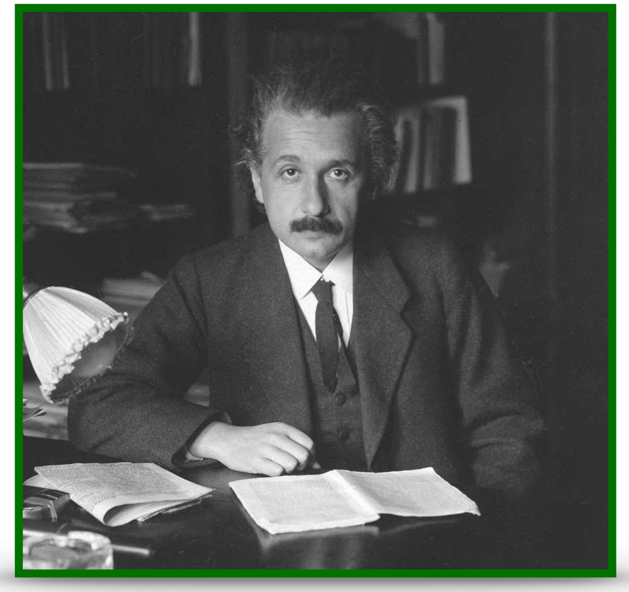
Eletromagnetismo Avançado

4º ciclo
Aula de 10 de dezembro

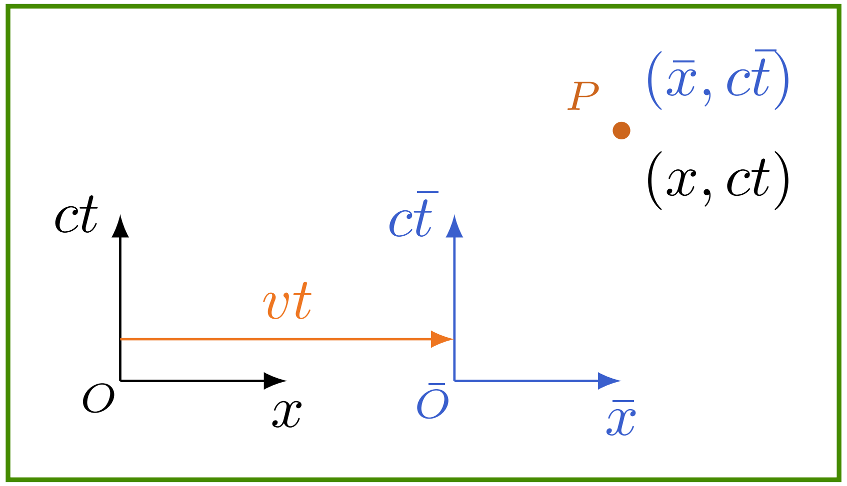
Os princípios da relatividade especial

Referenciais em movimento uniforme



I. Leis independem do referencial

II. Velocidade luz independe do referencial



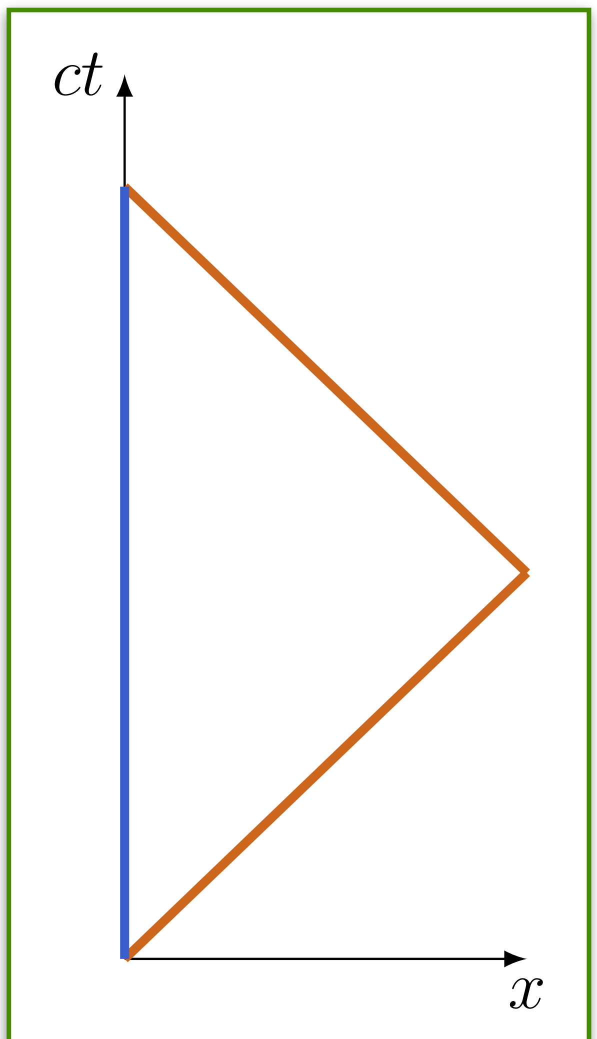
$$c^2\bar{t}^2 - \bar{x}^2 = c^2t^2 - x^2$$

