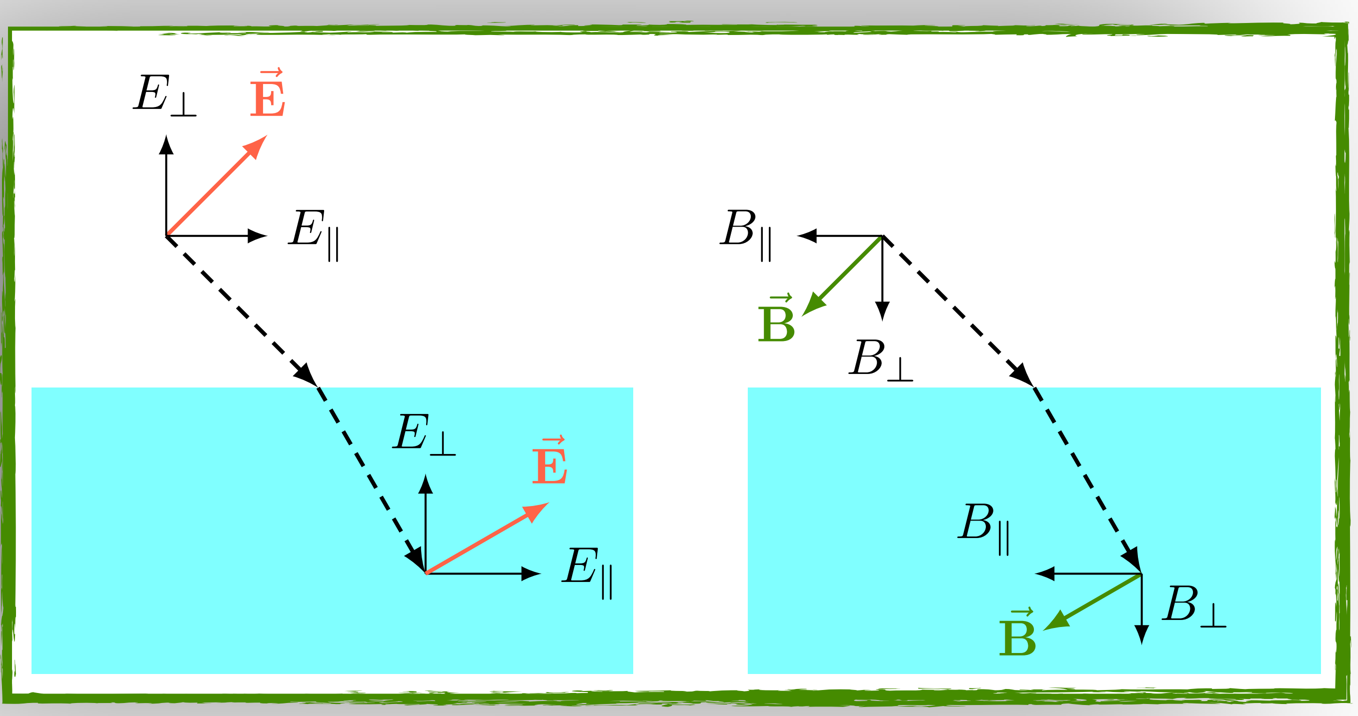
Eletromagnetismo Avançado

2º ciclo
Aula de 29 setembro

Ondas em meios lineares

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

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



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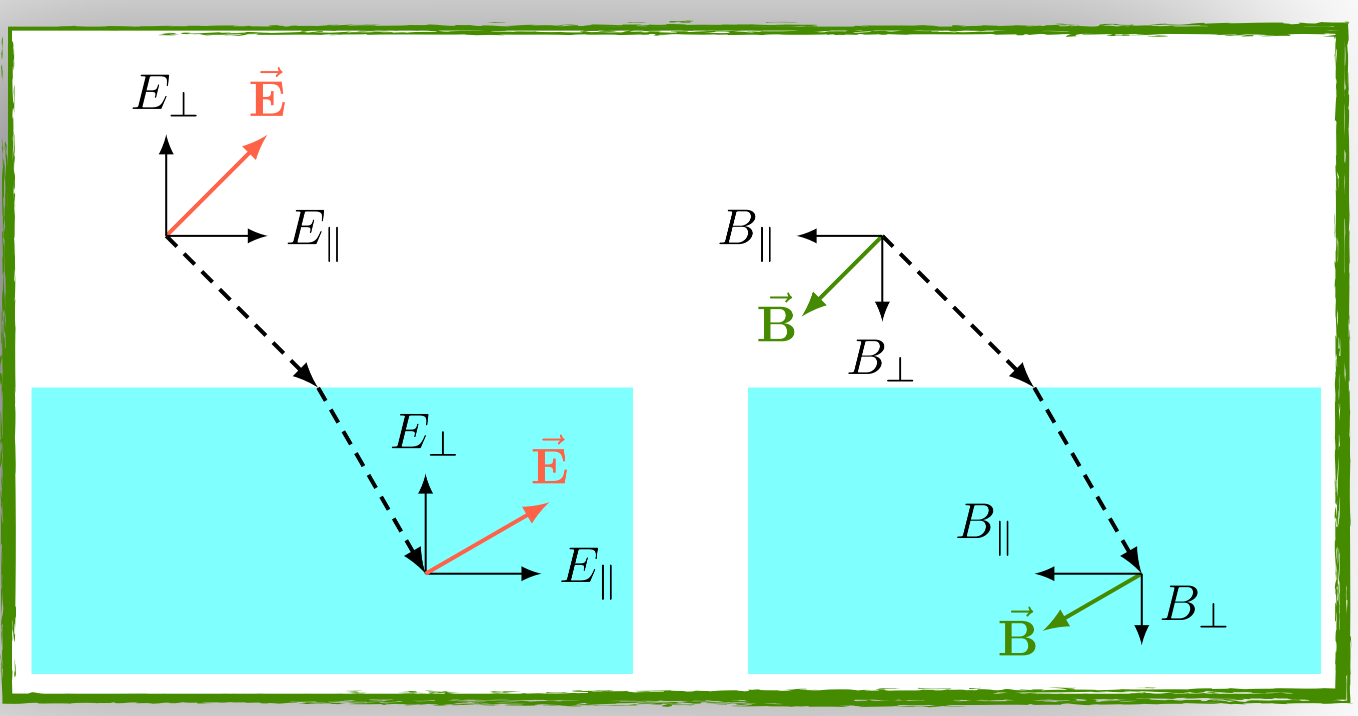
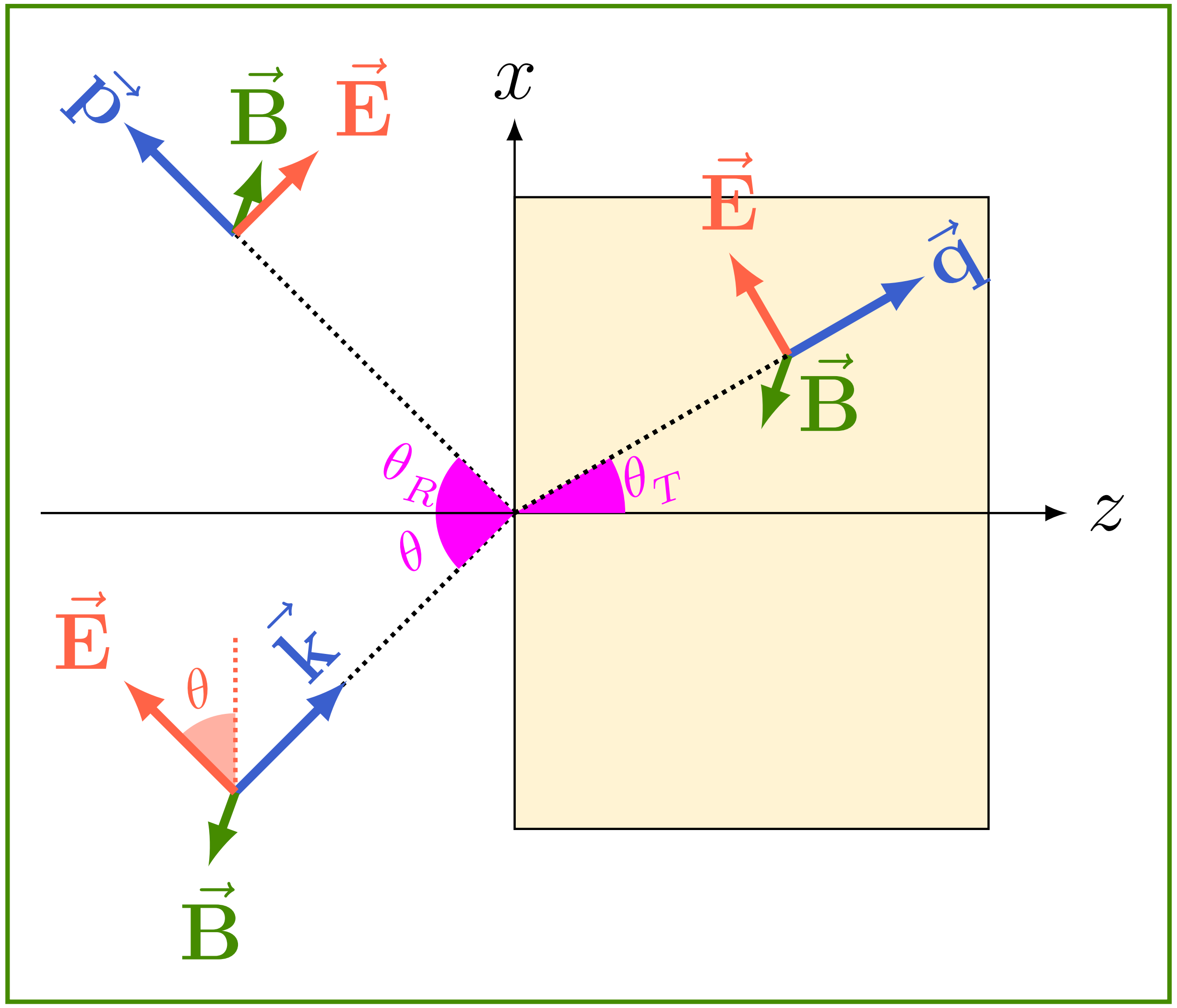


