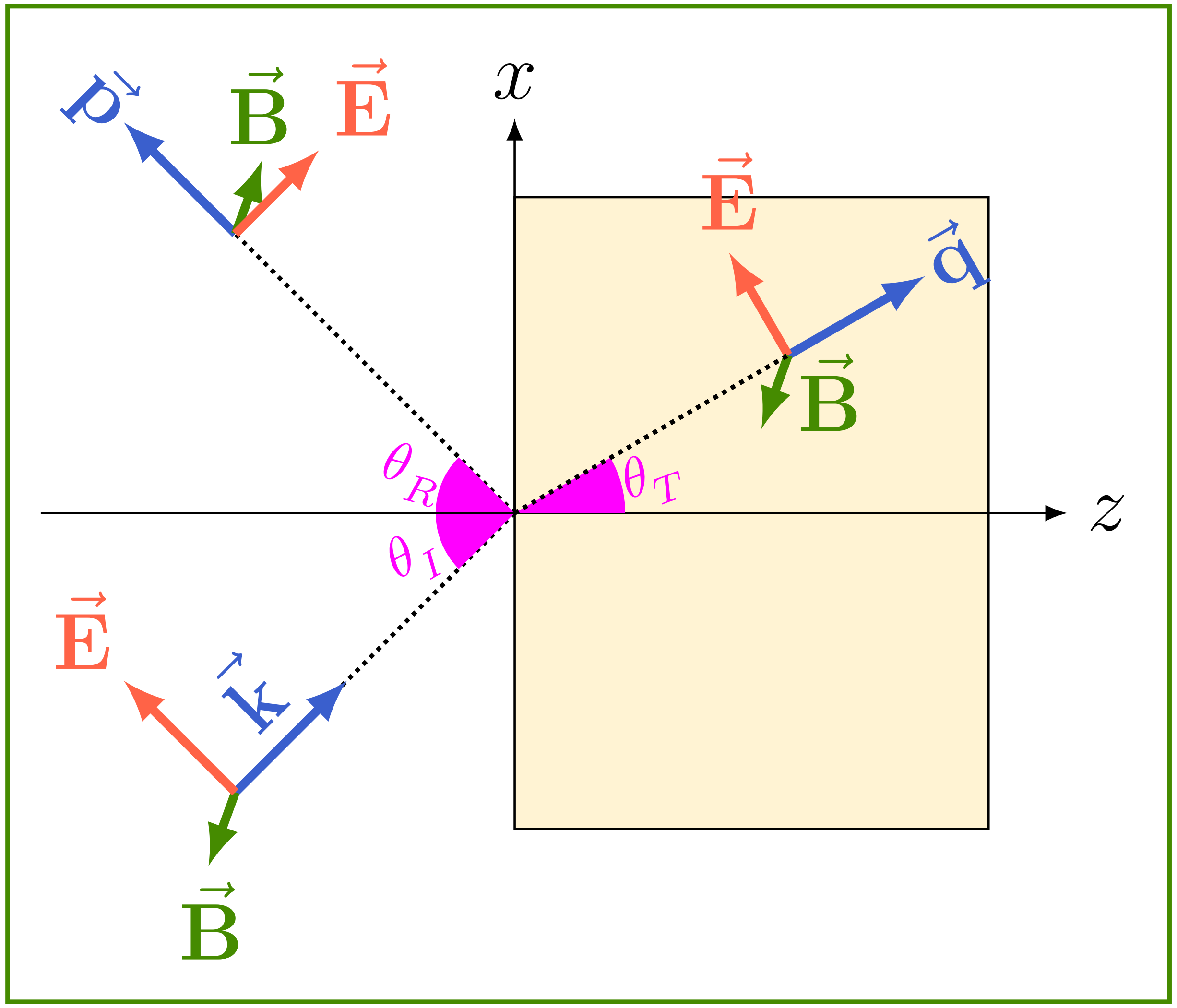
$$\tilde{\mathbf{E}}_I = \tilde{\mathbf{E}}_{\mathbf{0I}} e^{i(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_T = \tilde{\mathbf{E}}_{\mathbf{0T}} e^{i(\vec{\mathbf{q}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_R = \tilde{\mathbf{E}}_{\mathbf{0R}} e^{i(\vec{\mathbf{p}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$

