Eletromagnetismo Avançado

18 de setembro
Ondas Eletromagnéticas

Meios lineares

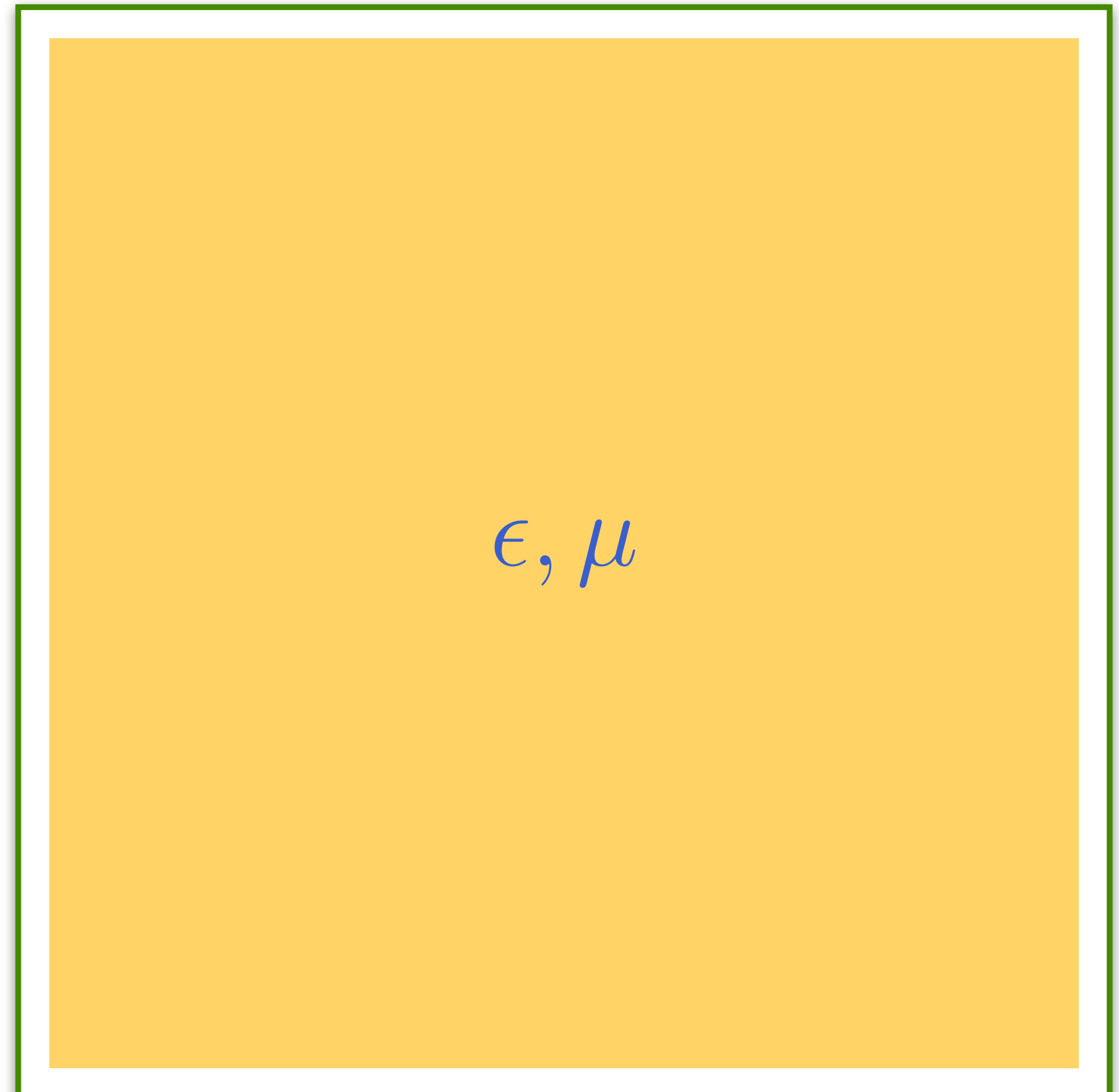
$$\vec{\nabla} \cdot \vec{\mathbf{E}} = \frac{\rho}{\epsilon}$$

$$\vec{\nabla} \times \vec{\mathbf{E}} = -\partial_t \vec{\mathbf{B}}$$

$$\vec{\nabla} \cdot \vec{\mathbf{B}} = 0$$

$$\vec{\nabla} \times \vec{\mathbf{B}} = \mu(\vec{\mathbf{J}} + \epsilon \partial_t \vec{\mathbf{E}})$$

$$\nabla^2 \vec{\mathbf{E}} = \frac{1}{v^2} \partial_t^2 \vec{\mathbf{E}} \qquad \left(v \equiv \frac{c}{n}\right)$$



$$\vec{\mathbf{E}}(\vec{\mathbf{r}}, t) = \vec{\mathbf{E}}_0 \exp\Big(i(\vec{\mathbf{k}} \cdot \vec{\mathbf{r}} - \omega t)\Big)$$

$$\vec{\mathbf{B}}(\vec{\mathbf{r}}, t) = \vec{\mathbf{B}}_0 \exp\Big(i(\vec{\mathbf{k}} \cdot \vec{\mathbf{r}} - \omega t)\Big)$$