$$\epsilon_1 E_{1\perp} = \epsilon_2 E_{2\perp} \qquad B_{1\perp} = B_{2\perp}$$

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

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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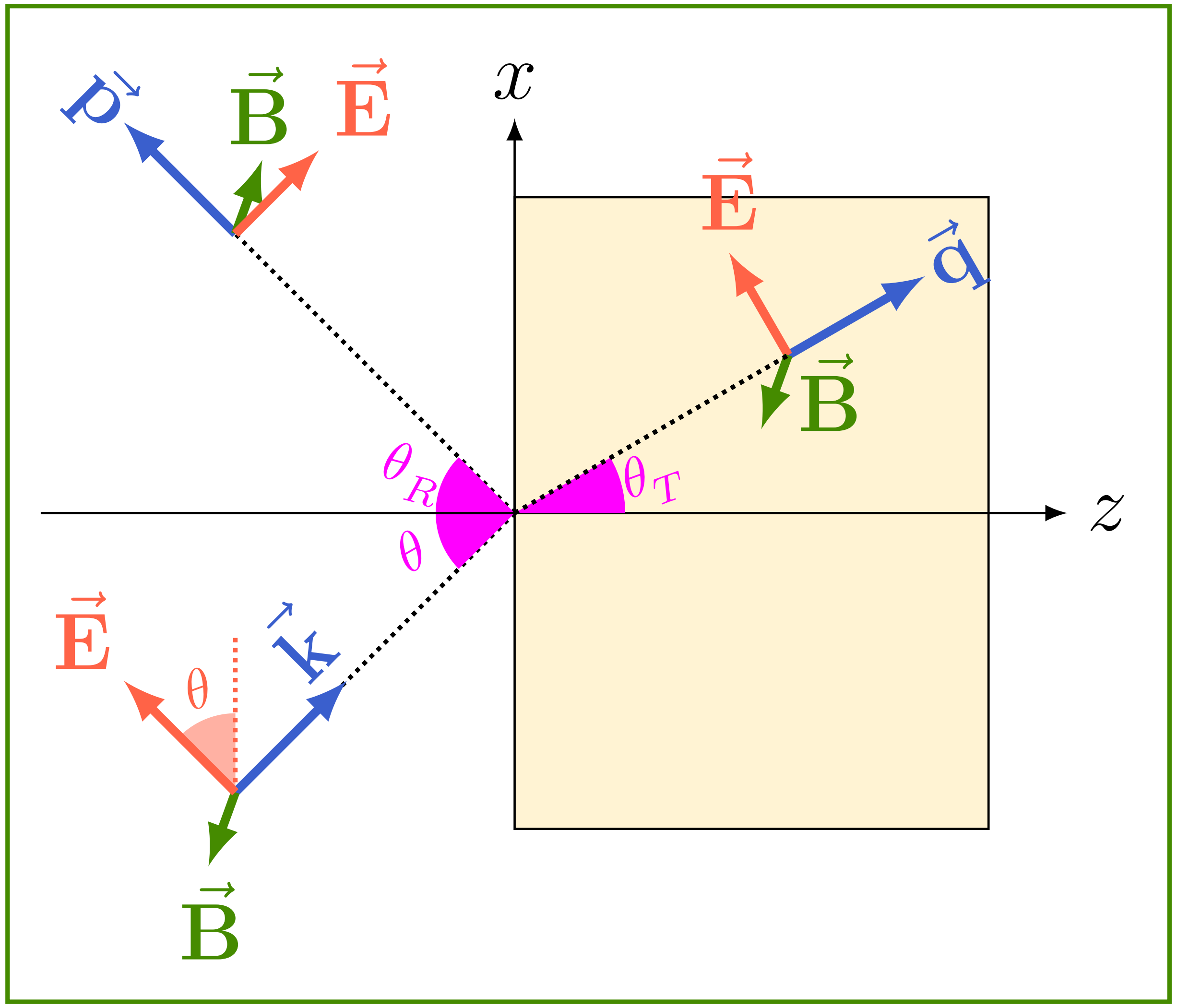

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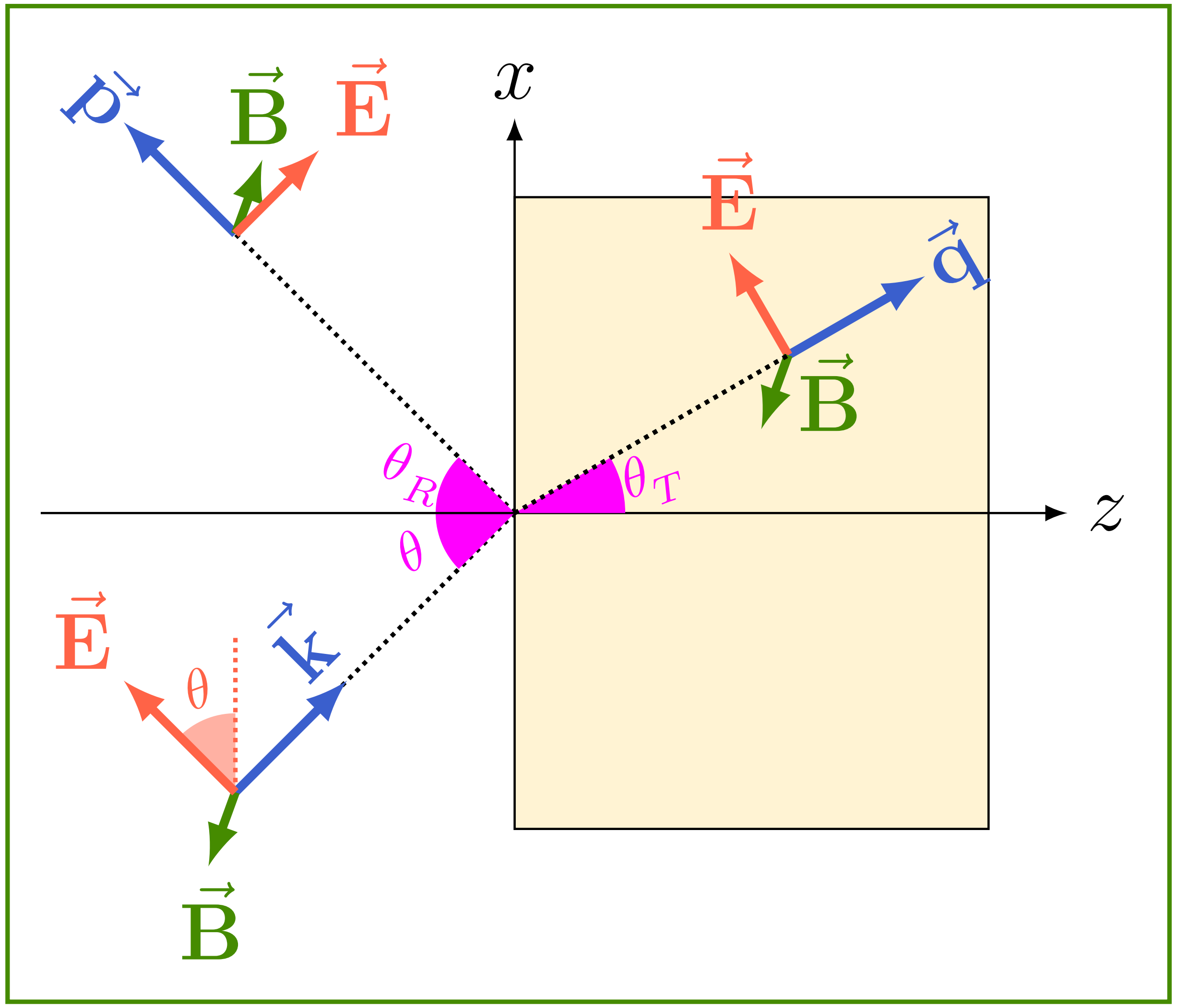
$$kc = pc = q\frac{c}{n}$$



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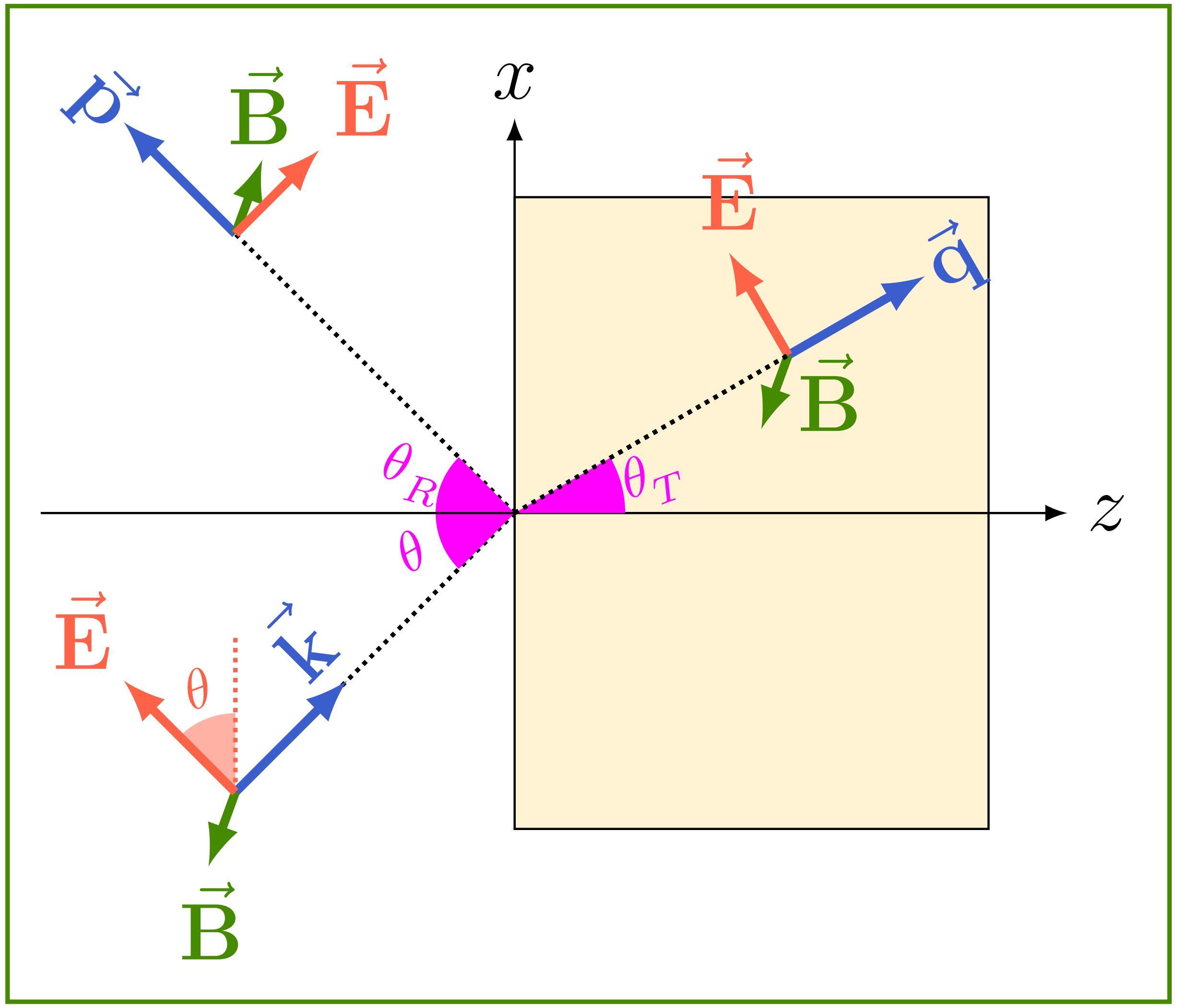
$$k = p = \frac{q}{n}$$

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



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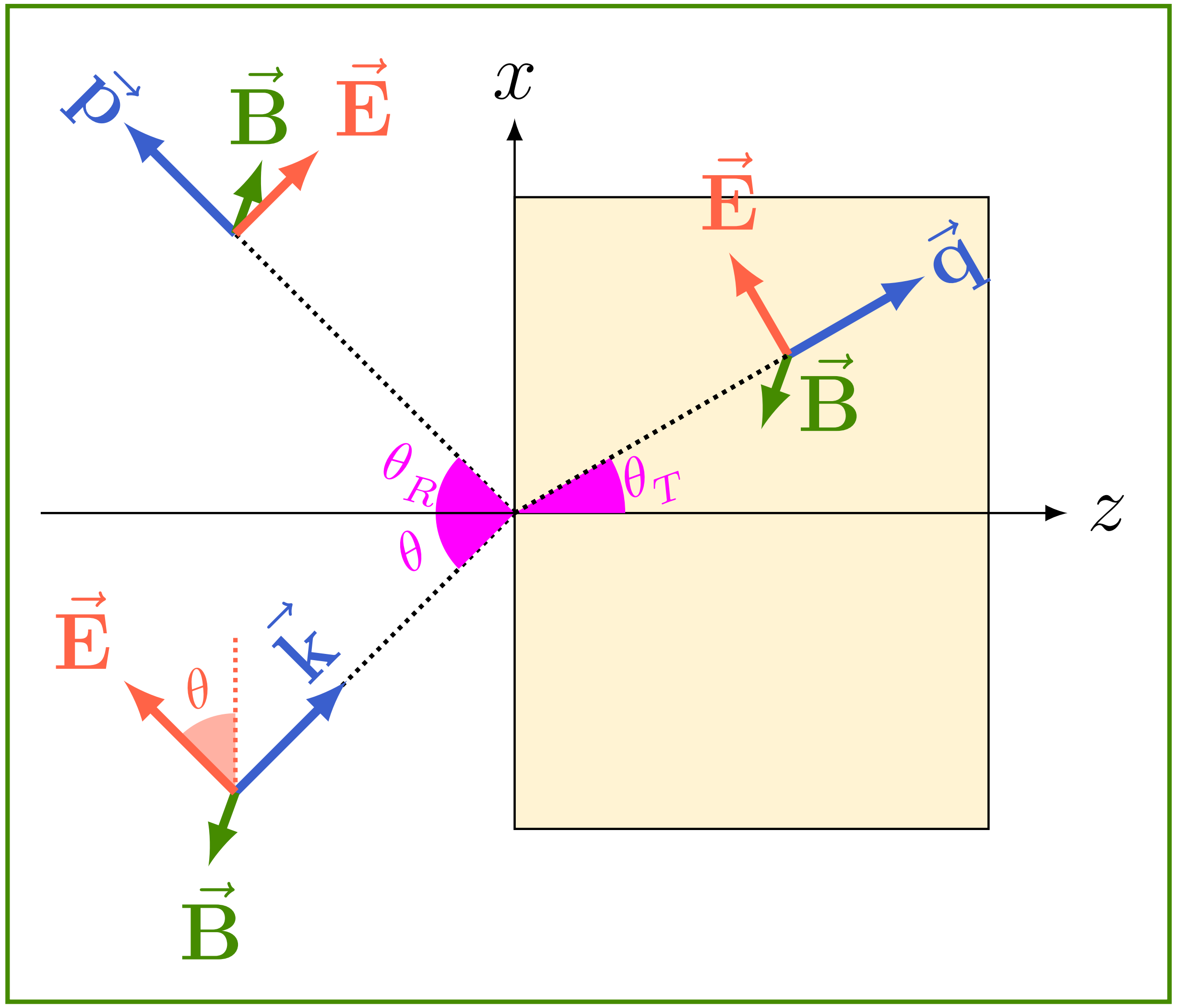

