4302212 – Física IV

Ondas Eletromagnéticas – II

– **Vácuo**: ausência de cargas ($\rho = 0$) e correntes ($\mathbf{j} = \mathbf{0}$) elétricas

$$\nabla \cdot \mathbf{E} = 0 \qquad \nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad \nabla \times \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

– Componentes escalares dos campos:

$$\nabla^2 E_i - \mu_0 \epsilon_0 \frac{\partial^2 E_i}{\partial t^2} = 0 \qquad \nabla^2 B_i - \mu_0 \epsilon_0 \frac{\partial^2 B_i}{\partial t^2} = 0$$

– Velocidade de propagação:

$$v = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.9977925 \times 10^8 \ \mathrm{m/s}$$

Ondas EM: Transversais

– Iremos considerar ondas EM em 1D:

$$\frac{\partial^2 f}{\partial z^2} - \frac{1}{v^2}\frac{\partial^2 f}{\partial t^2} = 0$$

$$f = F(z - vt) + G(z + vt)$$

– Soluções propagantes:

$$\mathbf{E} = \mathbf{E}(z - ct) \qquad \mathbf{B} = \mathbf{B}(z - ct)$$

– Condições a impor:

$$\nabla \cdot \mathbf{E} = 0 \qquad \nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t} \qquad \nabla \times \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

– Soluções independentes:

$$\frac{\partial E_y}{\partial z} = \frac{\partial B_x}{\partial t}$$

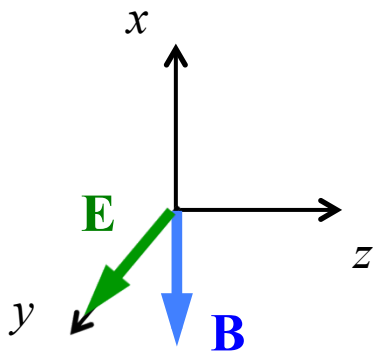
$$\frac{\partial B_x}{\partial z} = \frac{1}{c^2}\frac{\partial E_y}{\partial t}$$

$$\frac{\partial B_y}{\partial z} = -\frac{1}{c^2}\frac{\partial E_x}{\partial t}$$

$$\frac{\partial E_x}{\partial z} = -\frac{\partial B_y}{\partial t}$$

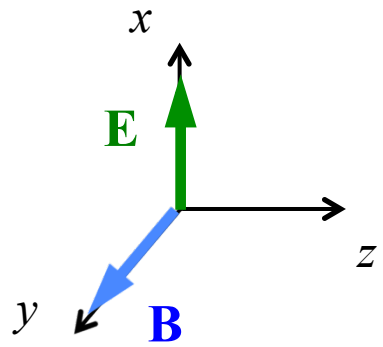
$$\mathbf{E} = E_y(z - ct)\,\hat{\mathbf{y}}$$

$$\mathbf{B} = \frac{1}{c}\hat{\mathbf{z}} \times \mathbf{E}$$



$$\mathbf{E} = E_x(z - ct)\,\hat{\mathbf{x}}$$

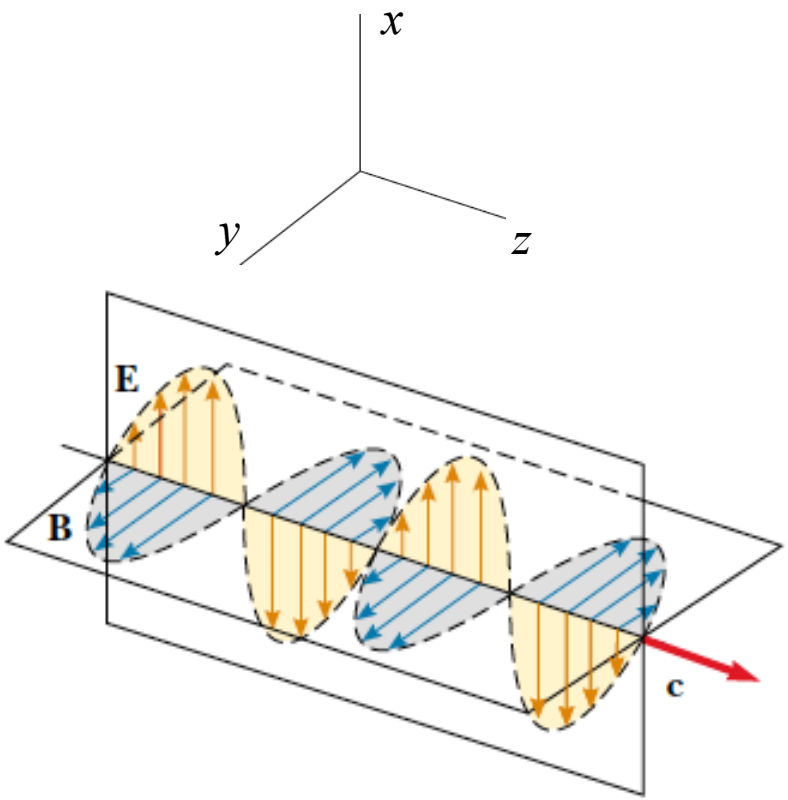
$$\mathbf{B} = \frac{1}{c}\hat{\mathbf{z}} \times \mathbf{E}$$