$$\omega = \frac{kc}{n}$$

$$\hat{\mathbf{k}} \times \vec{\mathbf{E}}_0 = \frac{c}{n} \vec{\mathbf{B}}_0$$

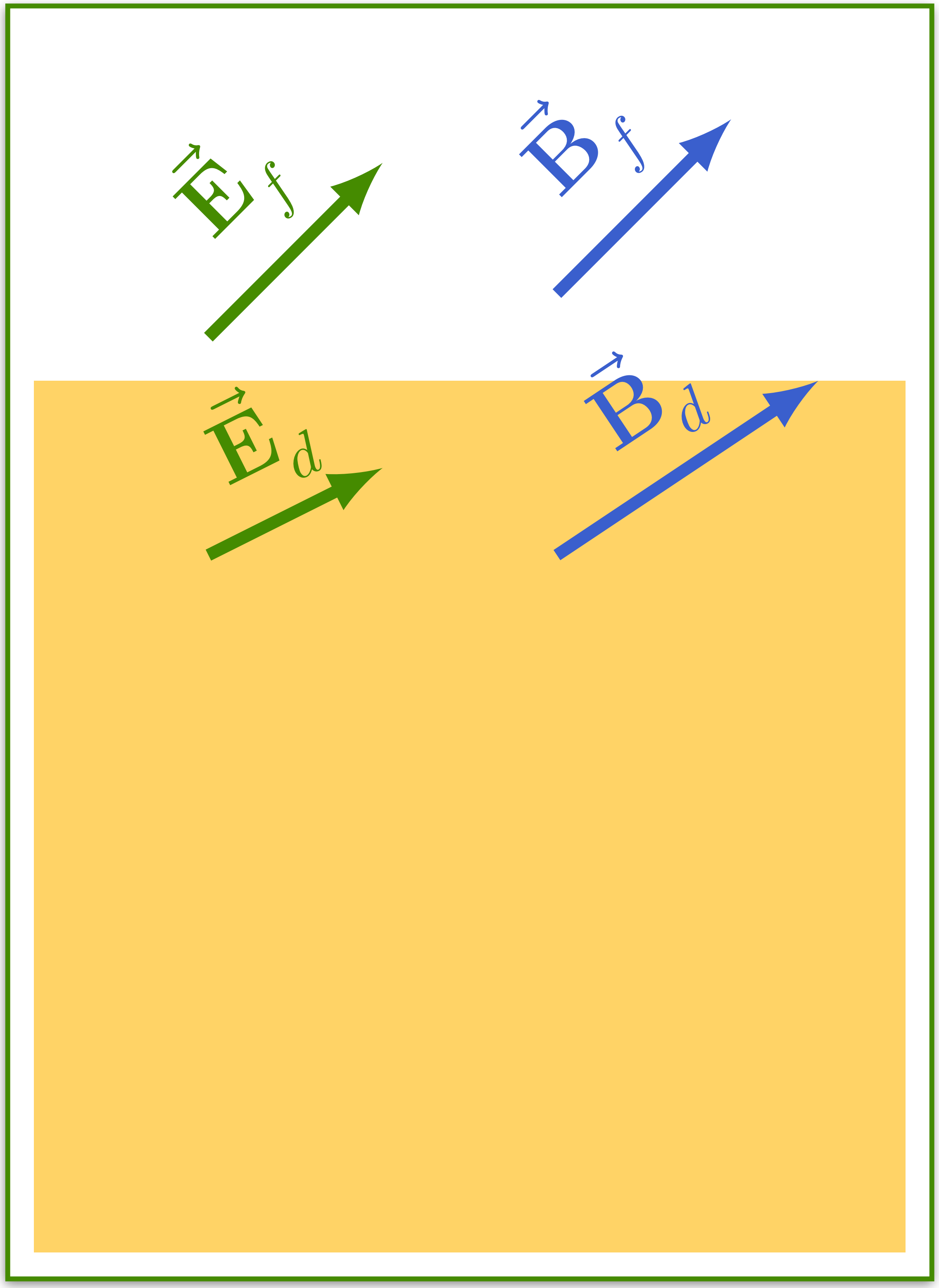
Meios lineares - fronteiras

$$E_{d\parallel} = E_{f\parallel}$$

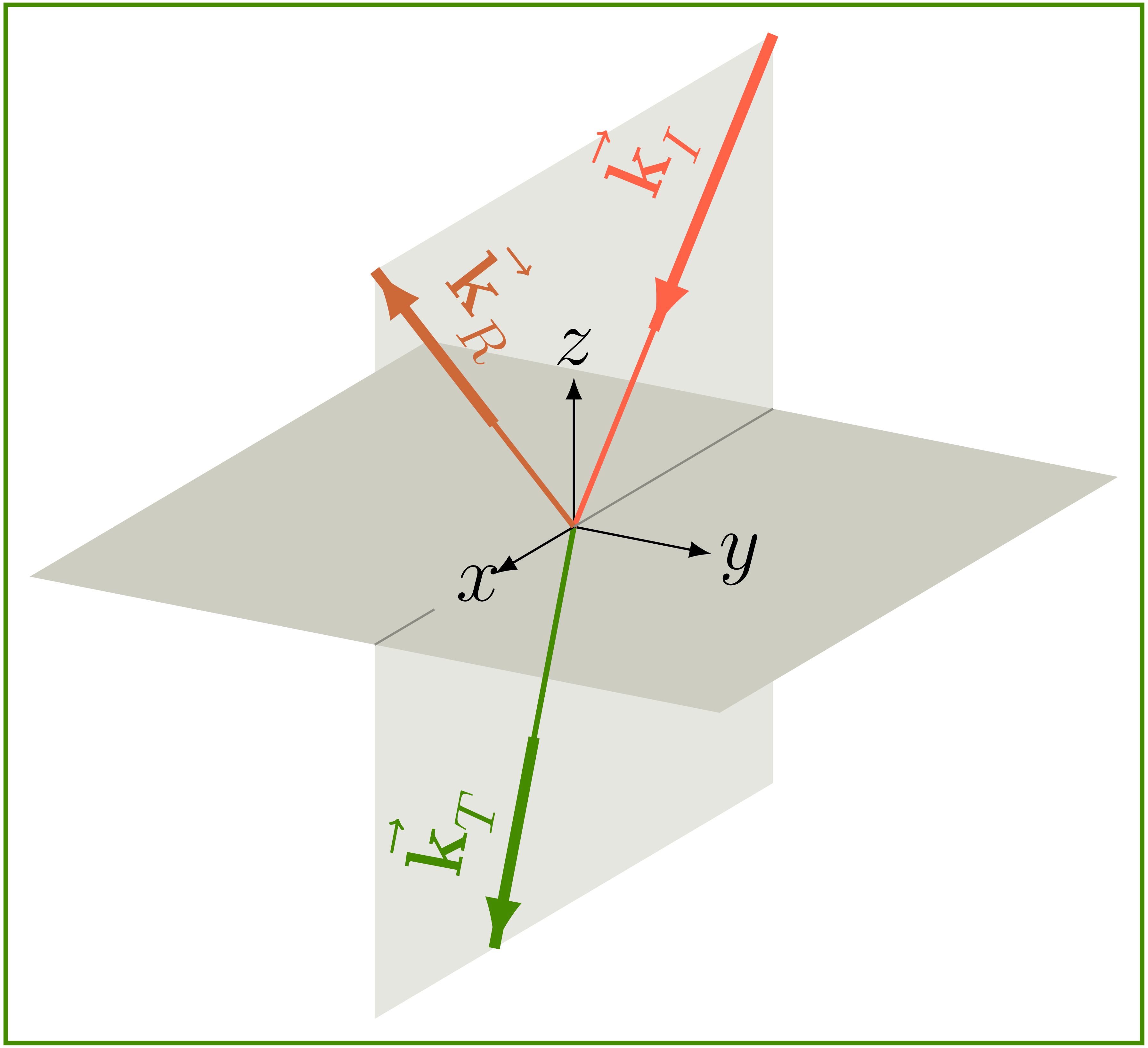
$$\epsilon E_{d\perp} = \epsilon_0 E_{f\perp}$$