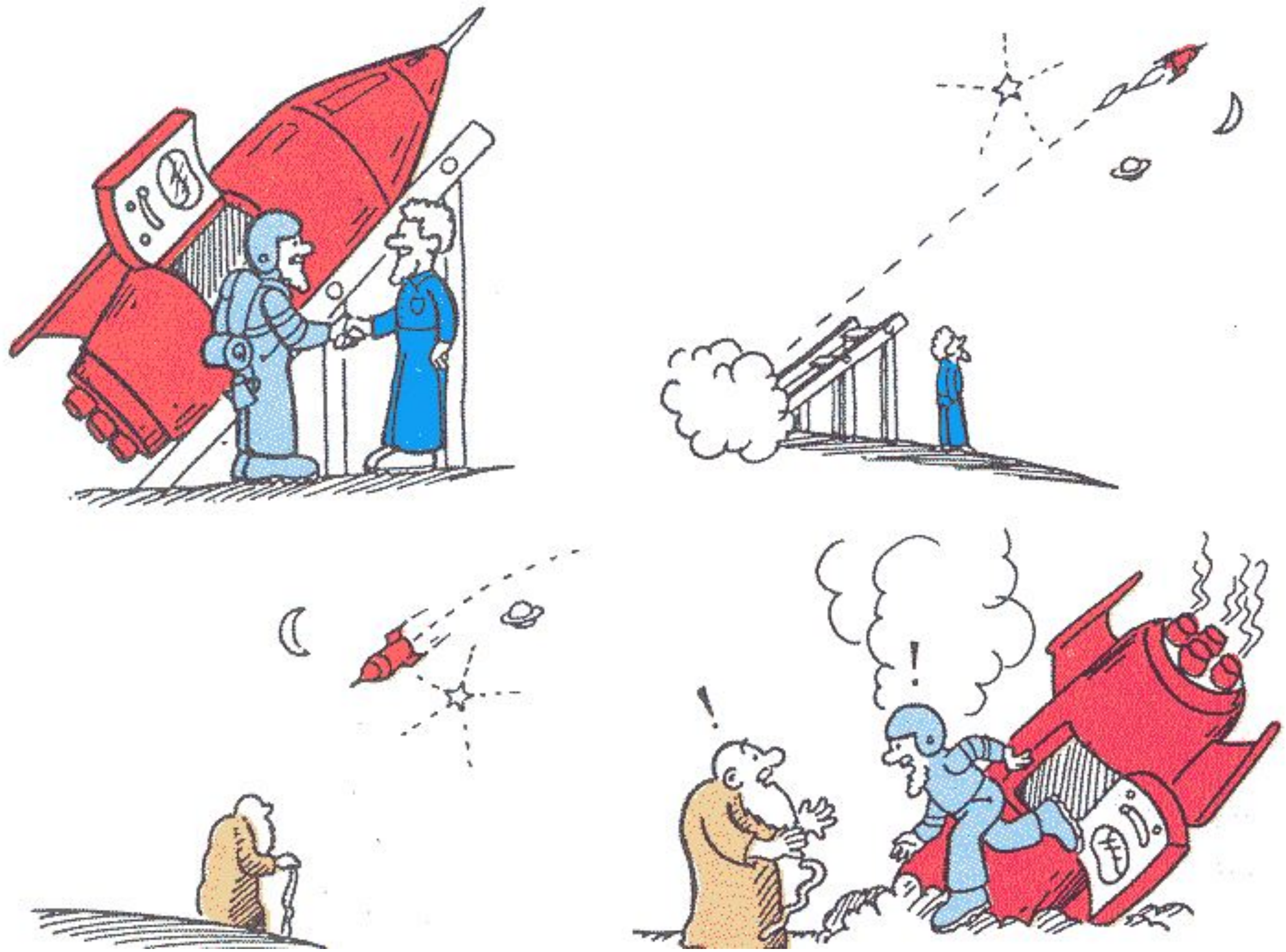
$$\begin{pmatrix} c\bar{t} \\ \bar{x} \\ \bar{y} \\ \bar{z} \end{pmatrix} = \begin{bmatrix} \gamma & -\beta\gamma & 0 & 0 \\ -\beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix}$$