$$\tilde{E}_{0x} + \tilde{E}_{0Rx} = \tilde{E}_{0Tx}$$



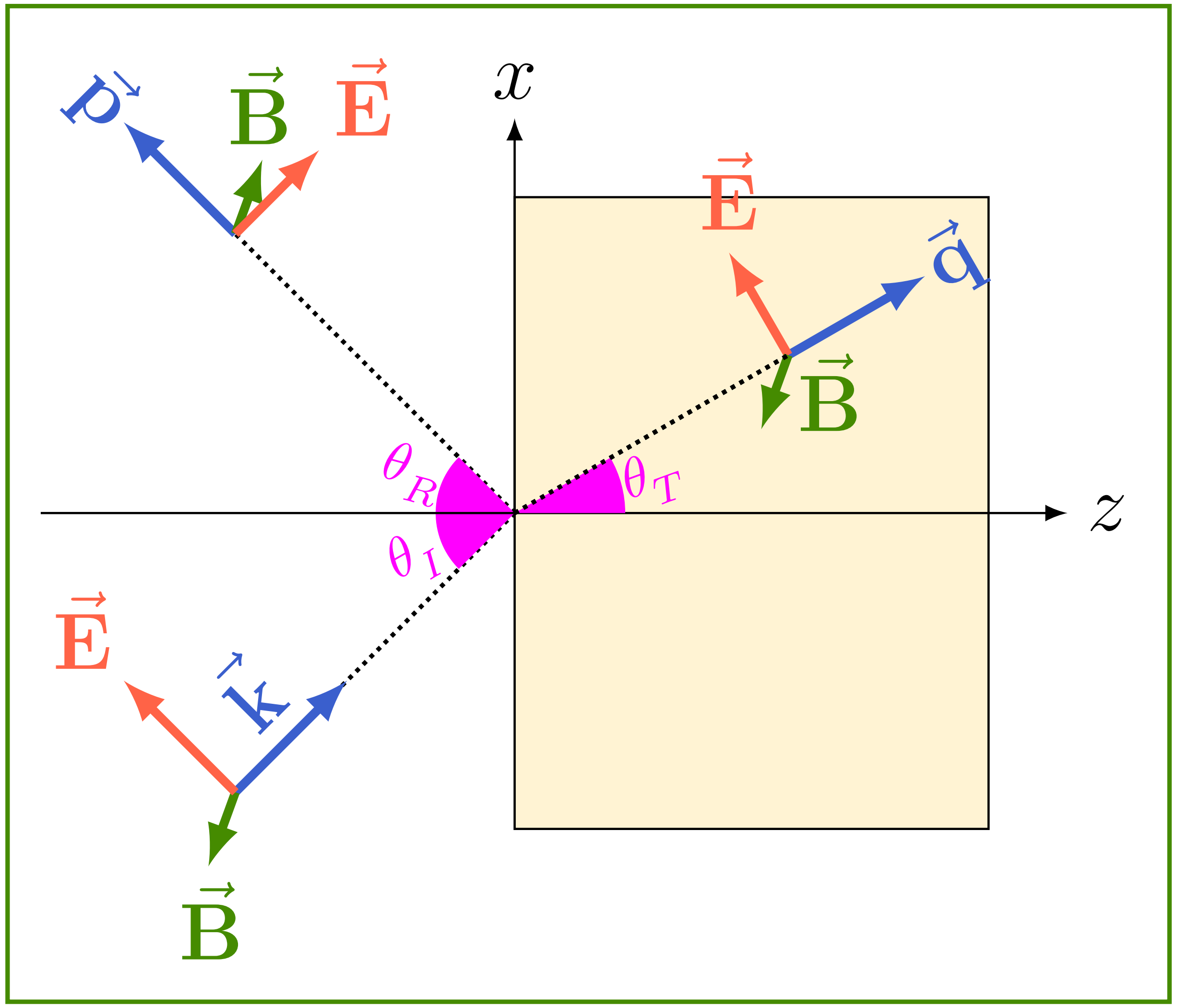

$$E_{0R} - E_0 = nE_{0T}$$

# Incidência oblíqua

$$\tilde{\mathbf{E}}_I = \tilde{\mathbf{E}}_{\mathbf{0I}} e^{i(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_T = \tilde{\mathbf{E}}_{\mathbf{0T}} e^{i(\vec{\mathbf{q}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_R = \tilde{\mathbf{E}}_{\mathbf{0R}} e^{i(\vec{\mathbf{p}}\cdot\vec{\mathbf{r}}-\omega t)}$$