$$\frac{1}{\mu} B_{d\parallel} = \frac{1}{\mu_0} B_{f\parallel}$$

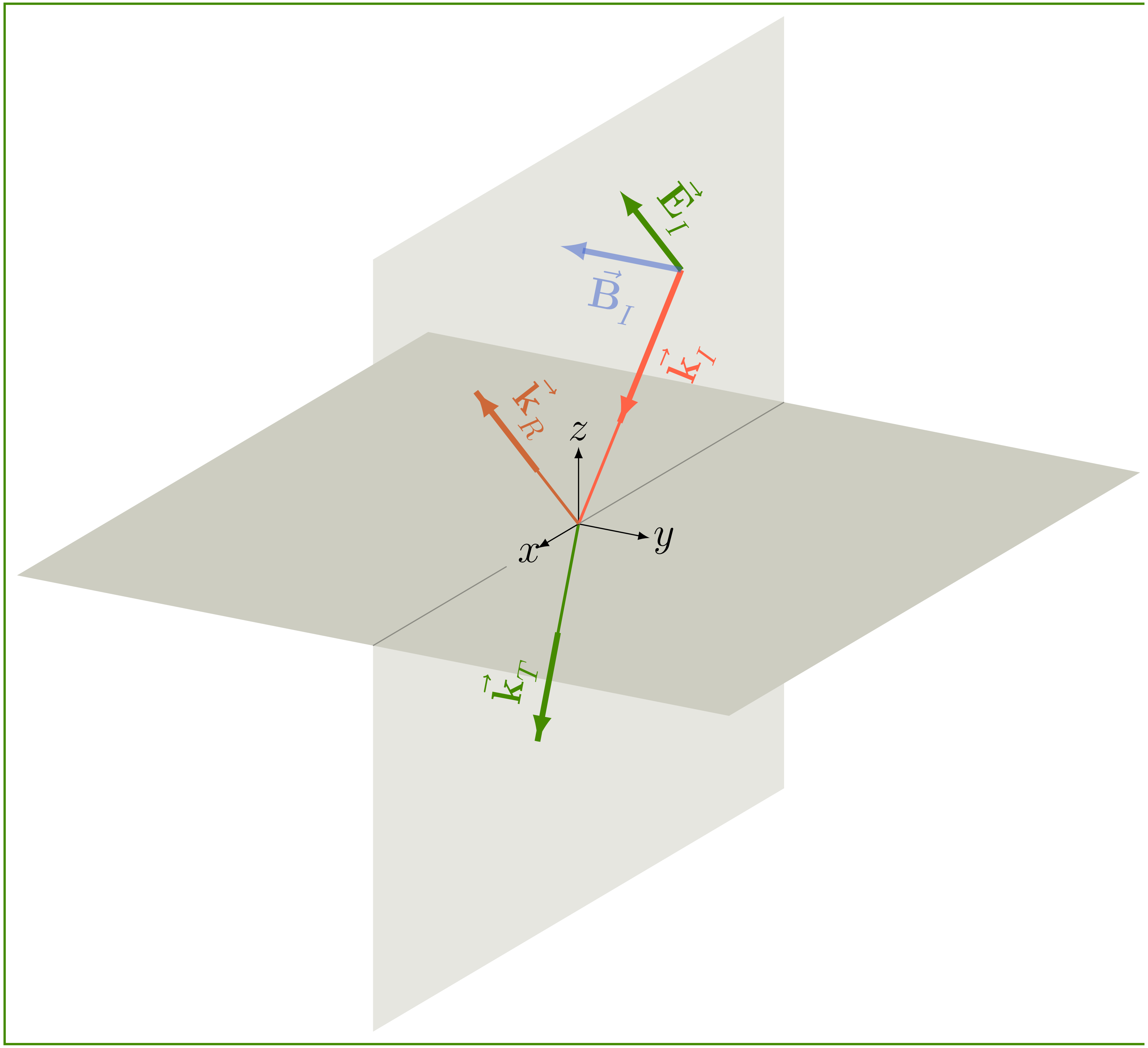
$$B_{d\perp} = B_{f\perp}$$



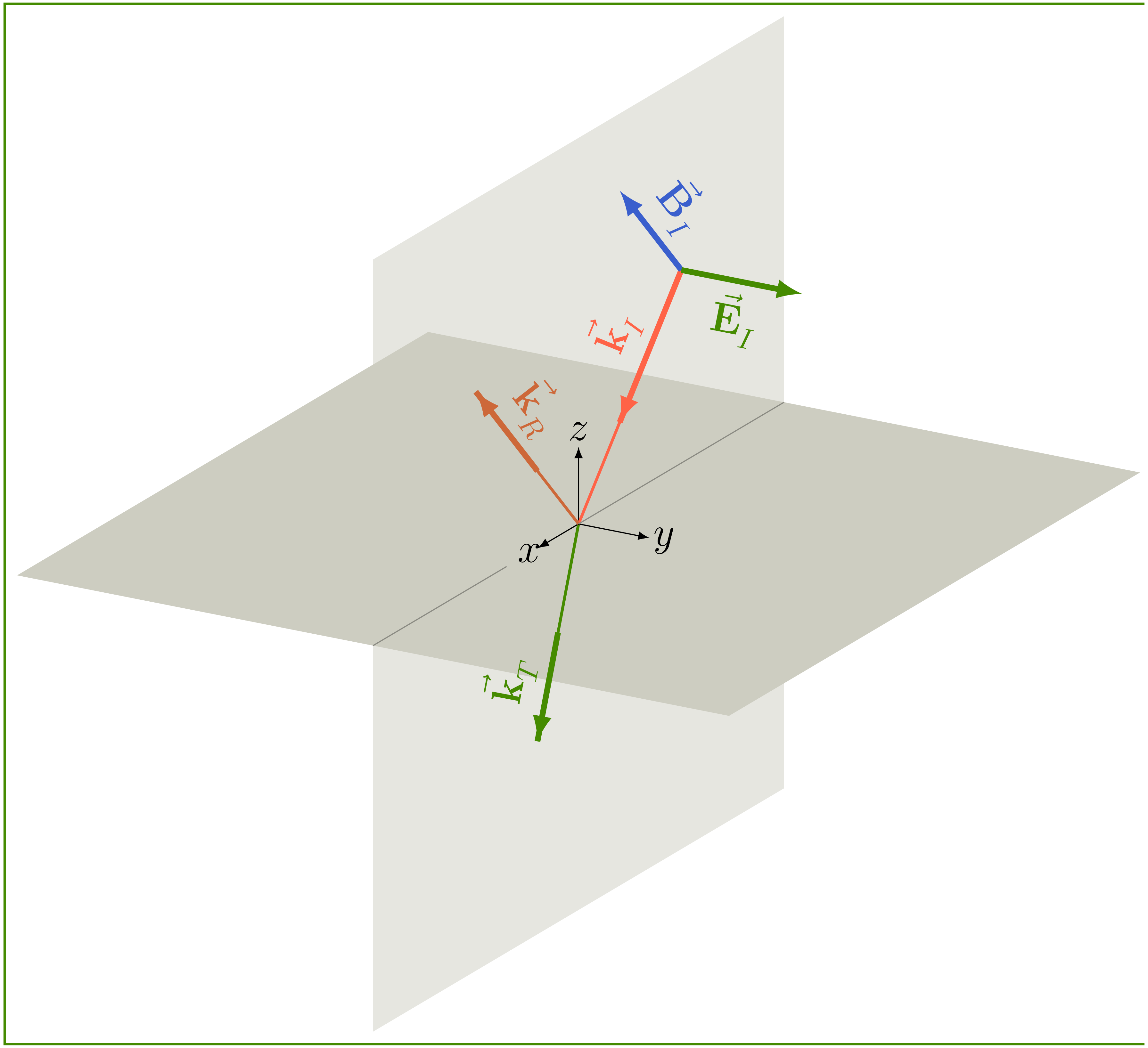
Equações de Fresnel



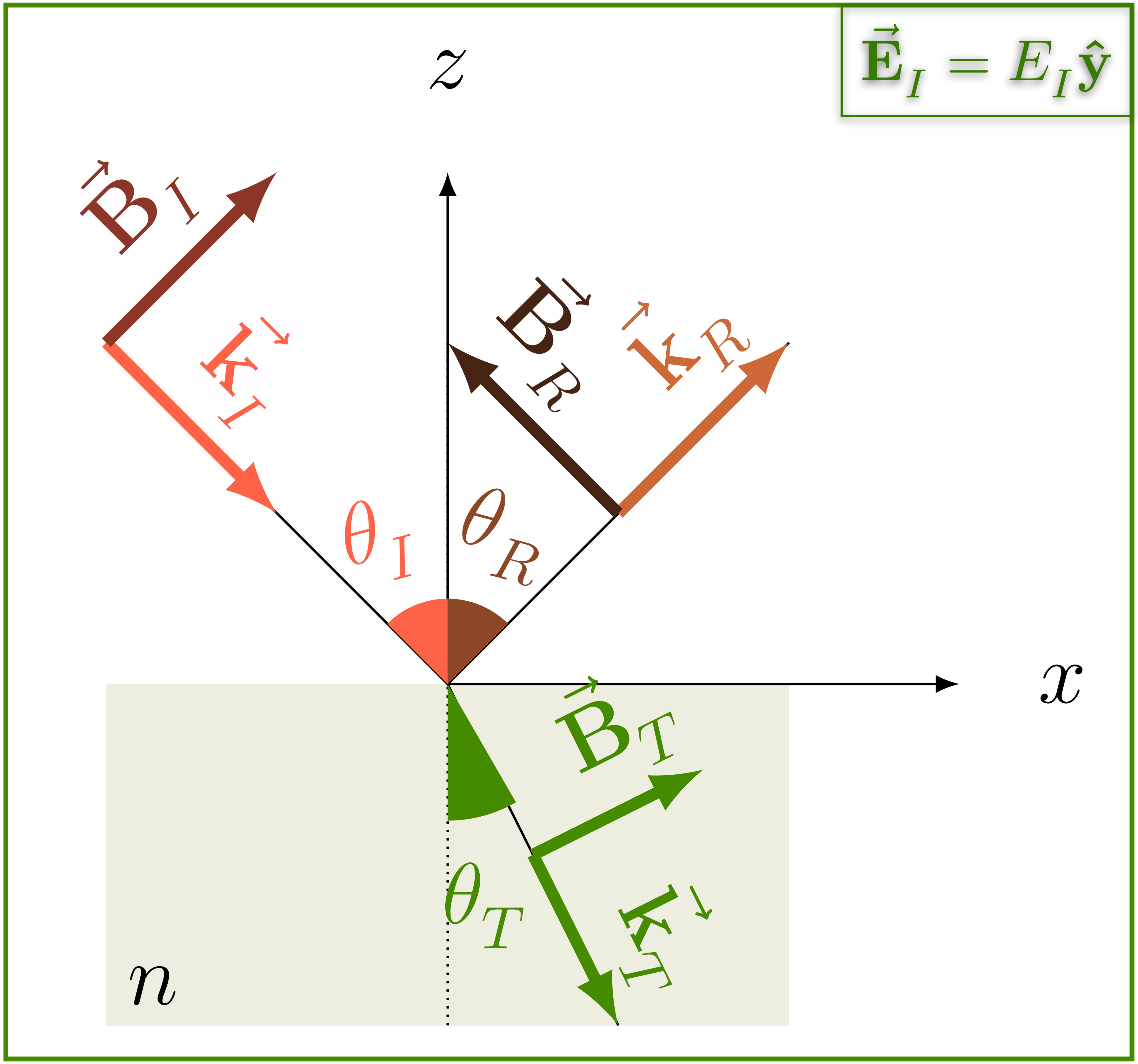
Equações de Fresnel