Pratique o que aprendeu

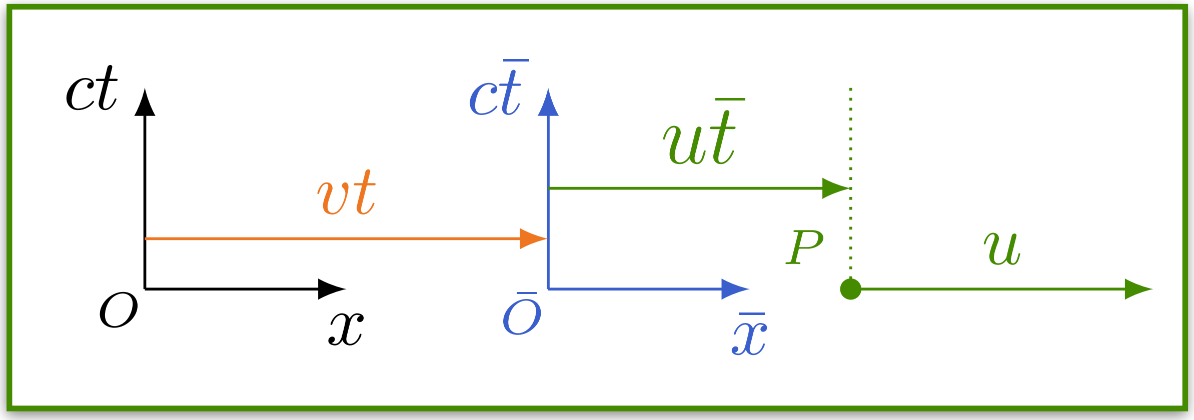
$$\beta = \frac{v}{c} \qquad \gamma \equiv \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$$

O paradoxo dos gêmeos



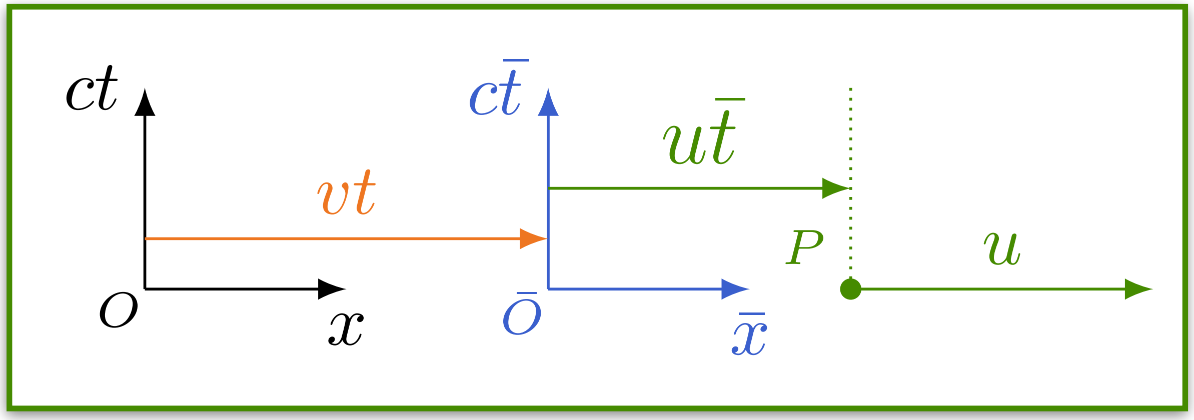


Velocidade relativa



Velocidade relativa

$$\begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix} = \begin{bmatrix} \gamma & \beta\gamma & 0 & 0 \\ \beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} c\bar{t} \\ \bar{x} \\ \bar{y} \\ \bar{z} \end{pmatrix}$$