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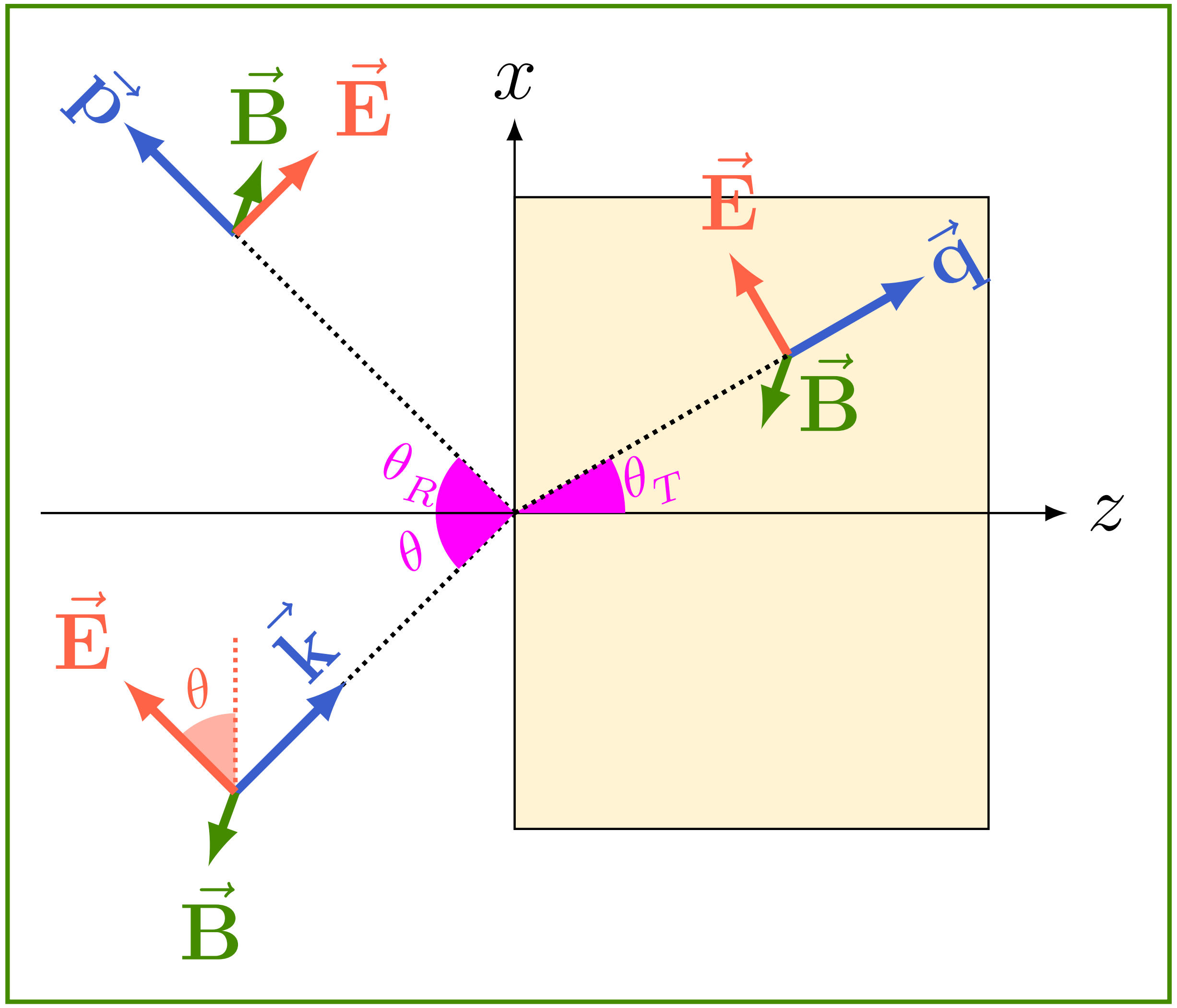
$$\theta_I = \theta_R$$

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



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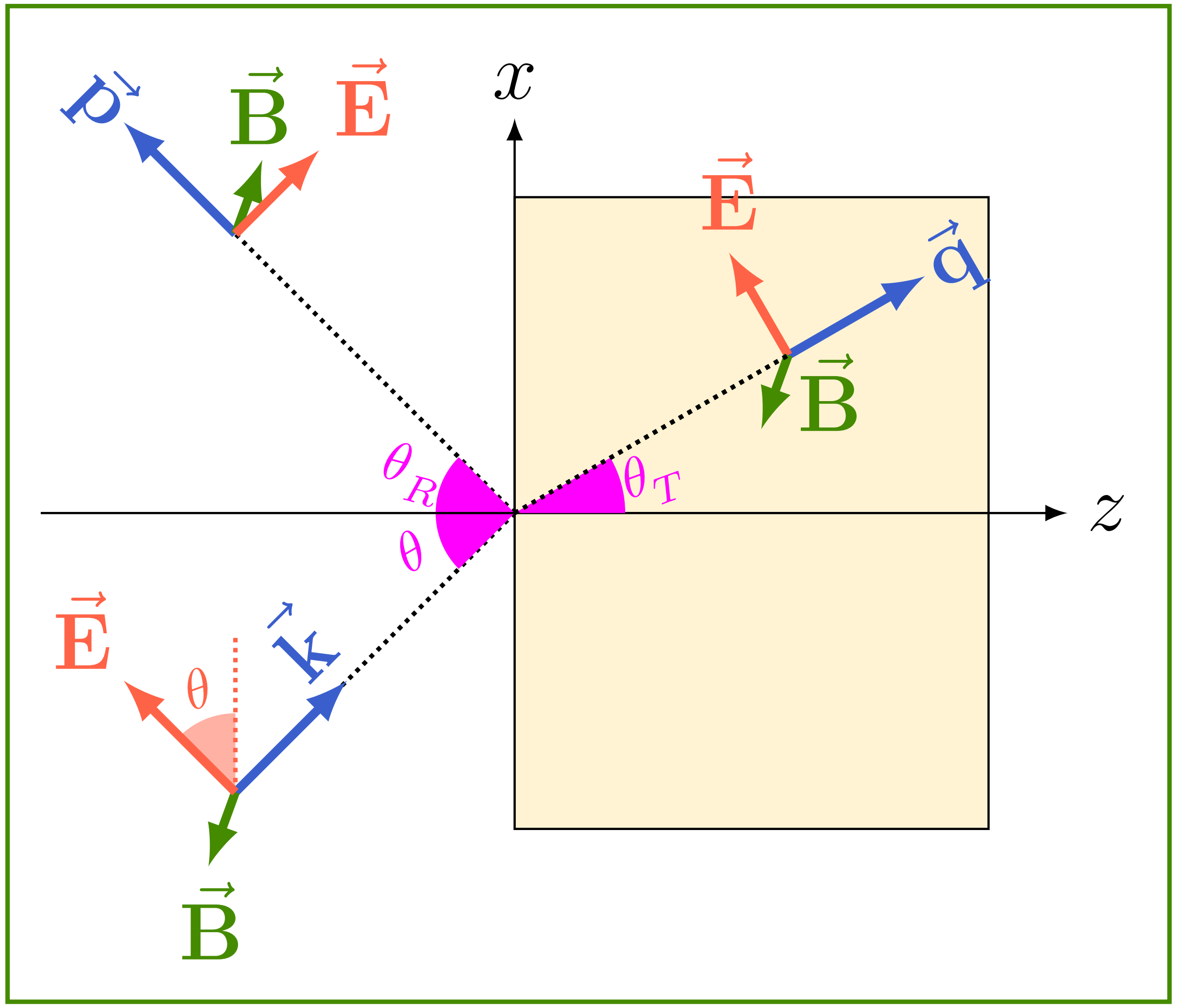

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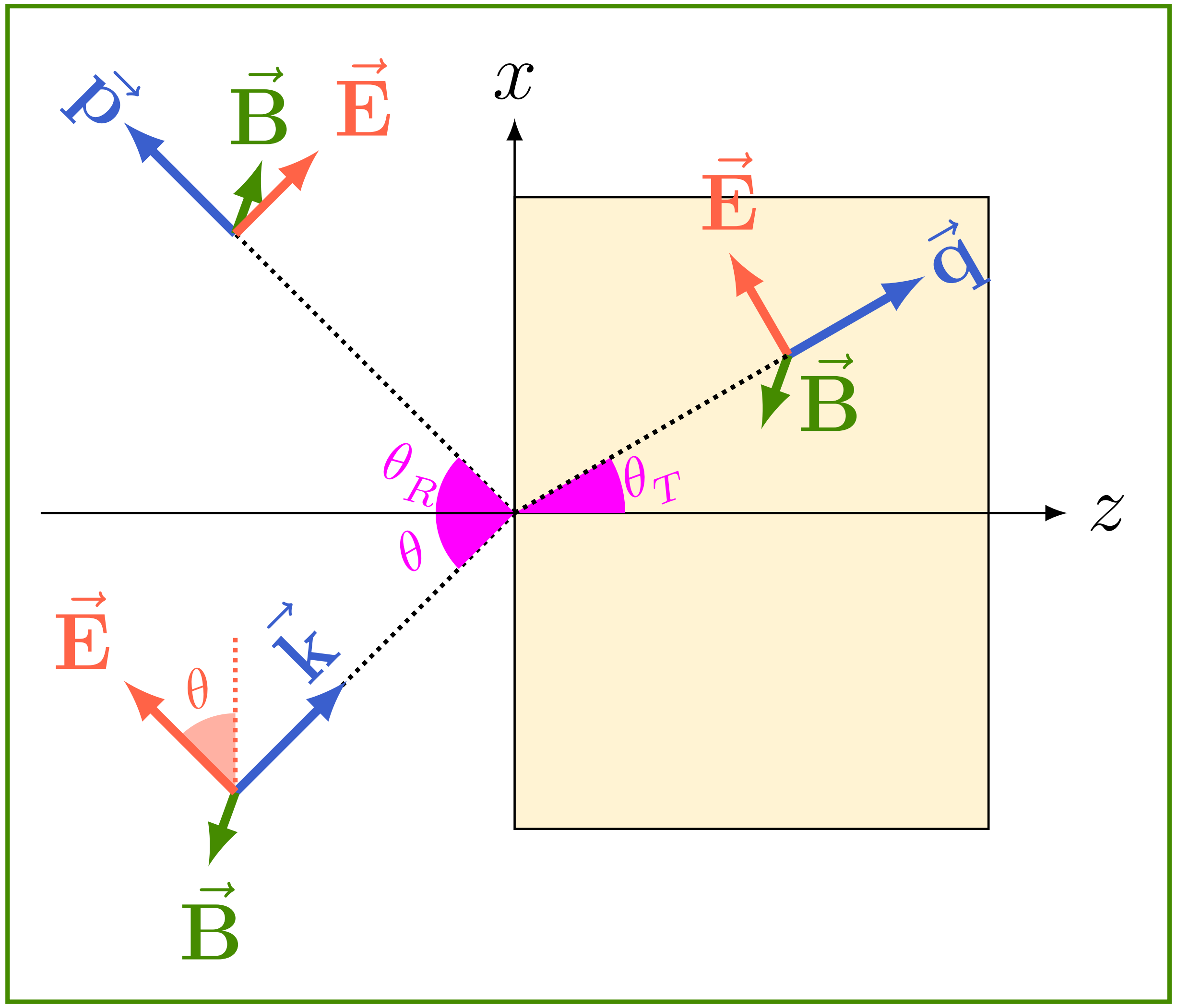
$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$