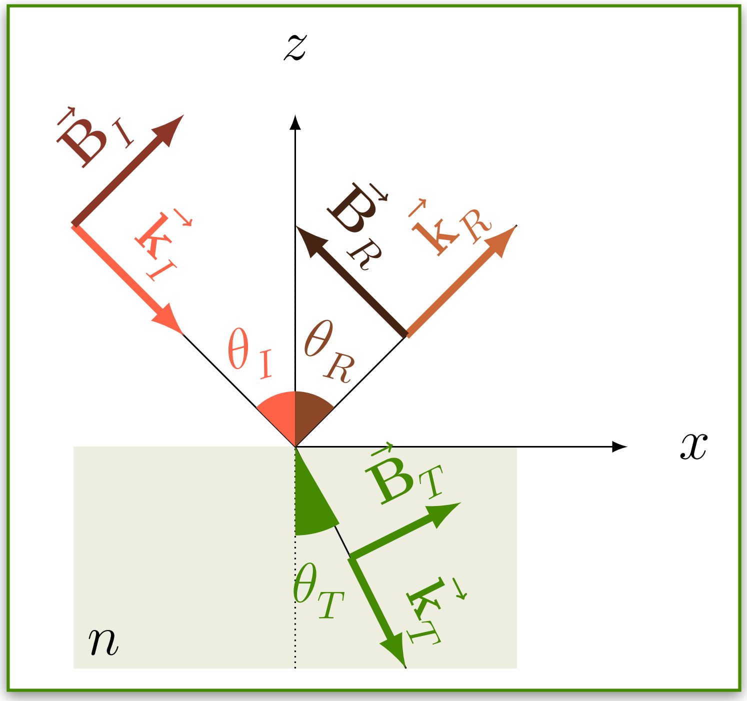
Equações de Fresnel



Equações de Fresnel



Condições de contorno



$$\vec{\mathbf{E}}_I(0,x,y,t) + \vec{\mathbf{E}}_R(0,x,y,t) = \vec{\mathbf{E}}_T(0,x,y,t)$$

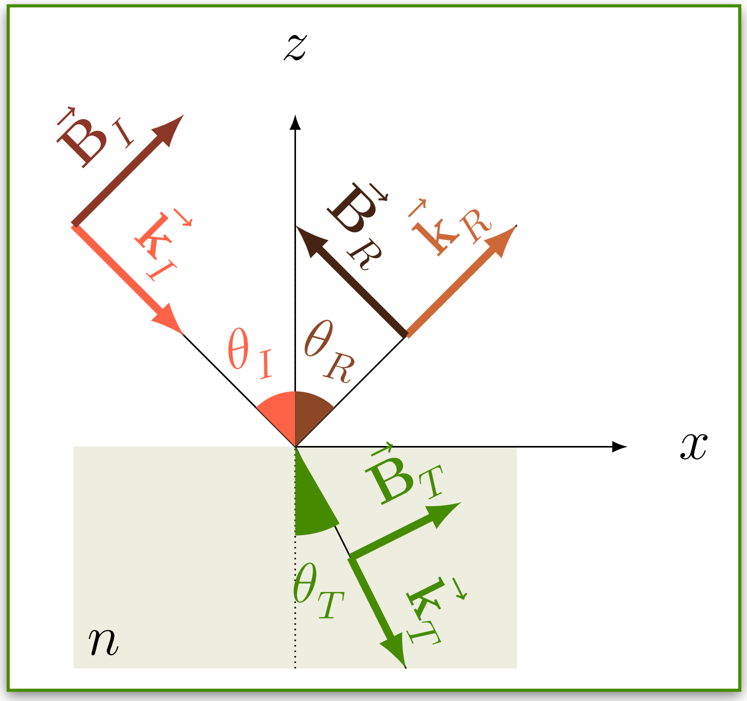
$$B_{I_z}(0,x,y,t) + B_{R_z}(0,x,y,t) = B_{T_z}(0,x,y,t)$$