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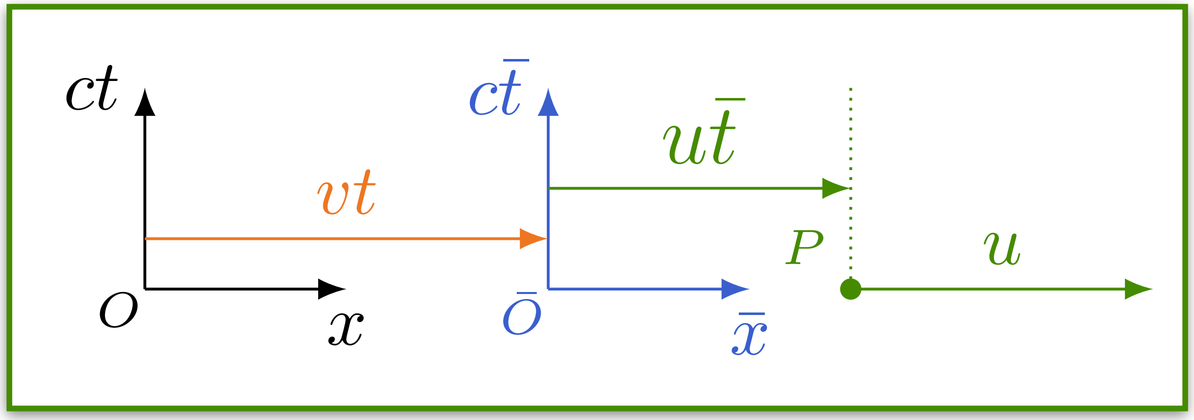


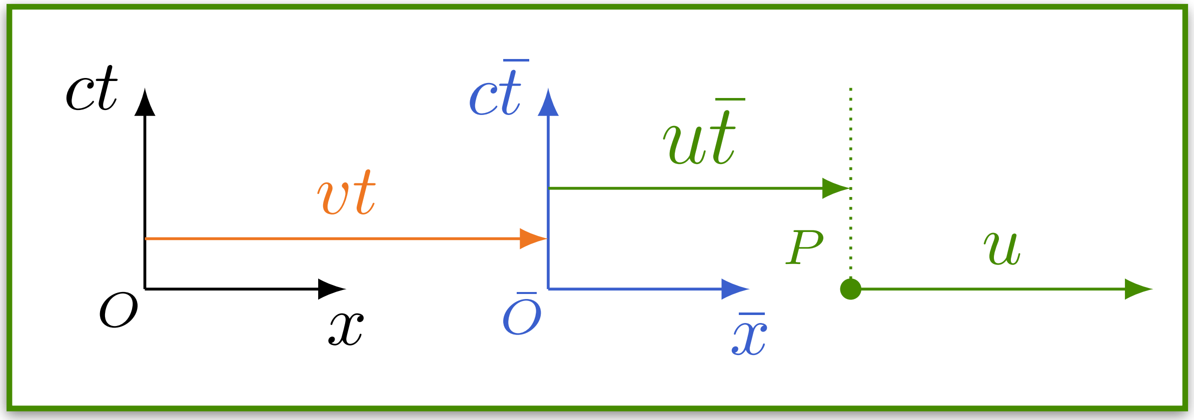
$$\begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix} = \begin{bmatrix} \gamma & \beta\gamma & 0 & 0 \\ \beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} c\bar{t} \\ u\bar{t} \\ 0 \\ 0 \end{pmatrix}$$

$$ct = \gamma c\bar{t} + \beta\gamma u\bar{t} \quad \Rightarrow \quad \bar{t} = \frac{t}{\gamma(1+\beta\frac{u}{c})}$$

$$x = \beta\gamma c\bar{t} + \gamma u\bar{t} \quad \Rightarrow \quad x = \gamma(\beta c + u)\bar{t} \qquad \Rightarrow \quad x = \frac{v+u}{1+\frac{vu}{c^2}}t$$