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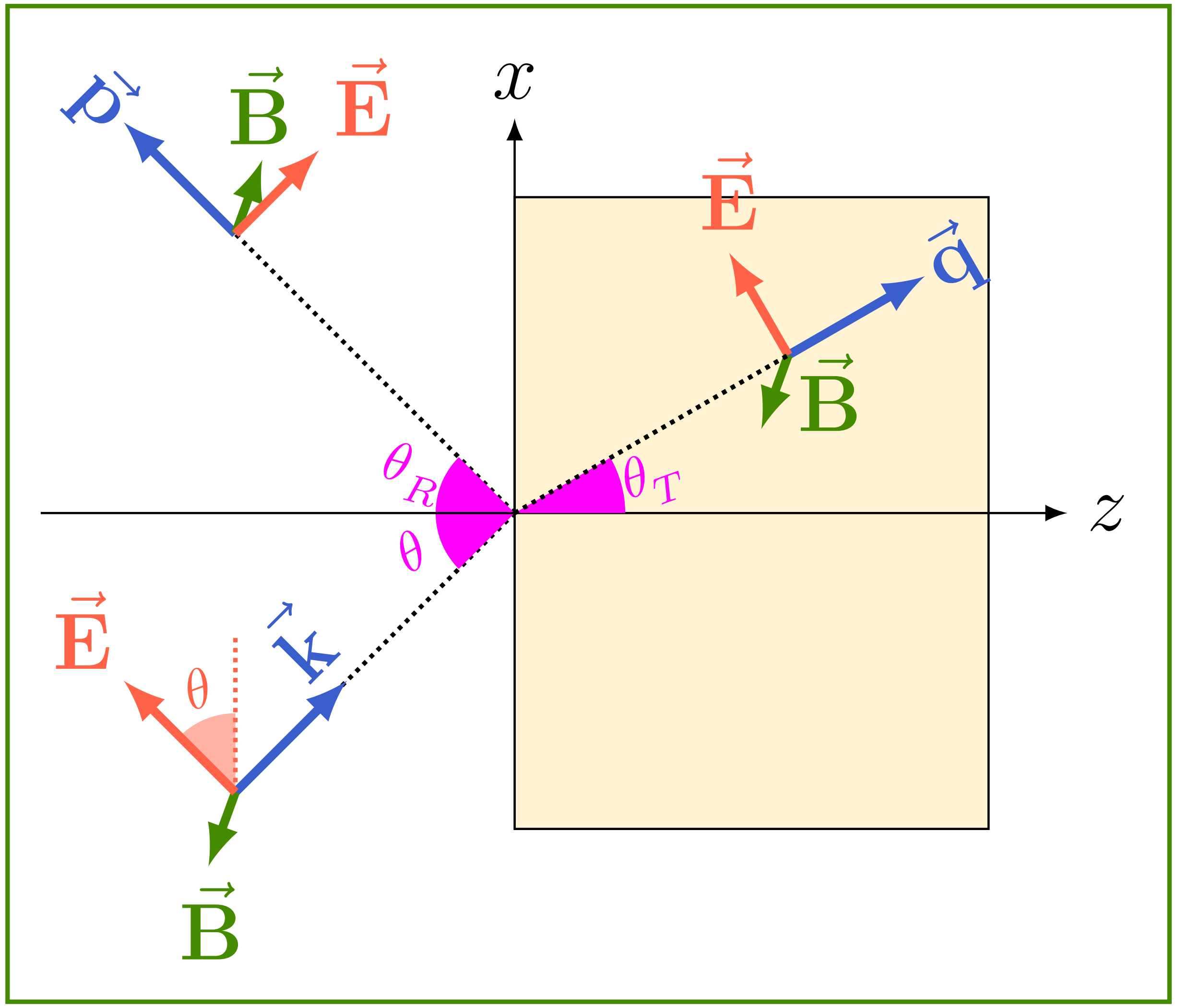

$$\epsilon_0(\tilde{E}_{0z} + \tilde{E}_{0Rz}) = \epsilon \tilde{E}_{0Tz}$$

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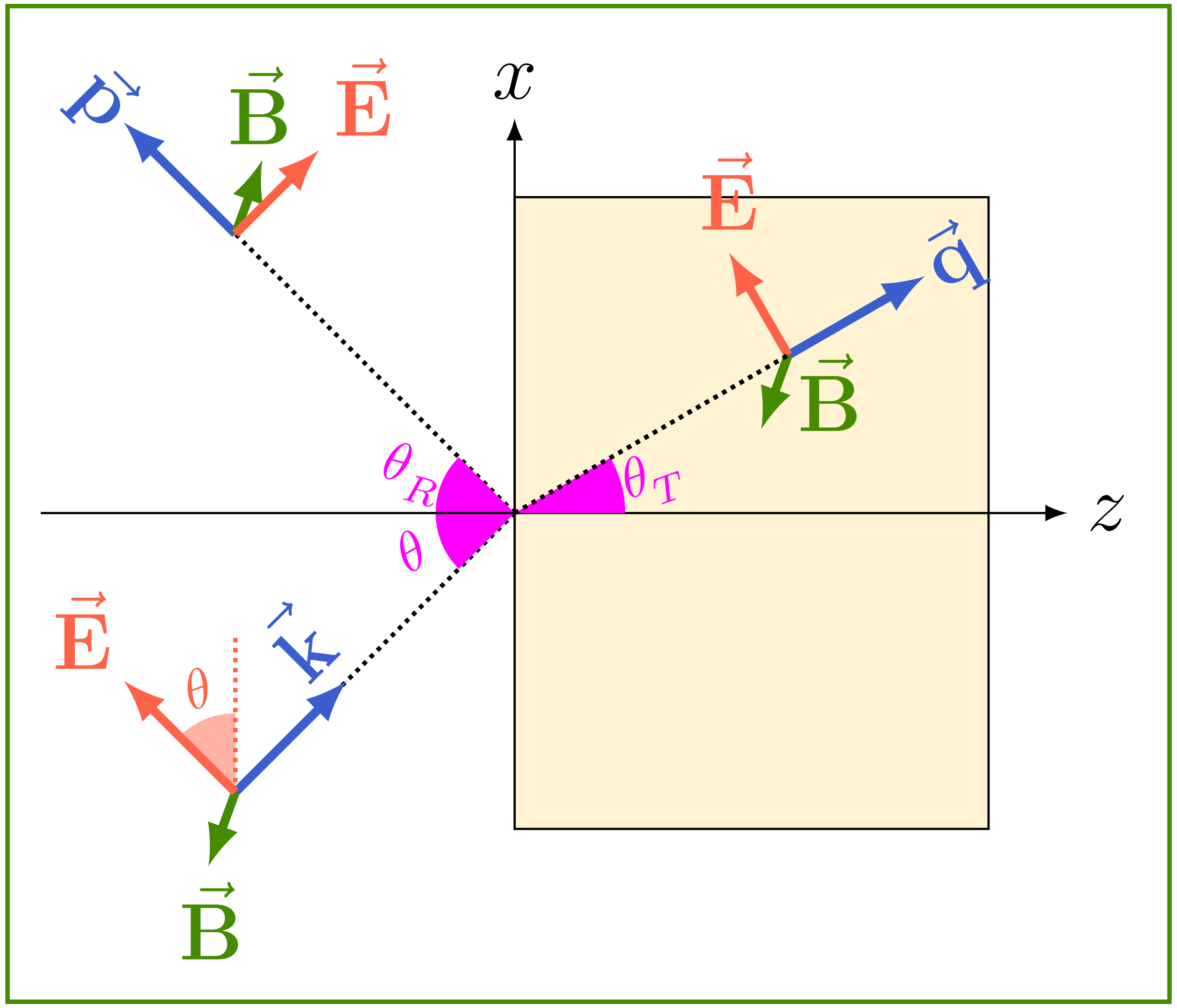

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$$-E_0 \sin\theta + E_{0R} \sin\theta = -n^2 E_{0T} \sin\theta_T$$

Incidência oblíqua

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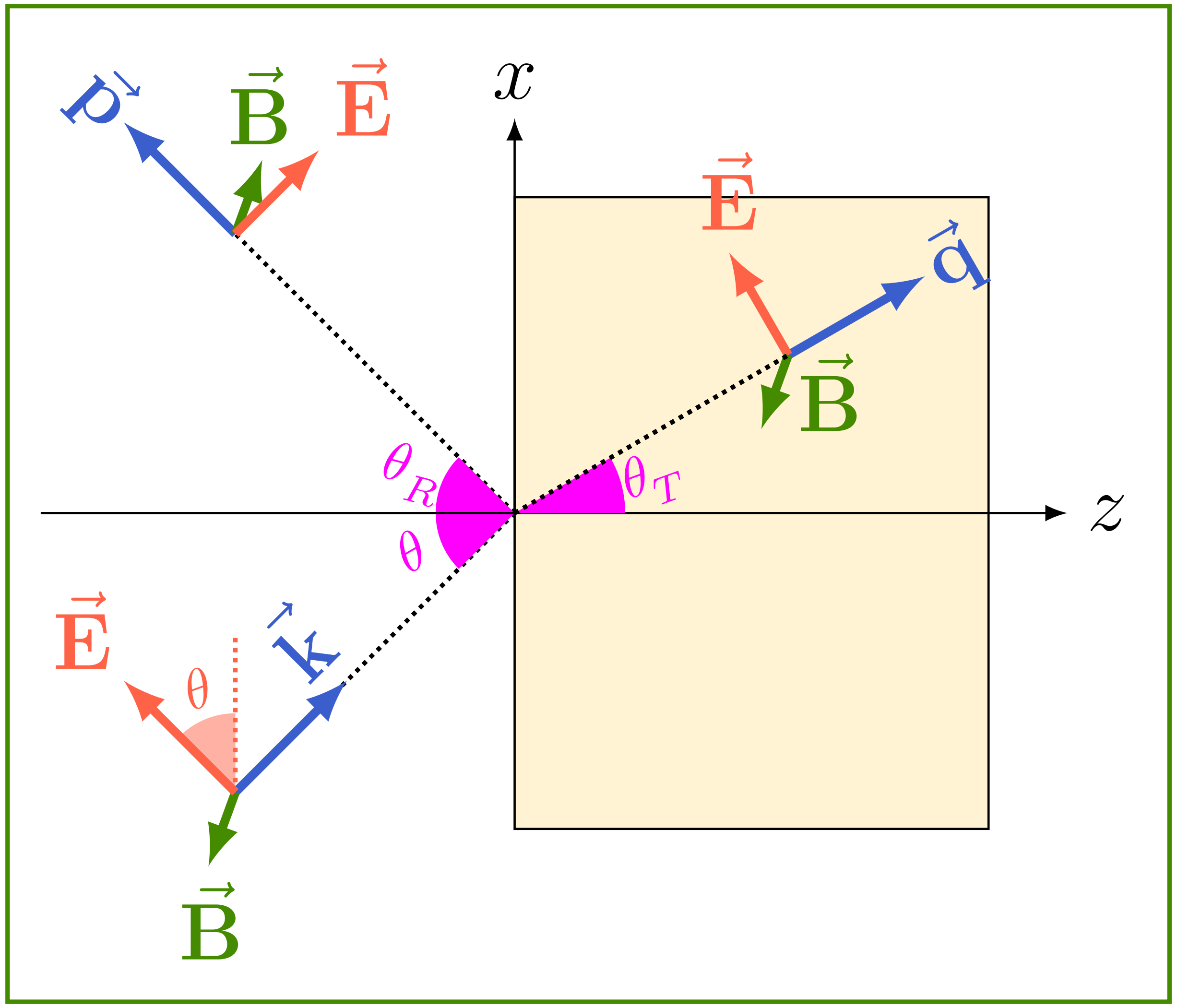