$$B_{I_x}(0,x,y,t) + B_{R_x}(0,x,y,t) = \frac{\mu_0}{\mu} B_{T_x}(0,x,y,t)$$

$$\vec{\mathbf{E}}_I = E_I \hat{\mathbf{y}}$$

$$B_{I_y}(0,x,y,t) + B_{R_y}(0,x,y,t) = \frac{\mu_0}{\mu} B_{T_y}(0,x,y,t)$$

Condições de contorno



$$E_{Iy}(0,x,y,t) + E_{Ry}(0,x,y,t) = E_{Ty}(0,x,y,t)$$

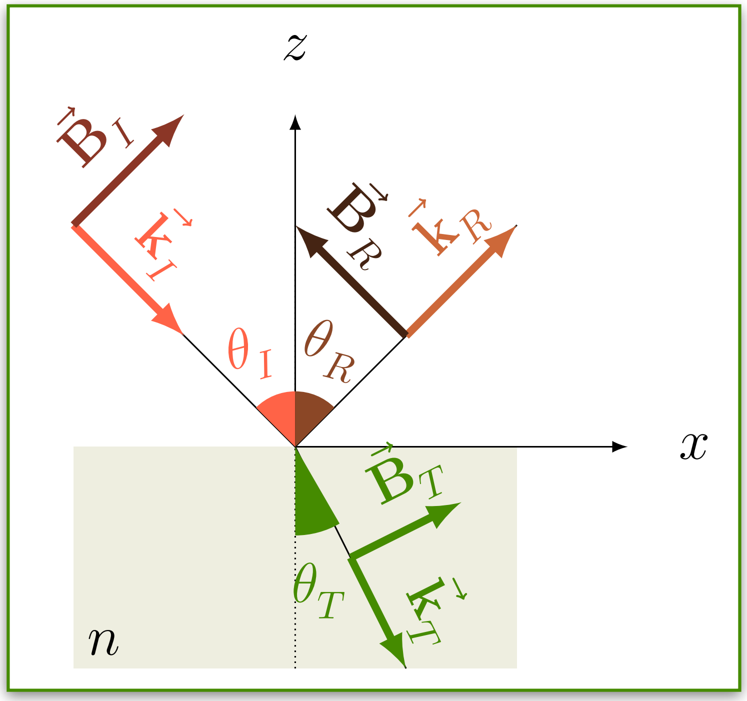
$$B_{Iz}(0,x,y,t) + B_{Rz}(0,x,y,t) = B_{Tz}(0,x,y,t)$$

$$B_{Ix}(0,x,y,t) + B_{Rx}(0,x,y,t) = \frac{\mu_0}{\mu} B_{Tx}(0,x,y,t)$$

$$\mathbf{\vec{E}}_I = E_I \hat{\mathbf{y}}$$

$$\cancel{B_{Iy}(0,x,y,t)} + B_{Ry}(0,x,y,t) = \frac{\mu_0}{\mu} B_{Ty}(0,x,y,t)$$

Condições de contorno



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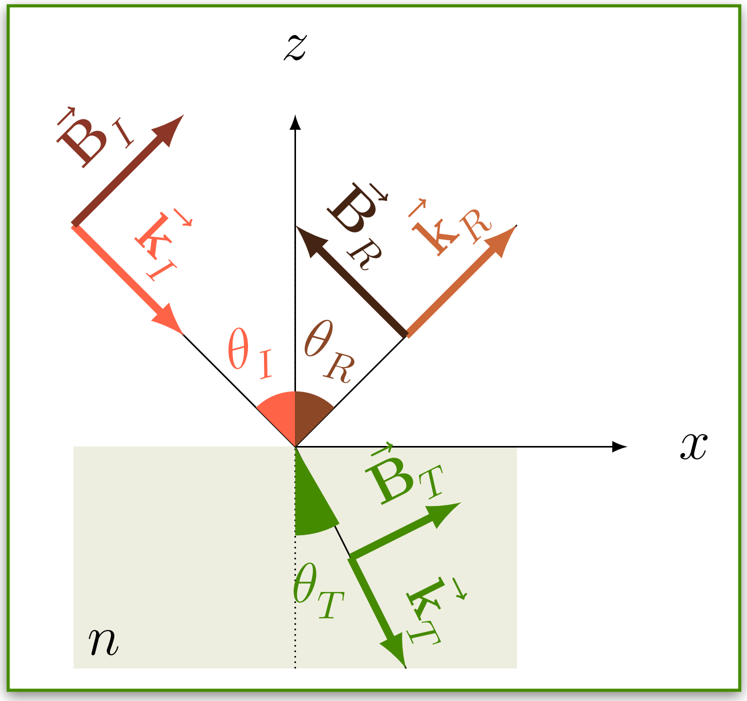
$$\cancel{B_{Iy}(0,x,y,t)} + \cancel{B_{Ry}(0,x,y,t)} = \frac{\mu_0}{\mu} \cancel{B_{Ty}(0,x,y,t)}$$

Condições de contorno

$$\Rightarrow \quad \vec{\mathbf{k}}_{Iy} = \vec{\mathbf{k}}_{Ry} = \vec{\mathbf{k}}_{Ty} = 0$$

$$\Rightarrow \quad \vec{\mathbf{k}}_{Ix} = \vec{\mathbf{k}}_{Rx} = \vec{\mathbf{k}}_{Tx}$$