Velocidade relativa

$$w = \frac{v+u}{1+\frac{vu}{c^2}}$$



Quadrivetores

$$\vec{\mathbf{r}} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} \longrightarrow x^{\mu} = \begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix}$$

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Quadrivetores

contravariante

$$\vec{\mathbf{r}} = \begin{pmatrix} x \\ y \\ z \end{pmatrix} \longrightarrow x^\mu = \begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix}$$

covariante

$$\vec{\mathbf{r}} = \begin{pmatrix} x & y & z \end{pmatrix} \longrightarrow x_\mu = \begin{pmatrix} -ct & x & y & z \end{pmatrix}$$

$$\vec{\mathbf{r}} \cdot \vec{\mathbf{r}} = \begin{pmatrix} x & y & z \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix} = x^2 + y^2 + z^2 \longrightarrow x_\mu x^\mu = -c^2t^2 + x^2 + y^2 + z^2$$

Quadrivetores

$$\begin{pmatrix} c\bar{t} \\ \bar{x} \\ \bar{y} \\ \bar{z} \end{pmatrix} = \begin{bmatrix} \gamma & -\beta\gamma & 0 & 0 \\ -\beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{pmatrix} ct \\ x \\ y \\ z \end{pmatrix}$$

$$\bar{x}^{\mu} = \Lambda^{\mu}_{\nu} x^{\nu}$$

$$\Lambda \equiv \begin{bmatrix} \gamma & -\beta\gamma & 0 & 0 \\ -\beta\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

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$$a_{\mu} b^{\mu} = -a_0 b_0 + a_1 b_1 + a_2 b_2 + a_3 b_3$$

Intervalo

$\text{Evento A} \equiv x^\mu_A$

$\text{Evento B} \equiv x^\mu_B$

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$$\Delta x^\mu = x^\mu_A - x^\mu_B$$

Deslocamento

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$\text{Evento A} \equiv x^\mu_A$

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$$\Delta x^\mu = x^\mu_A - x^\mu_B$$

Deslocamento

$$\Delta x^\mu \Delta x_\mu = -\Delta x_0^2 + \Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2$$

Intervalo

Evento A $\equiv x^\mu_A$

Evento B $\equiv x^\mu_B$

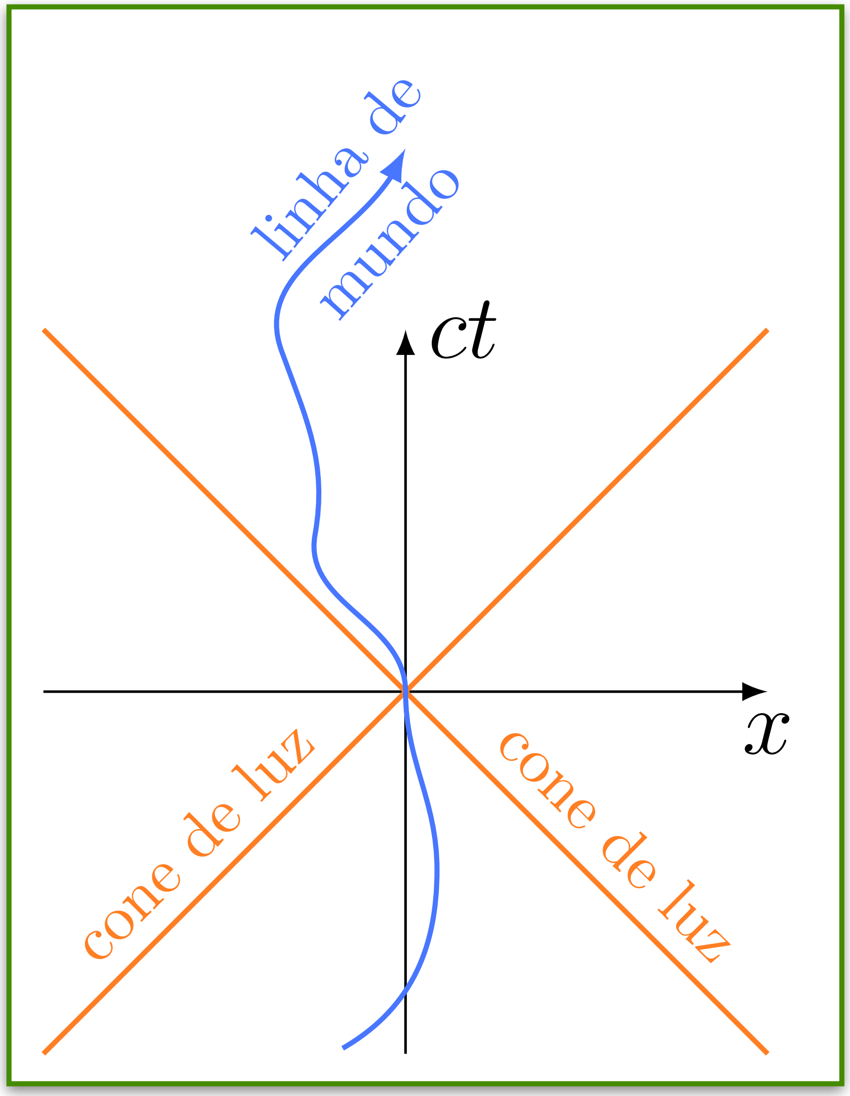
$$\Delta x^\mu = x^\mu_A - x^\mu_B$$ Deslocamento