$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon\tilde{E}_{0Tz}$$

$$\tilde{E}_{0x} + \tilde{E}_{0Rx} = \tilde{E}_{0Tx}$$

$$E_0 \cos\theta + E_{0R}\cos\theta = E_{0T}\cos\theta_T$$

$$E_{0R} - E_0 = nE_{0T}$$

# Incidência oblíqua

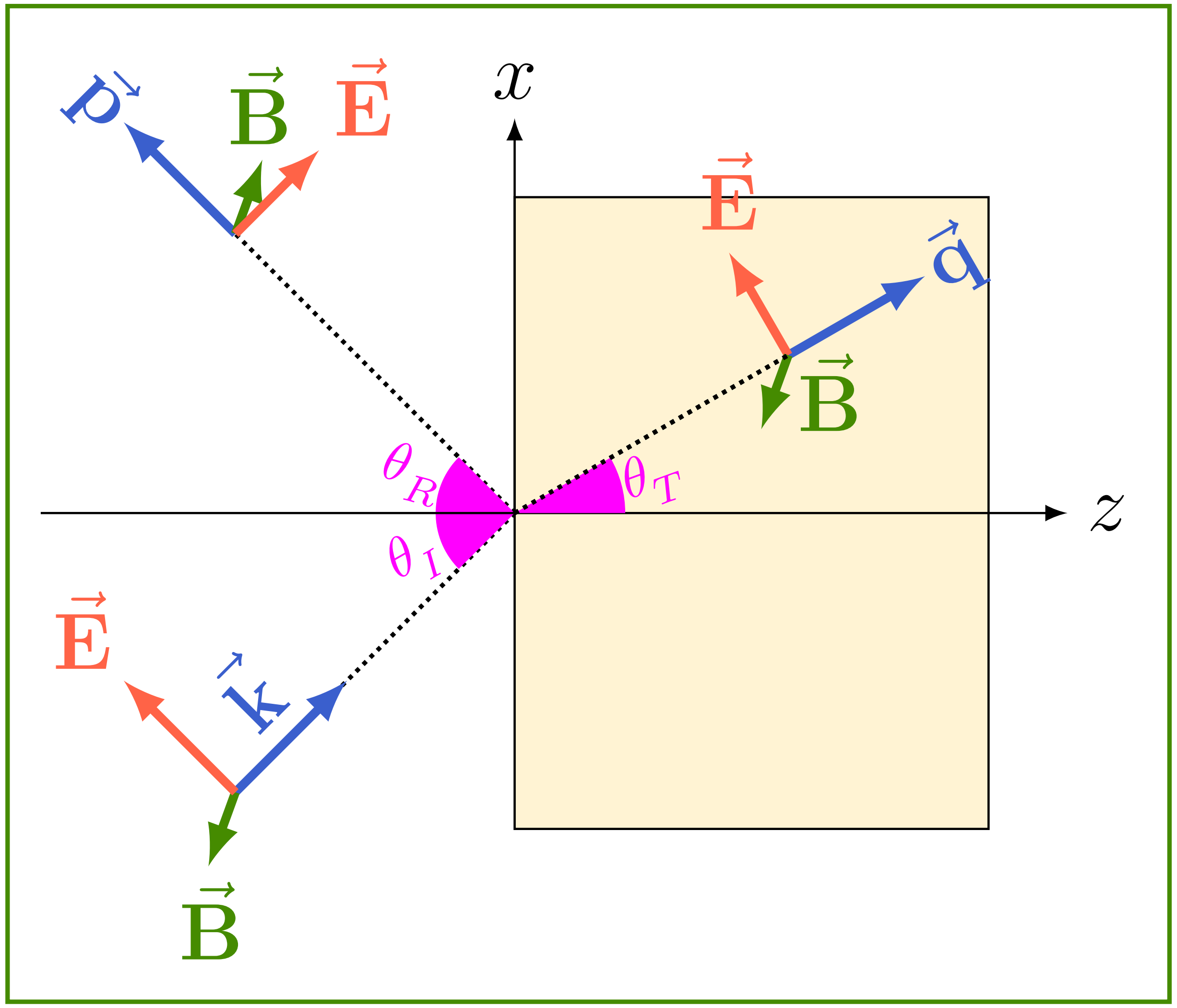
$$\tilde{\mathbf{E}}_I = \tilde{\mathbf{E}}_{\mathbf{0I}} e^{i(\vec{\mathbf{k}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_T = \tilde{\mathbf{E}}_{\mathbf{0T}} e^{i(\vec{\mathbf{q}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\tilde{\mathbf{E}}_R = \tilde{\mathbf{E}}_{\mathbf{0R}} e^{i(\vec{\mathbf{p}}\cdot\vec{\mathbf{r}}-\omega t)}$$