$$\theta_R = \theta_I \equiv \theta$$



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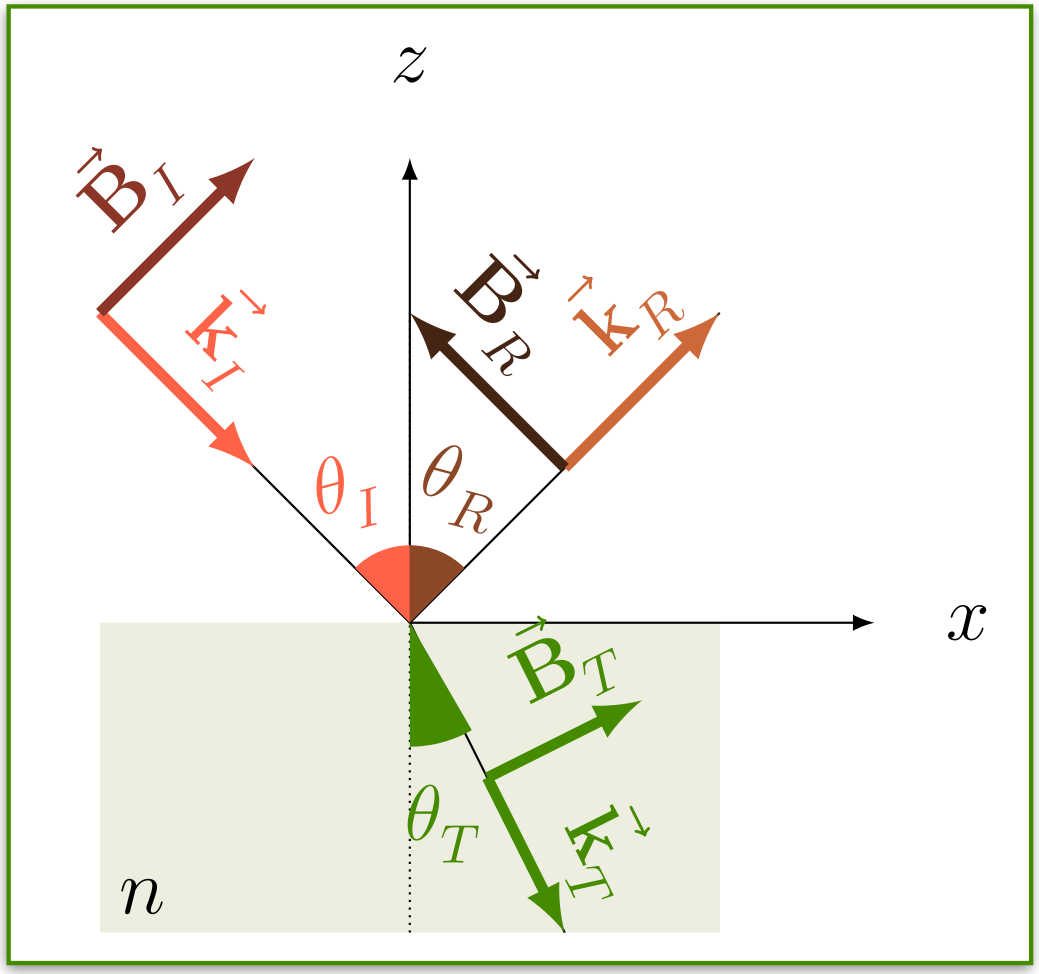
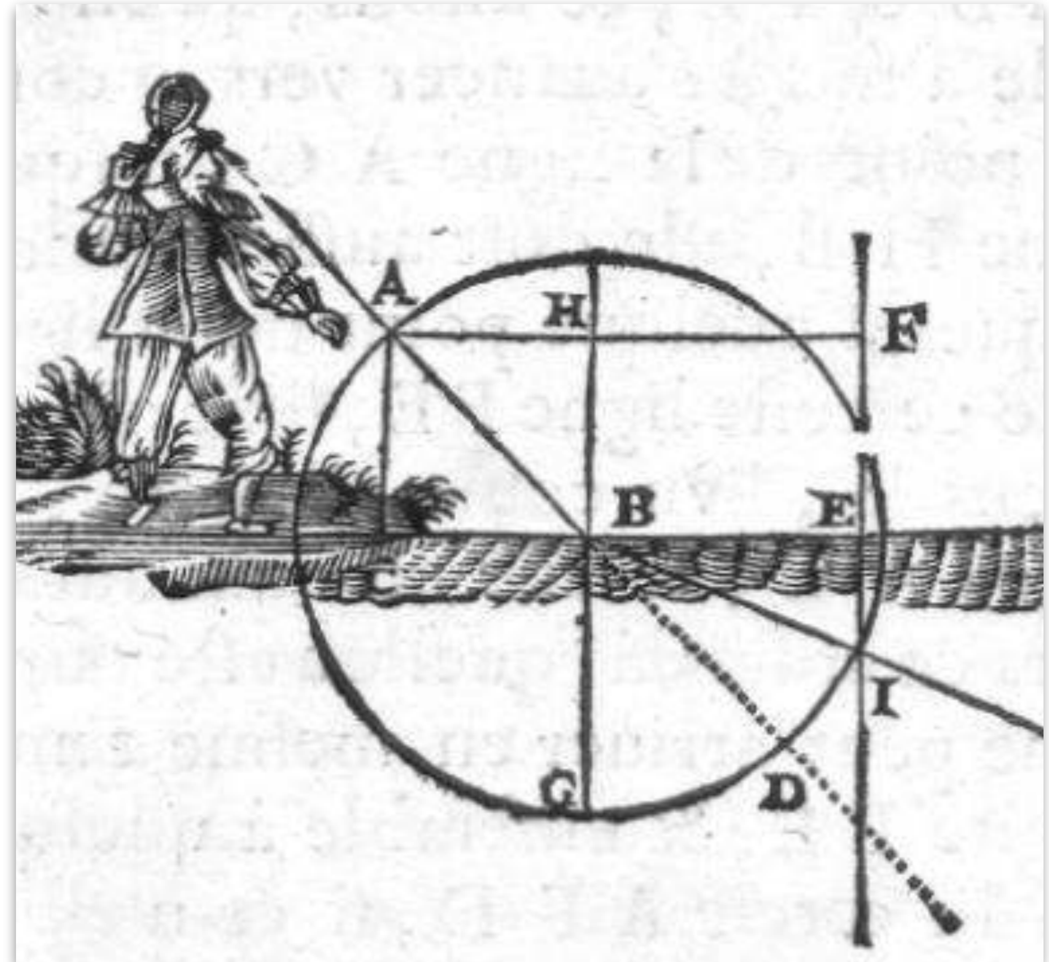
$$\theta_R = \theta_I \equiv \theta$$

$$n \sin \theta_T = \sin \theta$$



Evolução histórica

- Euclides
- Ptolomeu
- Ibn Sahl
- Al Haythem
- Snell
- Descartes
- Huygens



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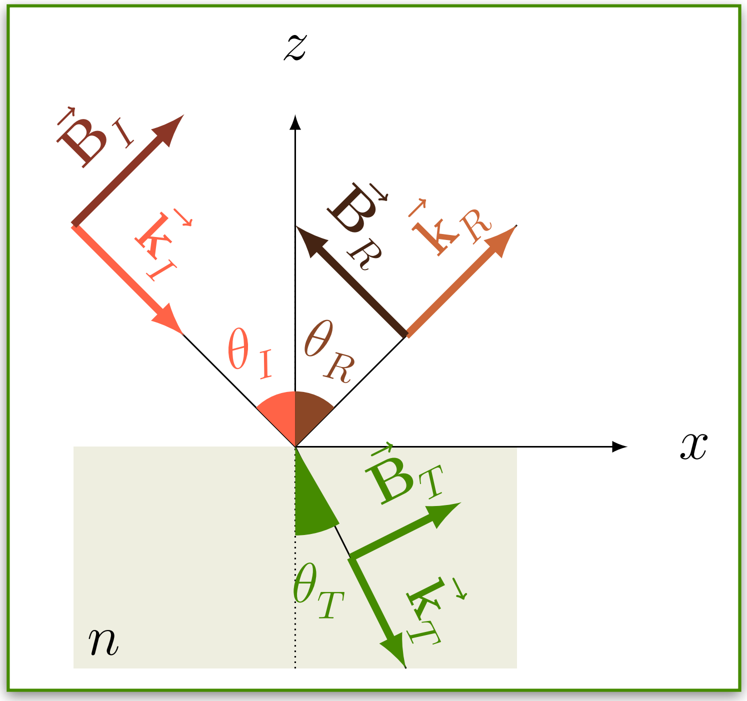