Ondas EM Monocromáticas

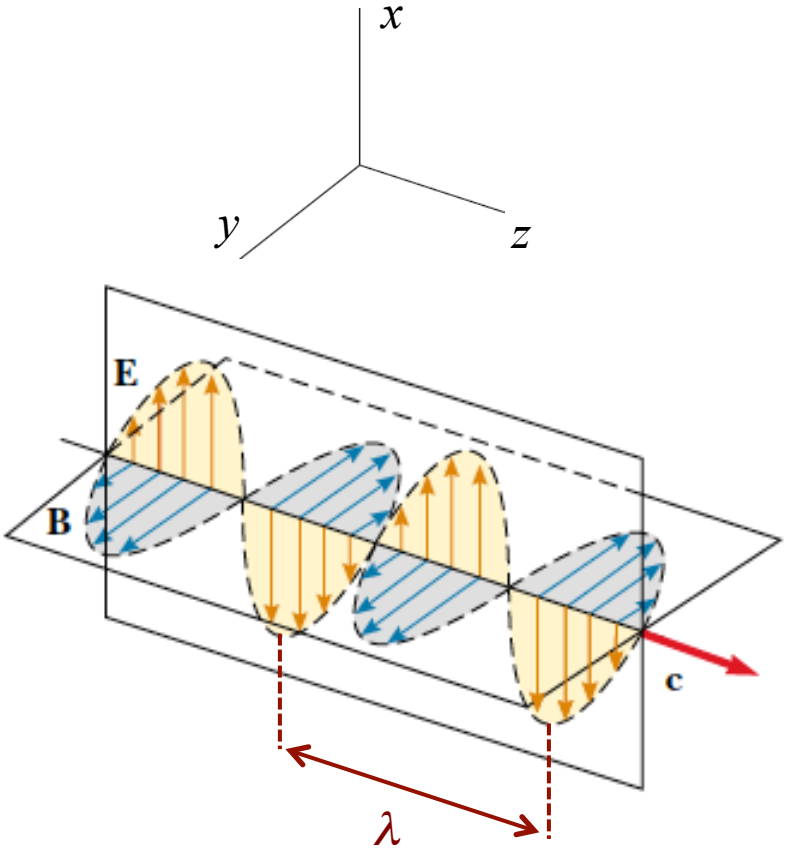
$$E_x(z,t) = E_{\max}\cos[k(z-ct)+\phi] \;=\; E_{\max}\cos(kz-\omega t+\phi)$$

$$\omega \;=\; kc$$



$$B_y = \frac{1}{c}E_{\max}\cos(kz-\omega t+\phi)$$

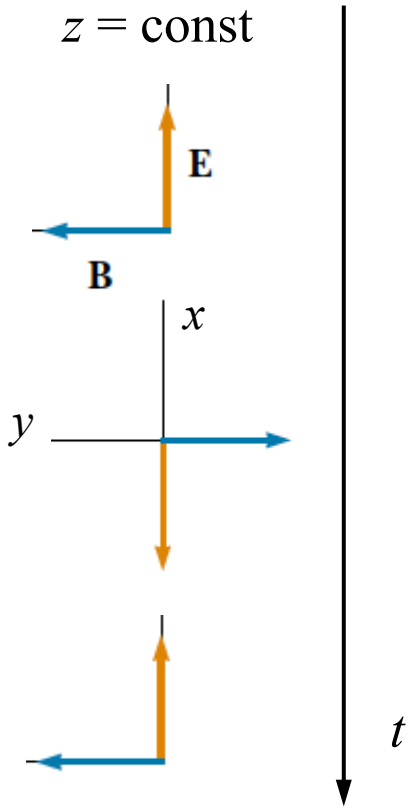
$$= B_{\max}\cos(kz-\omega t+\phi)$$



– Periodicidade espacial:

$$\mathbf{E} = E_{\max} \cos(kz - \omega t + \phi)\ \hat{\mathbf{x}}$$

$$\lambda = \frac{2\pi}{k}$$



– Periodicidade temporal:

$$\mathbf{E} = E_{\max} \cos(kz - \omega t + \phi)\ \hat{\mathbf{x}}$$

$$T = \frac{2\pi}{\omega}$$