$$E_0 - E_{0R} = nE_{0T}$$

Incidência oblíqua

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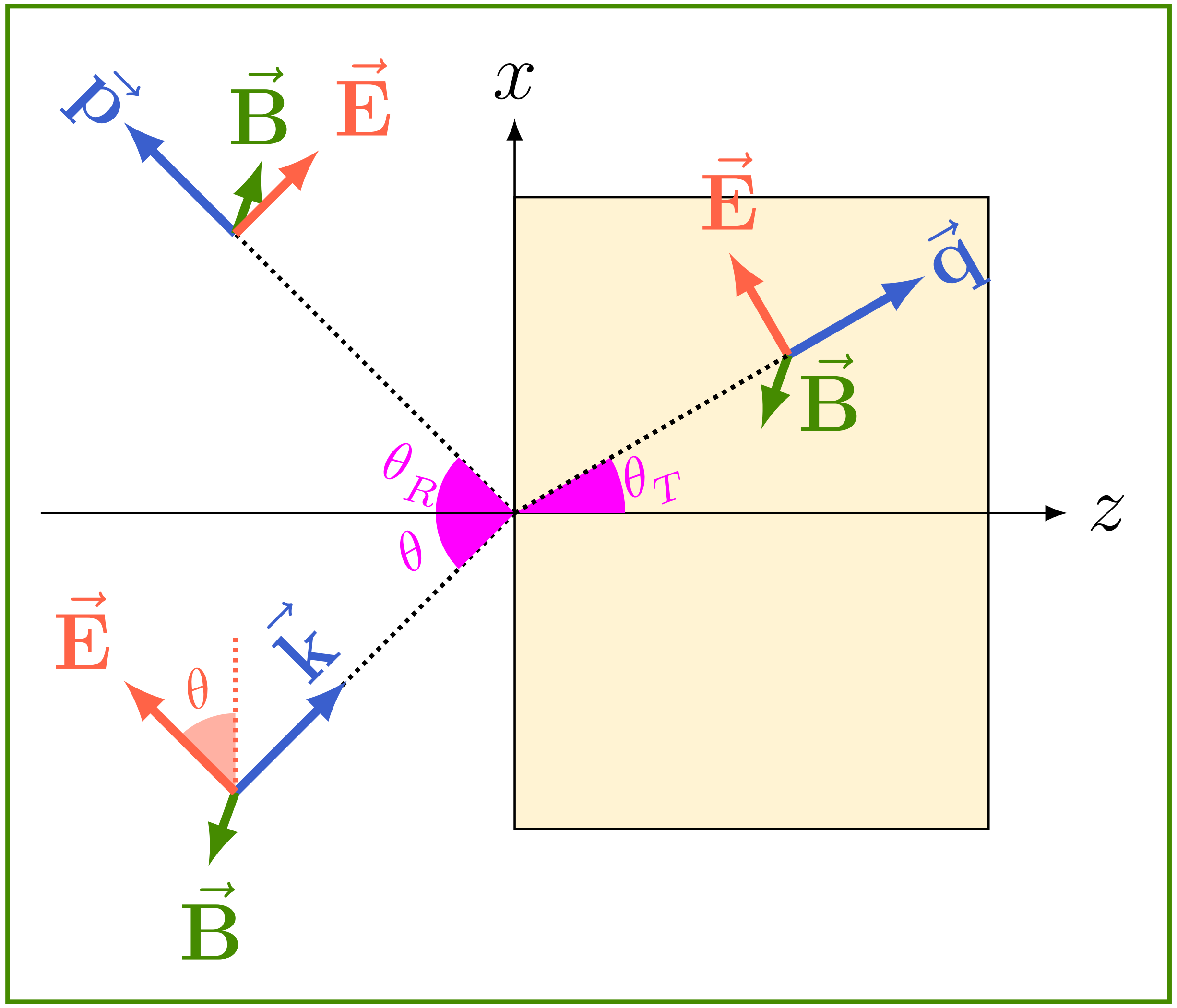

$$E_0 \cos\theta + E_{0R}\cos\theta = E_{0T}\cos\theta_T$$

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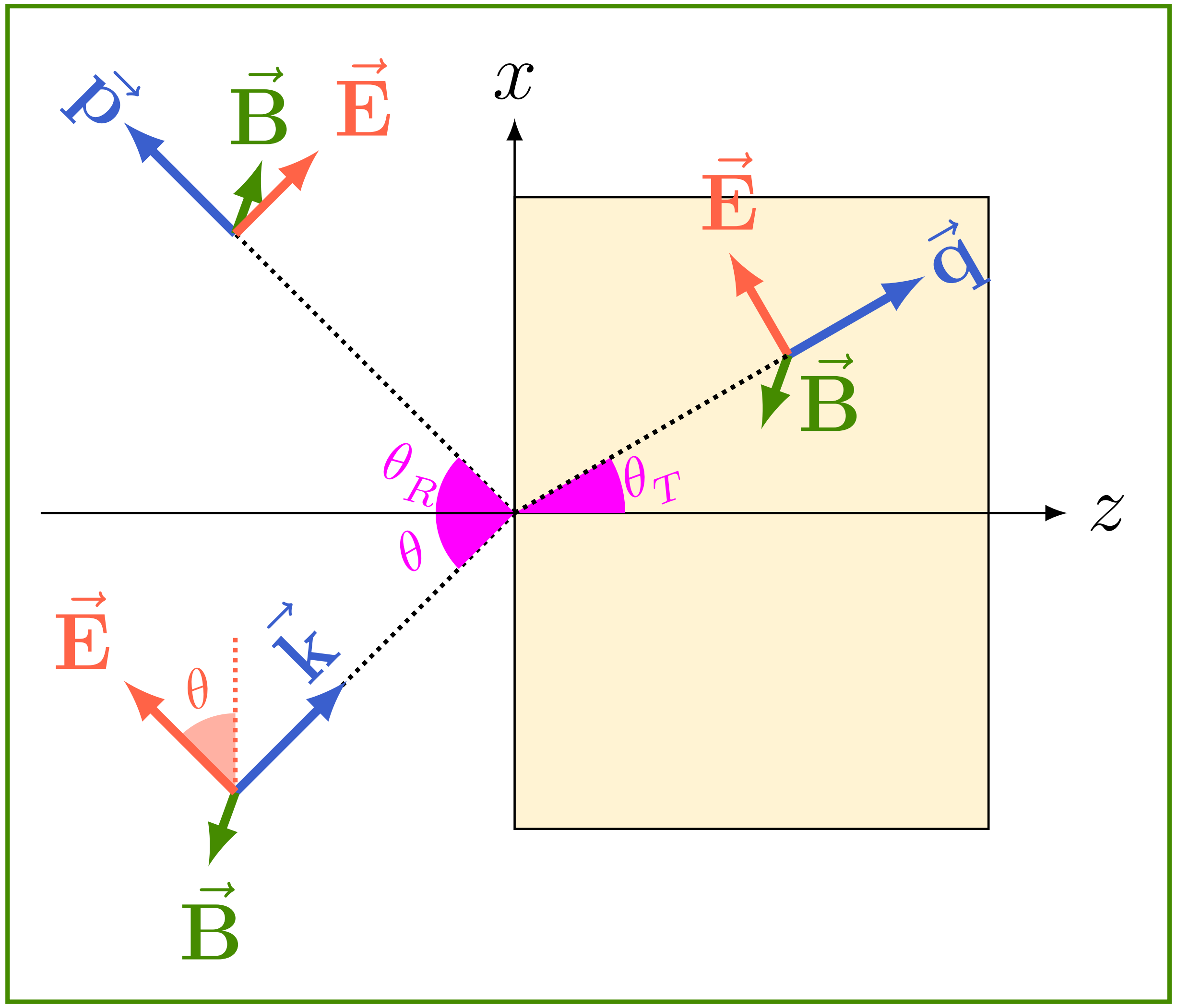

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$$E_0 - E_{0R} = nE_{0T}$$

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

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

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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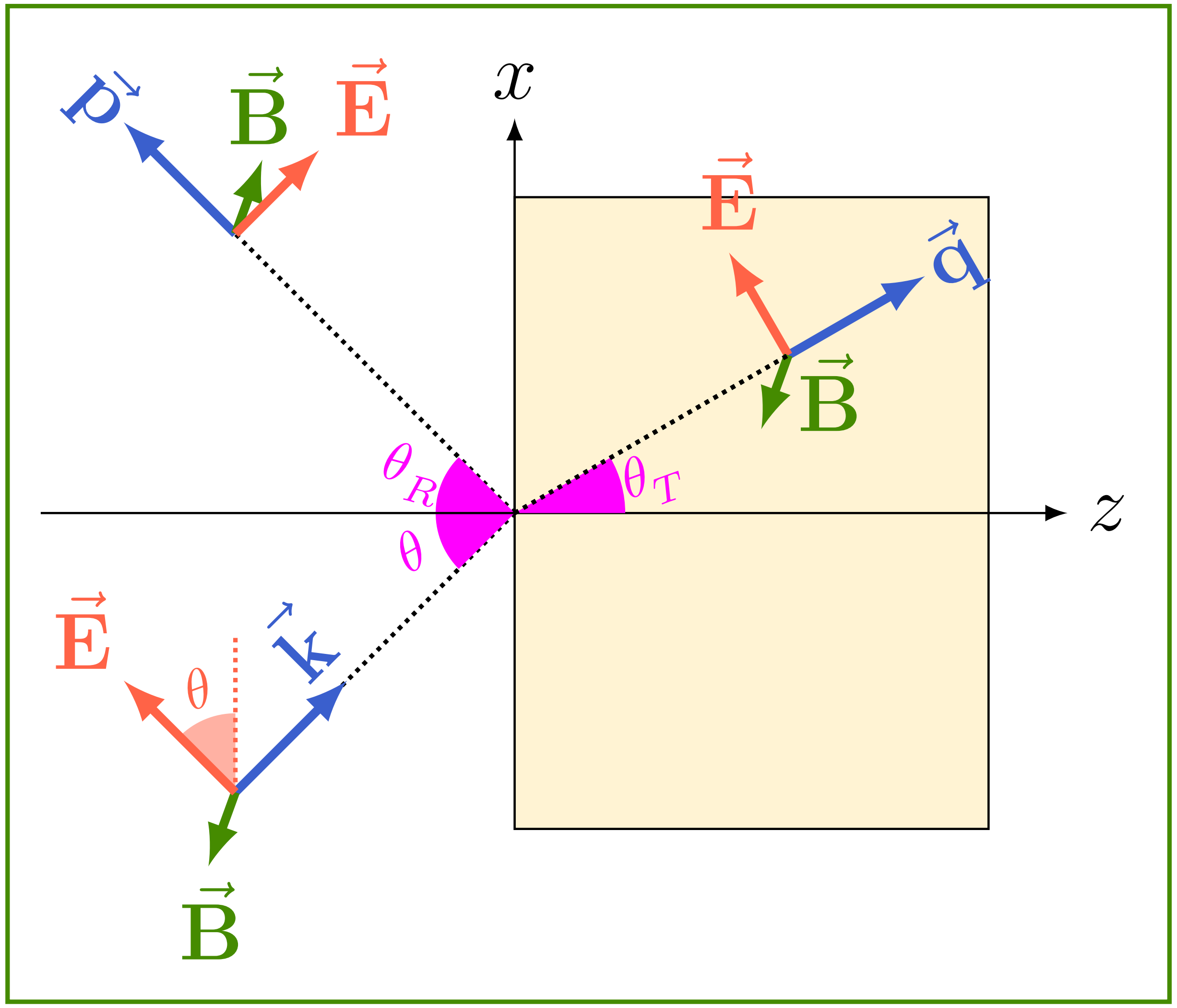