$$E_{Iy}(0,x,y,t) + E_{Ry}(0,x,y,t) = E_{Ty}(0,x,y,t)$$

$$B_{Iz}(0,x,y,t) + B_{Rz}(0,x,y,t) = B_{Tz}(0,x,y,t)$$

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Condições de contorno

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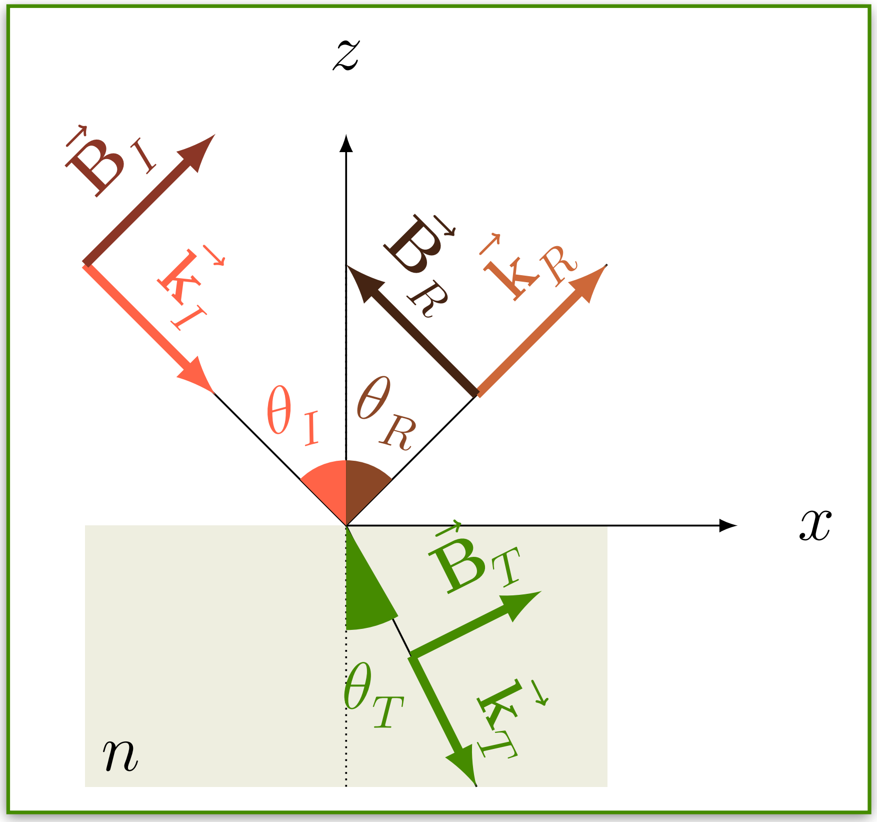
$$B_{Ix}(0,x,y,t) + B_{Rx}(0,x,y,t) = \frac{\mu_0}{\mu} B_{Tx}(0,x,y,t)$$

$$B_{Iz} + B_{Rz} = B_{Tz}$$

$$B_{Ix} + B_{Rx} = \frac{\mu_0}{\mu} B_{Tx}$$



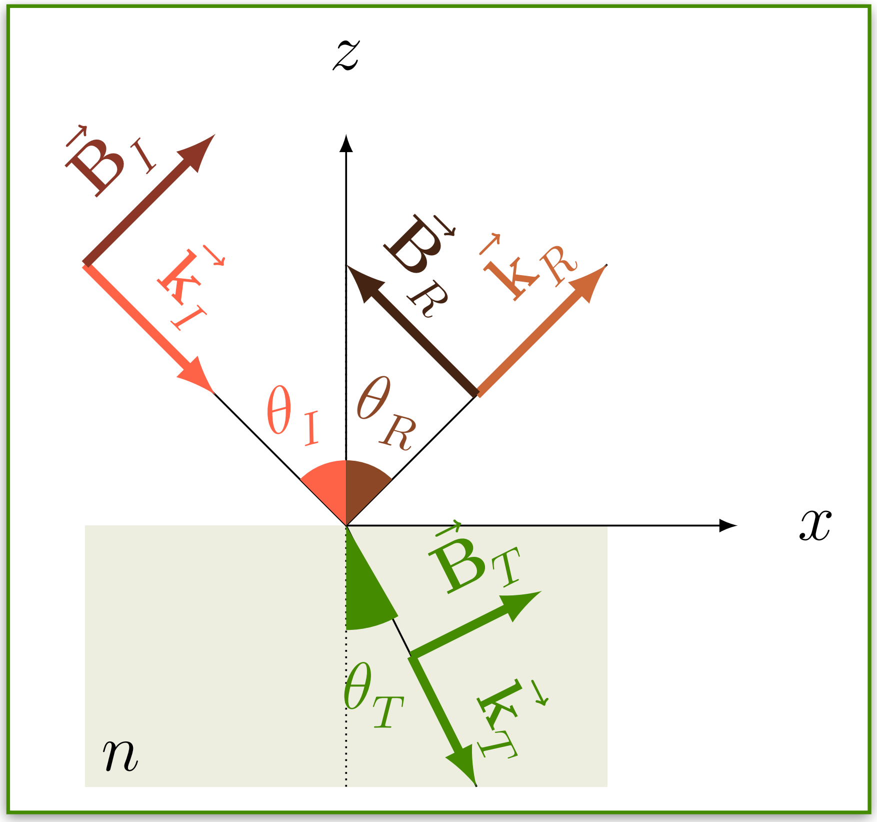
Condições de contorno

$$B_{Iz} + B_{Rz} = B_{Tz}$$

$$B_{Ix} + B_{Rx} = \frac{\mu_0}{\mu} B_{Tx}$$

$$(B_I + B_R) \sin\theta = B_T \sin\theta_T$$

$$(B_I - B_R) \cos\theta = \frac{\mu_0}{\mu} B_T \cos\theta_T$$



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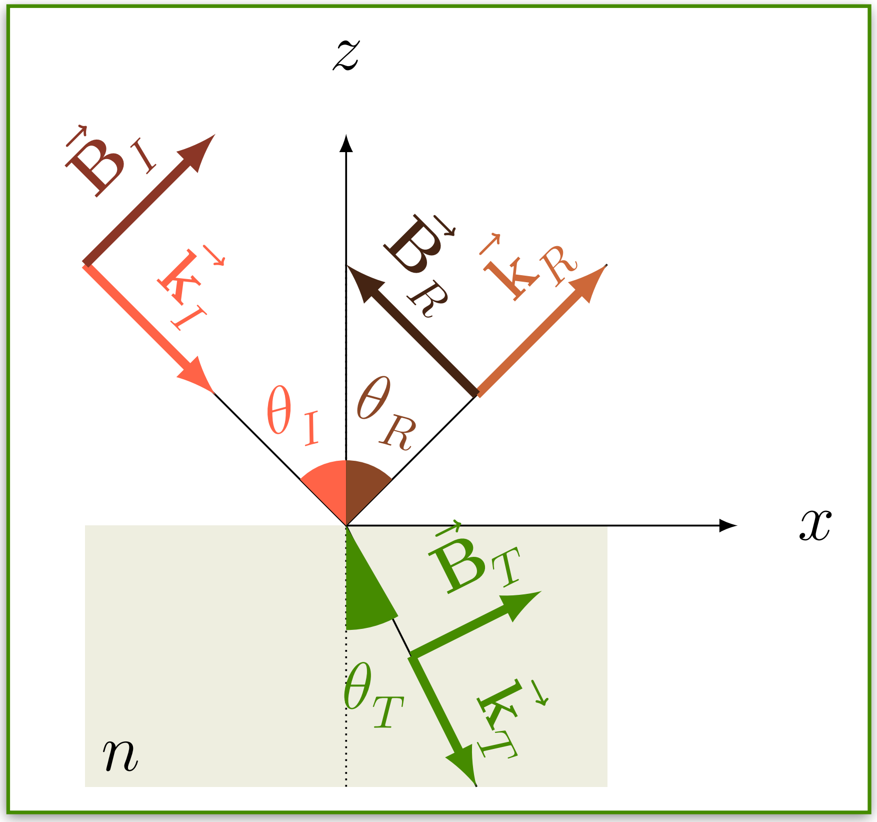