$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$

$$\tilde{E}_{0x} + \tilde{E}_{0Rx} = \tilde{E}_{0Tx}$$

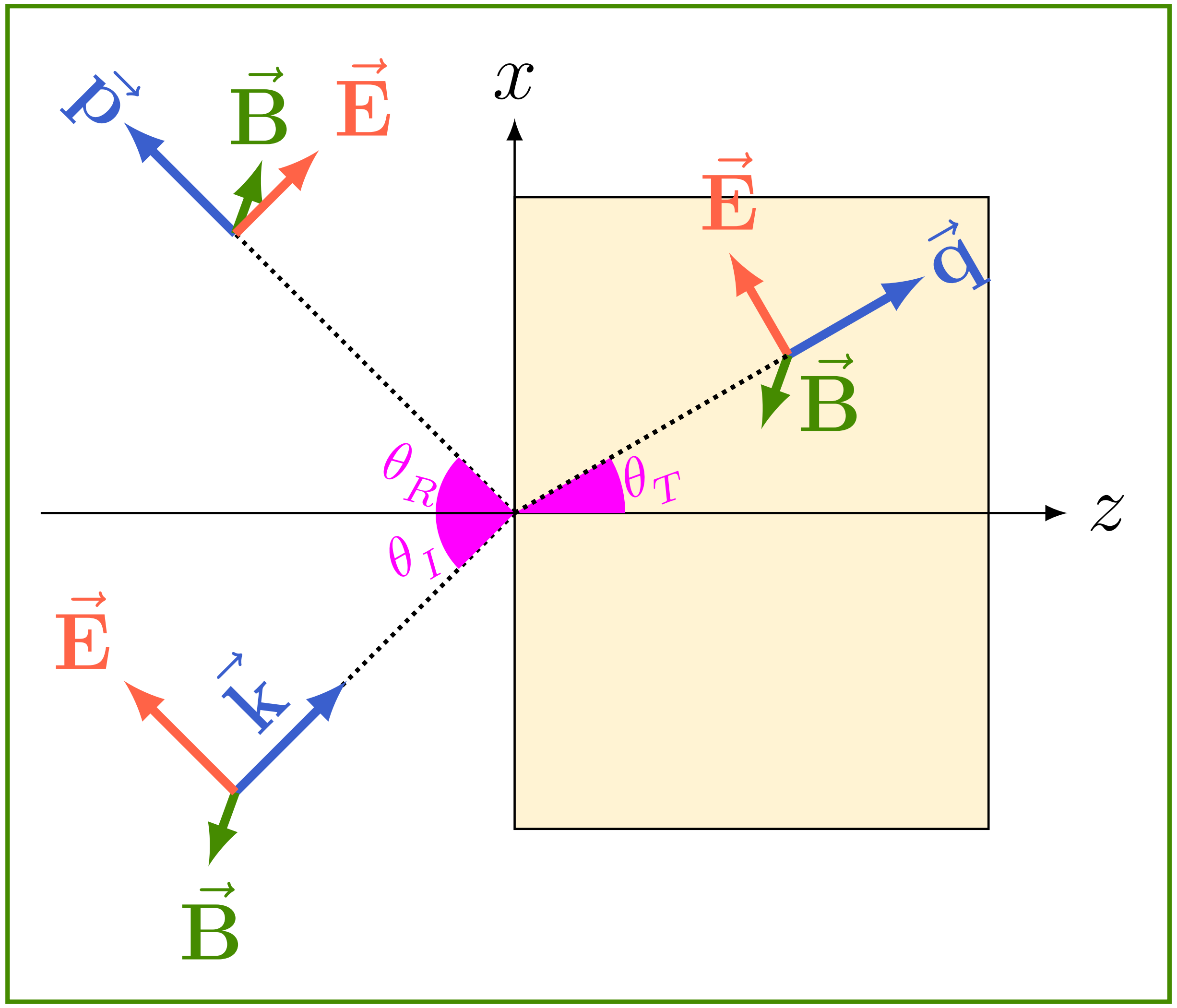



$$E_{0R} - E_0 = nE_{0T}$$

$$E_0 + E_{0R} = \alpha E_{0T}$$

$$\alpha \equiv \frac{\cos\theta_T}{\cos\theta}$$

# Incidência oblíqua




$$E_{0R} - E_0 = nE_{0T}$$

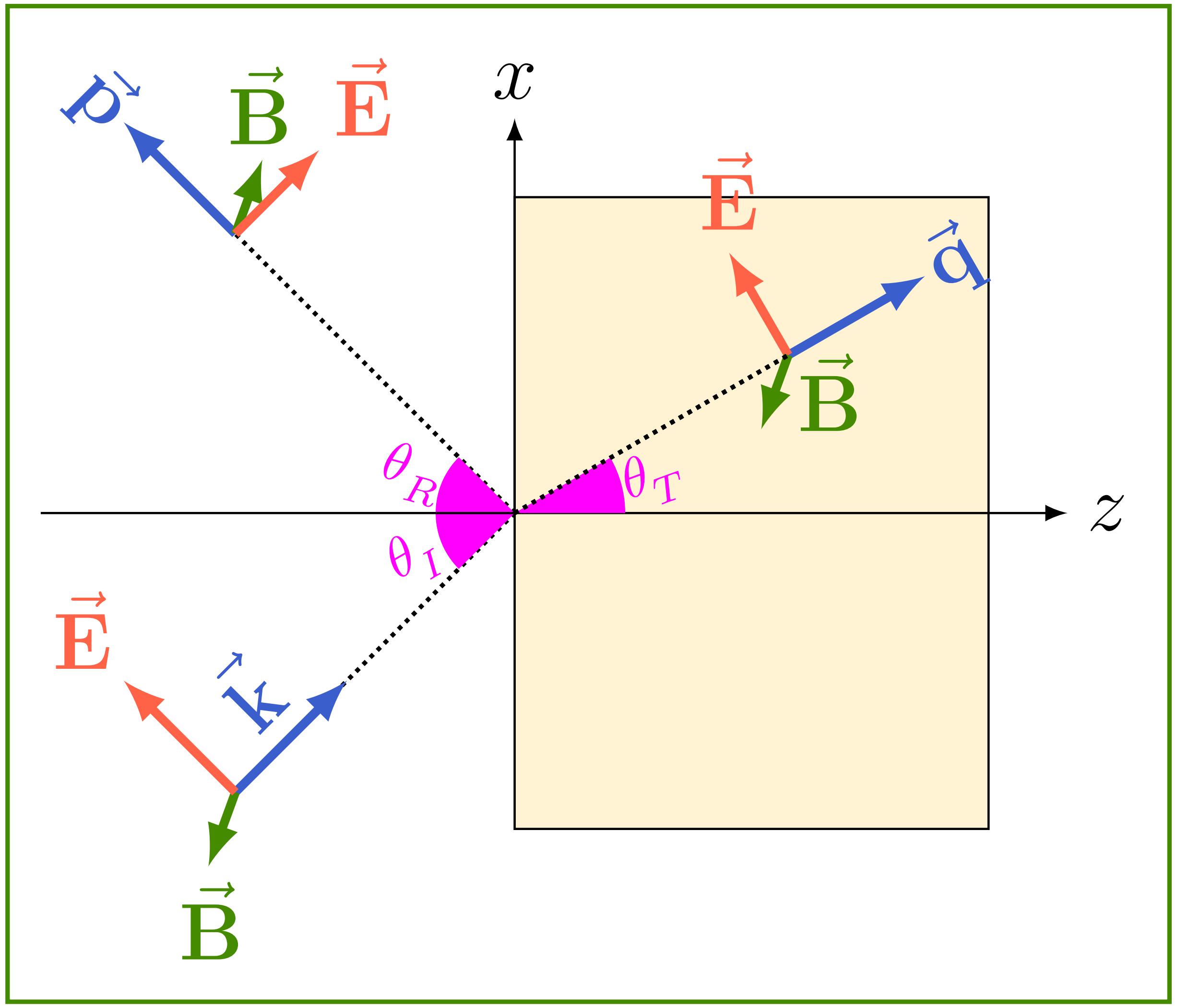
$$E_0 + E_{0R} = \alpha E_{0T}$$

$$\alpha \equiv \frac{\cos\theta_T}{\cos\theta}$$

# Incidência oblíqua

$$\tilde{E}_{0R} = \frac{\alpha - n}{\alpha + n}\tilde{E}_0$$

$$\tilde{E}_{0T} = \frac{2}{\alpha + n}\tilde{E}_0$$




$$E_{0R} - E_0 = nE_{0T}$$

$$E_0 + E_{0R} = \alpha E_{0T}$$

$$\alpha \equiv \frac{\cos\theta_T}{\cos\theta}$$