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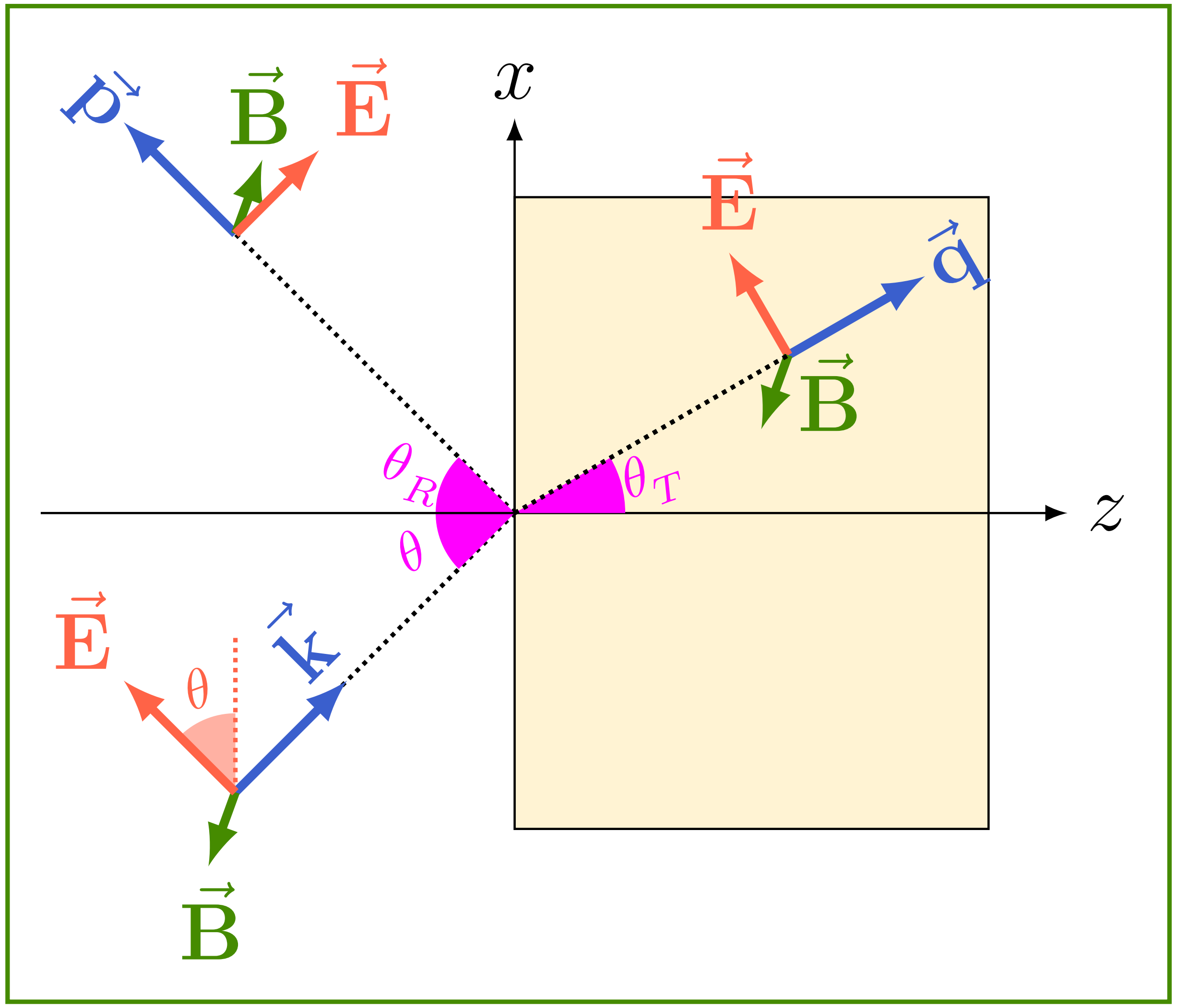

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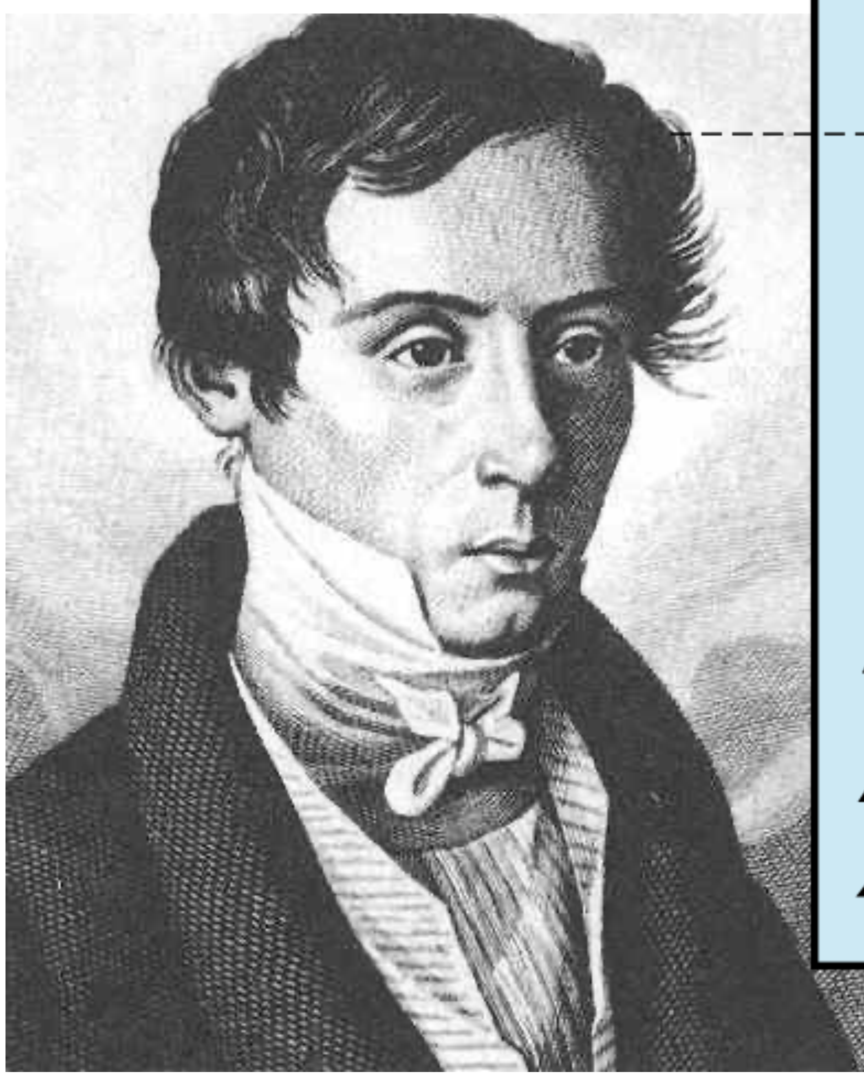
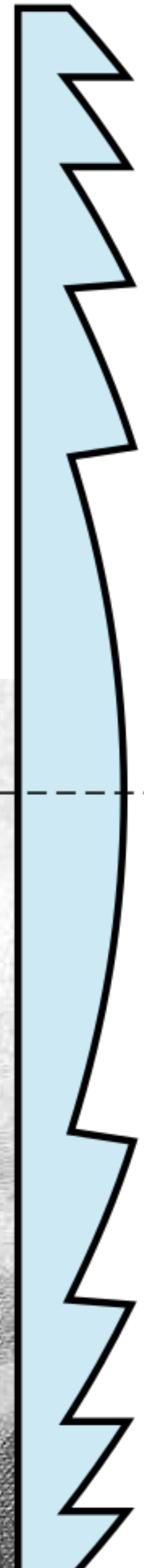
Inc[illegible]ência oblíqua

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

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



Augustin Fresnel



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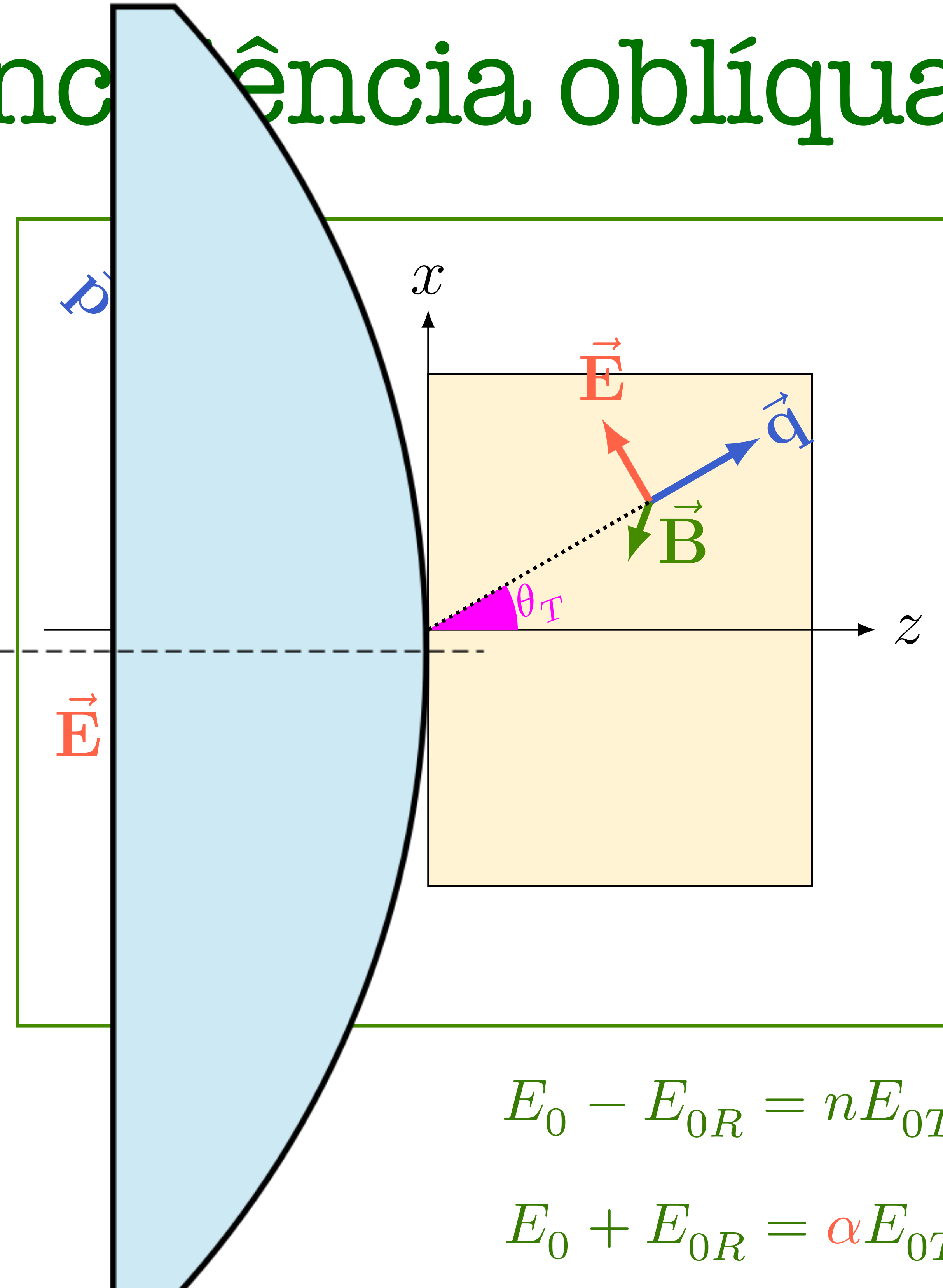