$$\Delta x^\mu \Delta x_\mu = -\Delta x_0^2 + \Delta x_1^2 + \Delta x_2^2 + \Delta x_3^2$$

$$I_{AB} \equiv \Delta x^\mu \Delta x_\mu$$ Intervalo (invariante)

Diagramas de Minkowski

$I_{AB} \equiv \Delta x^{\mu} \Delta x_{\mu}$



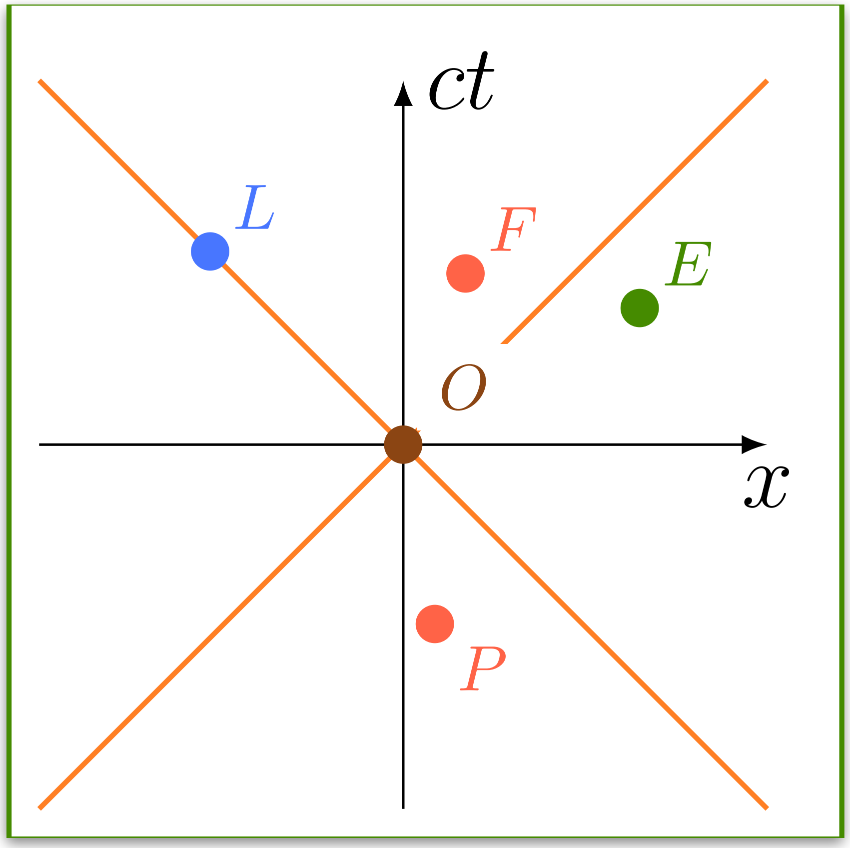
Diagramas de Minkowski

$$I_{AB} \equiv \Delta x^{\mu} \Delta x_{\mu}$$

$F, P:$ tipo tempo $(I < 0)$

$E:$ tipo espaço $(I > 0)$

$L:$ tipo luz $(I = 0)$



Quanto tempo até a lâmpada se acender?