$$n \sin\theta_T = \sin\theta$$

Condições de contorno

$$B_{Iz} + B_{Rz} = B_{Tz}$$

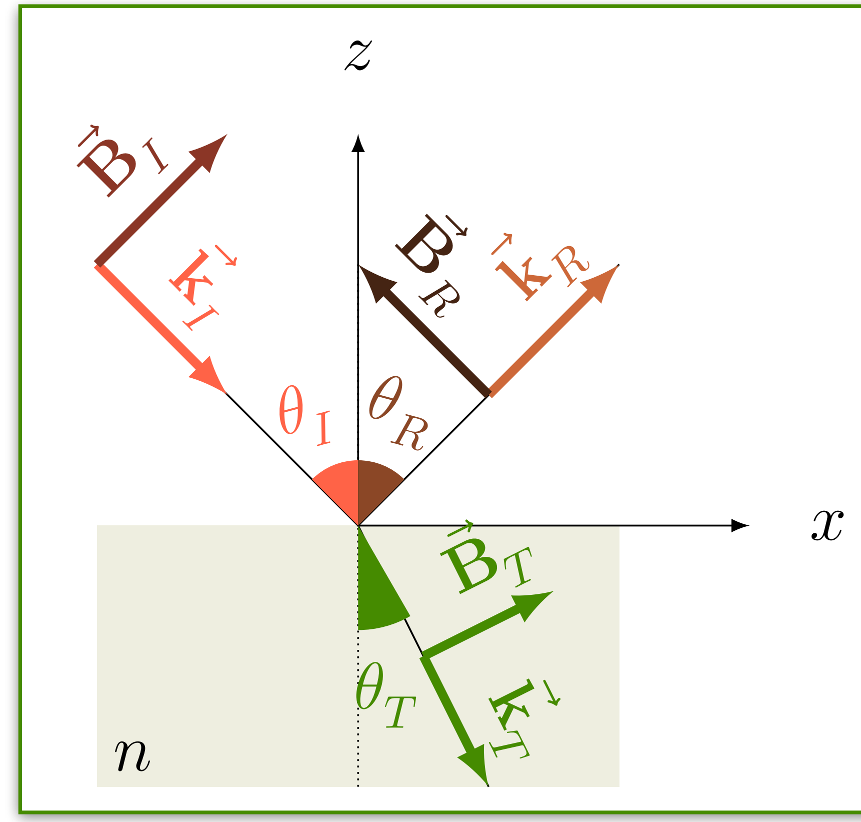
$$B_{Ix} + B_{Rx} = \frac{\mu_0}{\mu} B_{Tx}$$

$$(B_I + B_R)\sin\theta = B_T \sin\theta_T$$

$$(B_I - B_R)\cos\theta = \frac{\mu_0}{\mu} B_T \cos\theta_T$$

$$n(B_I + B_R) = B_T$$

$$B_I - B_R = \underbrace{\frac{\mu_0}{\mu}\frac{\cos\theta_T}{\cos\theta}}_{\gamma} B_T$$

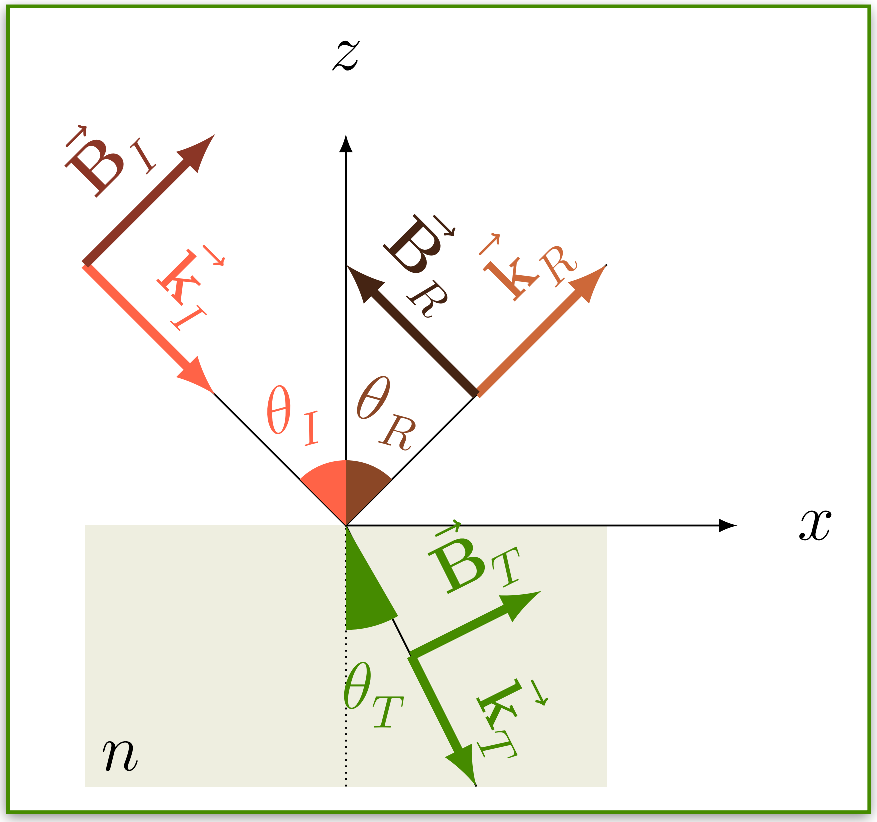


$$n\sin\theta_T = \sin\theta$$

Condições de contorno

$$B_{Iz} + B_{Rz} = B_{Tz}$$

$$B_{Ix} + B_{Rx} = \frac{\mu_0}{\mu} B_{Tx}$$



$$B_R = \frac{1 - n\gamma}{1 + n\gamma} B_I$$

$$B_T = \frac{2n}{1 + n\gamma} B_I$$

Condições de contorno

$$B_{Iz} + B_{Rz} = B_{Tz}$$

$$B_{Ix} + B_{Rx} = \frac{\mu_0}{\mu} B_{Tx}$$

$$B_R = \frac{1 - n\gamma}{1 + n\gamma} B_I$$

$$B_T = \frac{2n}{1 + n\gamma} B_I$$