2

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

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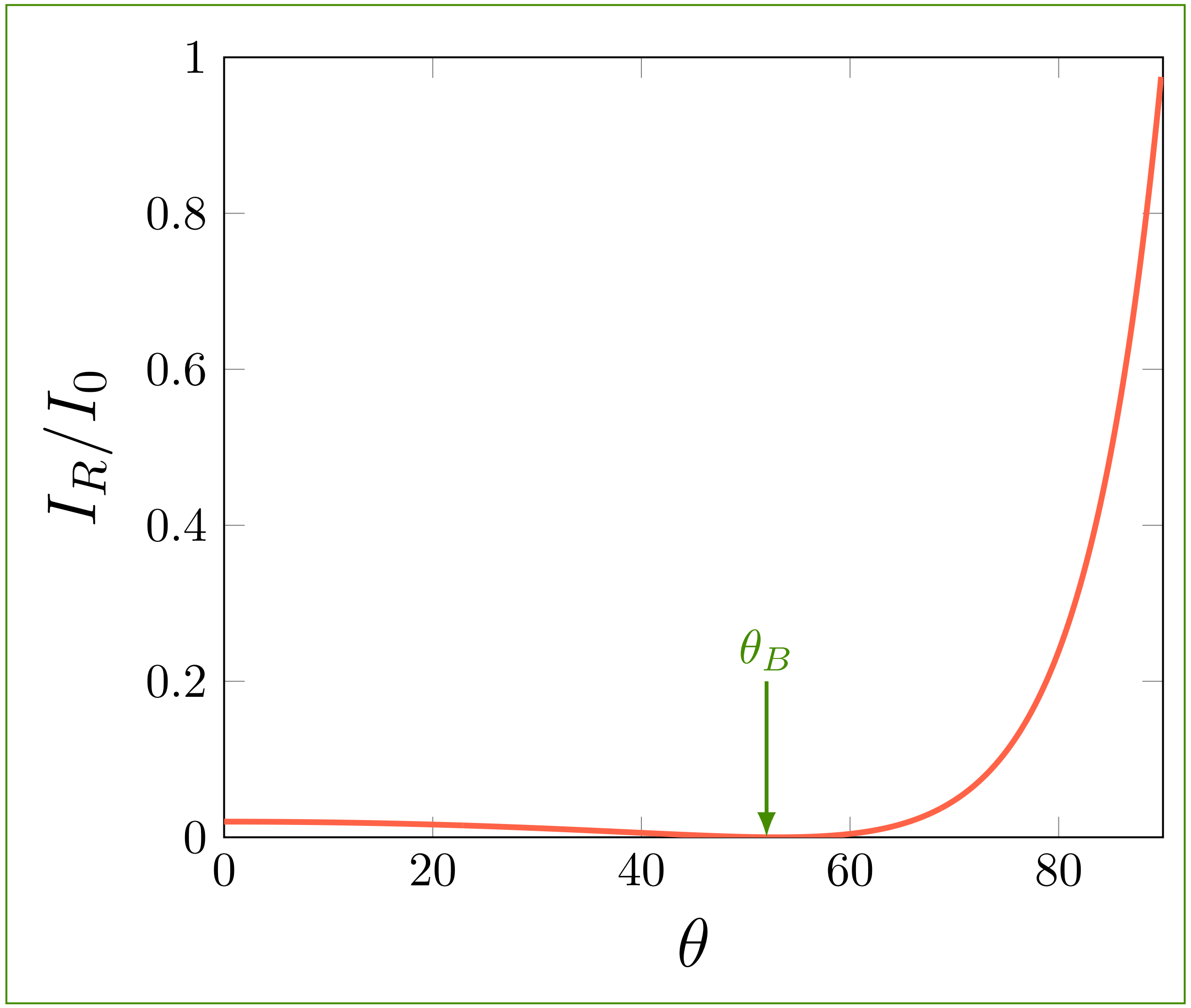
$$\alpha \equiv \frac{\cos\theta_T}{\cos\theta}$$

Incidência oblíqua

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

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

$$sin(\theta_B) = \frac{n}{\sqrt{1+n^2}} \Rightarrow \quad I_R = 0$$



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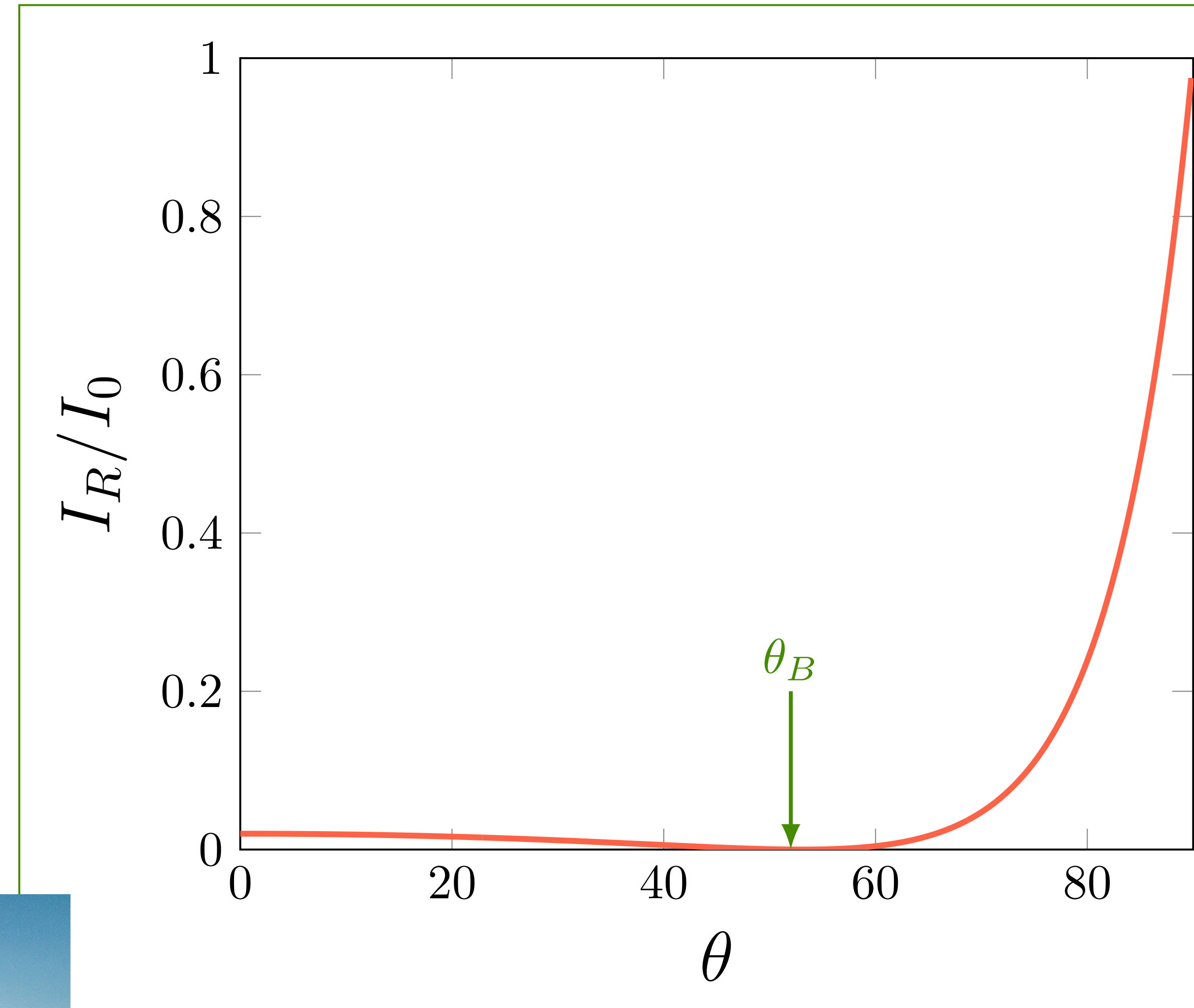

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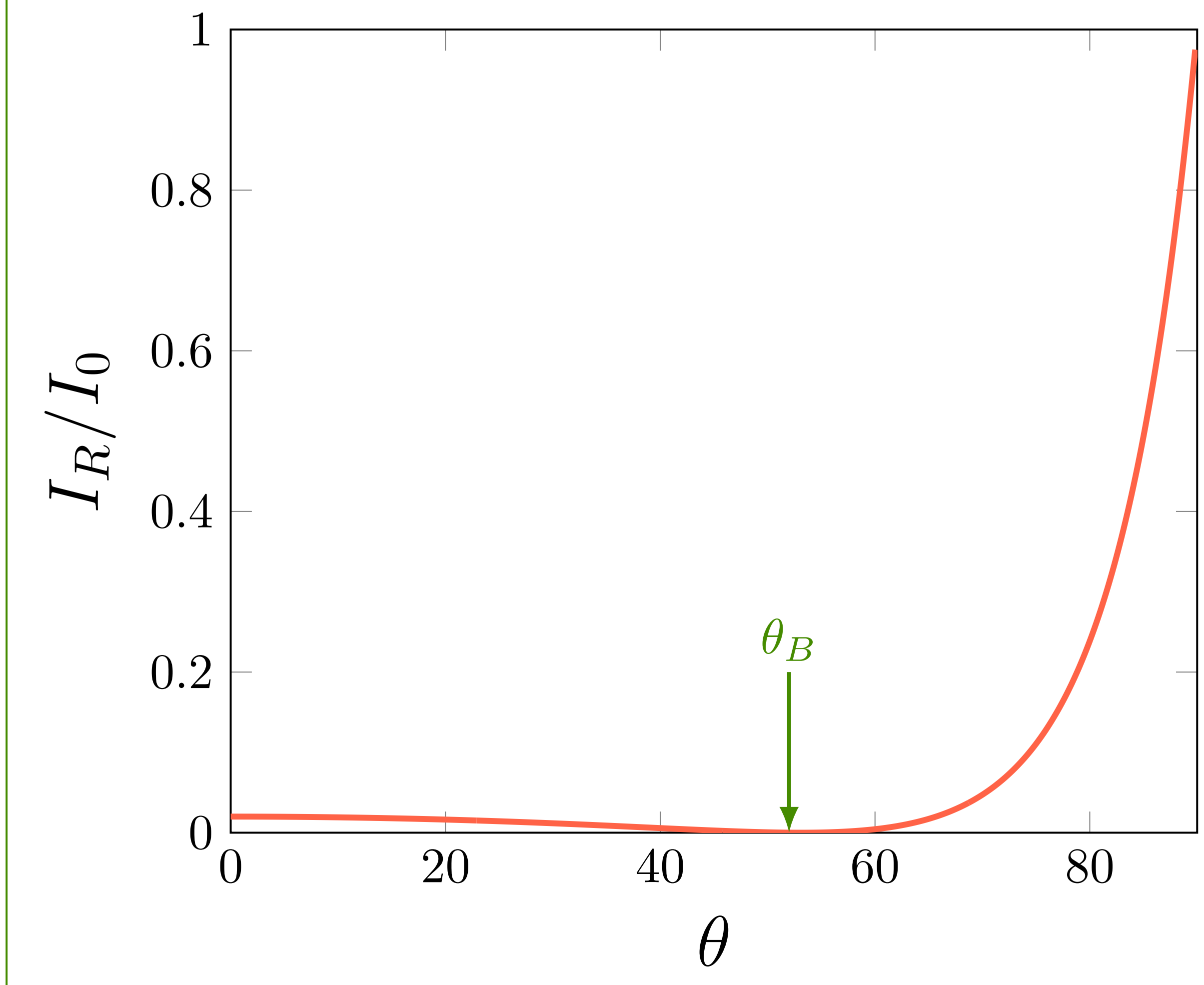

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Meios condutores

$$\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} = \mu\sigma\vec{\mathbf{E}} + \mu\epsilon\frac{\partial\vec{\mathbf{E}}}{\partial t}$$

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$$\vec{\nabla} \times \vec{\mathbf{B}} = \mu\sigma\vec{\mathbf{E}} + \mu\epsilon\frac{\partial\vec{\mathbf{E}}}{\partial t}$$

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

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

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$$\tilde{k}^2 = \mu\epsilon\omega^2 + i\mu\sigma\omega$$

$$\tilde{k}^2 = \left(\frac{\omega}{v}\right)^2\left(1 + \frac{i}{\omega\tau}\right) \qquad \left(\tau \equiv \frac{\epsilon}{\sigma}\right)$$

$$\tilde{k} = k + i\kappa$$

Meios condutores

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Meios condutores

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TIBTECH Innovations (TIBTECH innovations logo)	Electric conductivity [illegible].E6 Siemens/m)	Electric resistivity (10.E-8 Ohms.m)
Silver	62,1	1,6
Copper	58,7	1,7
Gold	44,2	2,3
Aluminium	36,9	2,7
Molybdenum	18,7	5,34
Zinc	16,6	6,0
Lithium	10,8	9,3
Brass	15,9	6,3
Nickel	14,3	7,0
Steel	10,1	9,9
Palladium	9,5	10,5
Platinium	9,3	10,8
Tungsten	8,9	11,2

Tipicamente $\omega\tau << 1$

Meios condutores

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$$\tilde{k}^2 = \mu\epsilon\omega^2 + i\mu\sigma\omega$$

Tipicamente $\omega\tau << 1$

$$\tilde{k}^2 = \left(\frac{\omega}{v}\right)^2\left(1 + \frac{i}{\omega\tau}\right) \qquad \left(\tau \equiv \frac{\epsilon}{\sigma}\right)$$

$$\tilde{k} = \left(\frac{\omega}{v}\right)\frac{1}{\sqrt{2\omega\tau}}(1+i)$$

Meios condutores

$$\vec{\nabla} \times \vec{\mathbf{B}} = \mu\sigma\vec{\mathbf{E}} + \mu\epsilon\frac{\partial\vec{\mathbf{E}}}{\partial t}$$

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

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

$$\tilde{\mathbf{E}} = \tilde{E}_0 e^{i(\tilde{k}z-\omega t)}\hat{x}$$

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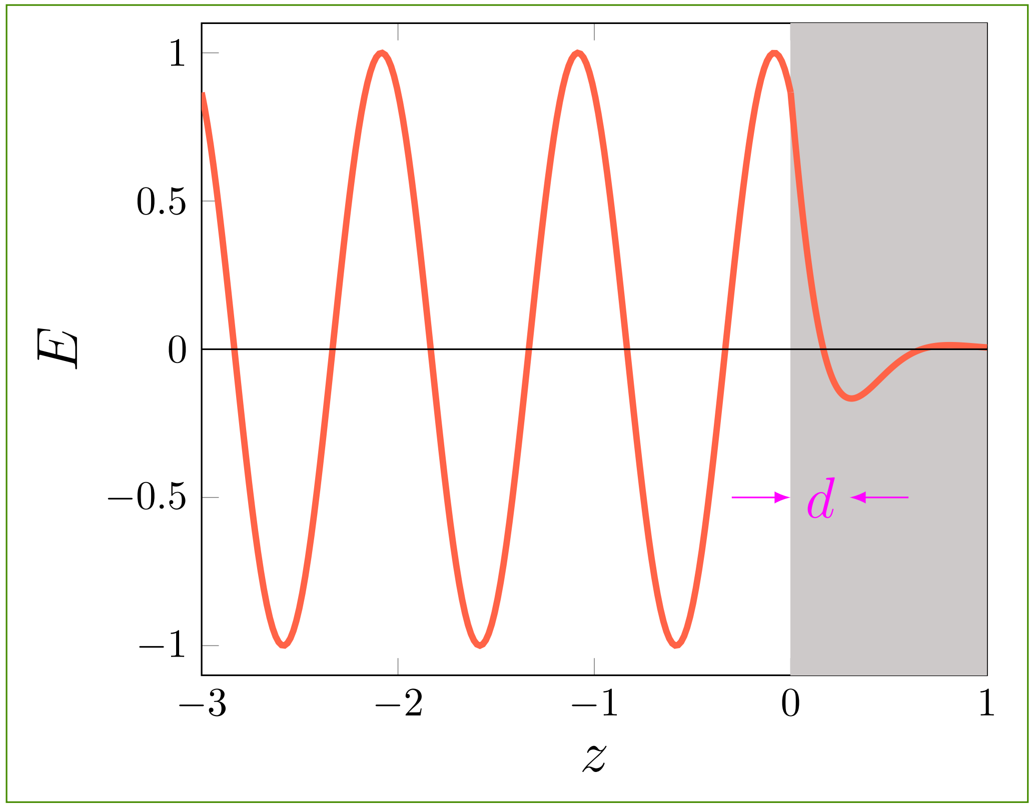

$$\tilde{\mathbf{E}} = \tilde{E}_0 e^{i(\tilde{k}z-\omega t)}\hat{x}$$

$$\tilde{E} = e^{-\kappa z}\tilde{E}_0 e^{i(kz-\omega t)}$$

$$\tilde{k}^2 = \mu\epsilon\omega^2 + i\mu\sigma\omega$$

Tipicamente $\omega\tau << 1$

$$\tilde{k}^2 = \left(\frac{\omega}{v}\right)^2\left(1 + \frac{i}{\omega\tau}\right) \qquad \left(\tau \equiv \frac{\epsilon}{\sigma}\right)$$

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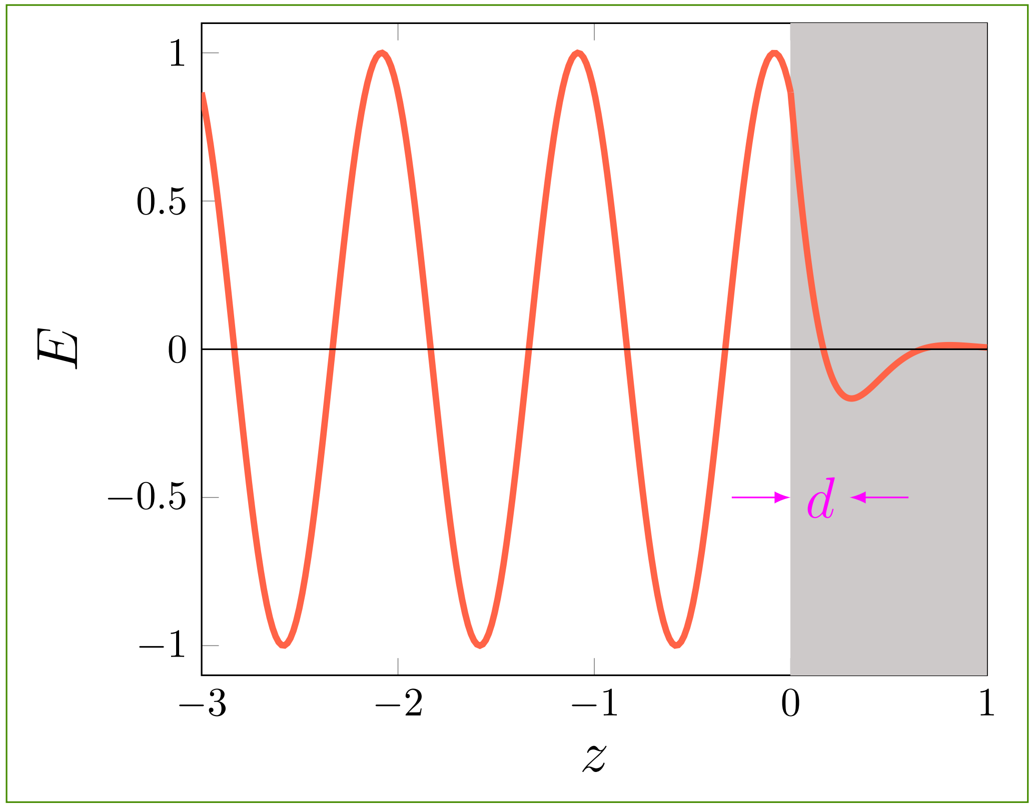

$$\tilde{\mathbf{E}} = \tilde{E}_0 e^{i(\tilde{k}z-\omega t)}\hat{x}$$

$$\tilde{\mathbf{B}} = \frac{1}{v}\tilde{\mathbf{k}} \times \tilde{\mathbf{E}}$$

Meios condutores

$$\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} = \mu\sigma\vec{\mathbf{E}} + \mu\epsilon\frac{\partial\vec{\mathbf{E}}}{\partial t}$$

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

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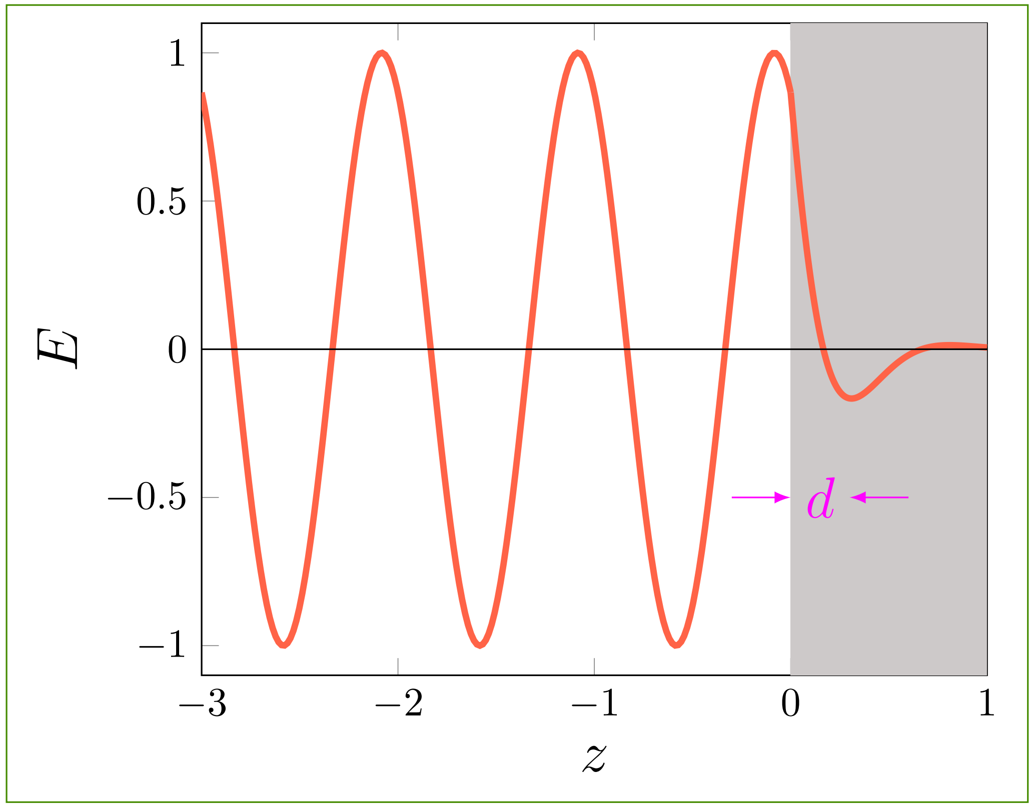

$$\tilde{\mathbf{E}} = \tilde{E}_0 e^{i(\tilde{k}z-\omega t)}\hat{x}$$

$$\tilde{\mathbf{B}} = \frac{\tilde{k}}{v}\tilde{E}_0 e^{i(\tilde{k}z-\omega t)}\hat{y}$$

B e E fora de fase

Augustin Fresnel