"Larmor" → Light from accelerated charge

$$P = \frac{1}{4\pi\varepsilon_0}\frac{2}{3}\frac{q^2 a^2}{c^3} \leftarrow \text{eg Rayleigh scattering}$$

electrons in air molecules ≈ SHO with $\omega \ll \omega_0$

$$Kx = qE \rightarrow x = \frac{qE}{K} \rightarrow a = \omega^2 \frac{qE}{K} \rightarrow P \propto \omega^4$$

so blue light scattered much more than red

$$\nabla \cdot B = 0 \qquad \nabla \cdot E = \rho/\varepsilon_0 \qquad \underbrace{\nabla \cdot A}_{\text{before }=0} + \frac{1}{c^2}\partial_t \phi = 0$$

$$\underbrace{\nabla \times E = -\partial_t B}_{\text{automatic}} \qquad \underbrace{\nabla \times B = \mu_0 (J + \varepsilon_0 \partial_t E)}_{\text{in Lorentz Gauge simple}}$$

automatic

$B = \nabla \times A$

$E = -(\nabla\phi + \partial_t \vec{A})$

$$\mu_0 \begin{pmatrix} \vec{J} \\ c\rho \end{pmatrix} = \Box^2 \begin{pmatrix} \vec{A} \\ \phi/c \end{pmatrix} \qquad \Box^2 = \nabla^2 - \frac{1}{c^2}\partial_t^2$$

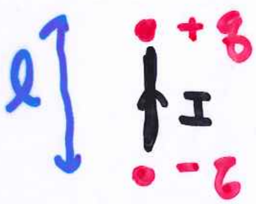
solution

$$\vec{A} = \frac{\mu_0}{4\pi} \int \frac{\vec{J}(r', t_R)}{|\vec{r} - \vec{r}\,'|} dV'$$

r in 2 places

retarded time $t_R = t - \frac{|\vec{r} - \vec{r}\,'|}{v}$

Oscillating Electric Dipole



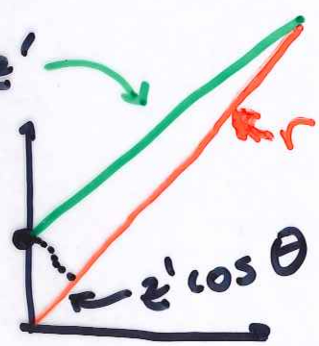
$I = I_0 \sin(\omega t)$

$q = q_0 \cos(\omega t)$

$\dot{q} = I \Rightarrow q_0 = -\omega I_0$

$$A_z = \frac{\mu_0}{4\pi} \int_{-l/2}^{l/2} \frac{I\left(z', t - \frac{|\vec{r} - \vec{r}\,'|}{c}\right)}{|\vec{r} - \vec{r}\,'|} dz'$$

$$|\vec{r} - \vec{r}\,'| \approx r - \cos\theta\, z'$$



Result: $E_r \propto \frac{1}{r^2}$, $E_\theta \sim \frac{\sin\theta}{r}$, $E_\phi = 0$

$B_r = 0$, $B_\theta = 0$, $B_\phi \sim \frac{\sin\theta}{r}$

$\vec{S} \sim \hat{r} \sin^2\theta$ "donut"

radiated Power $= 2\pi \left(\frac{l}{\lambda}\right)^2 \frac{I_0^2}{2} \frac{1}{3} \sqrt{\frac{\mu_0}{\varepsilon_0}}$; $R = 789\,\Omega \left(\frac{l}{\lambda}\right)^2$

Relativity

S, S'

$E = mc^2$

Lorentz Contr

Time dilation

$\longrightarrow$

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \rightarrow \infty \quad \beta \to 1$$

$$\beta = \frac{v}{c} < 1$$

~1900

$\vec{V}$ "vector" ?

"tensor" $\rightarrow$ transform

$\vec{F} = m\vec{a}$ any rotate C.S

Gibbs & Heaviside

"Matrix" $\begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} = \begin{pmatrix} & \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$

$v^T \cdot w$

$(\,)F = (\,)ma$

$\begin{pmatrix} d \\ e \\ f \end{pmatrix}^T \begin{pmatrix} a \\ b \\ c \end{pmatrix}$

$(d\,e\,f)\begin{pmatrix} a \\ b \\ c \end{pmatrix}$

$W = \bar{F} \cdot \Delta \bar{S}$

scale

$$\begin{cases} \vec{w}' = R\vec{w} \\ \vec{v}' = R\vec{v} \end{cases}$$

$v^T R^T$

$$\vec{v}' \cdot \vec{w}' = (R\vec{v})^T \cdot (Rw) = \vec{v} \cdot \vec{w}$$

$$(AB)^T = B^T A^T$$

$$v^T \underbrace{R^T R}_{1} w = \vec{v}^T w$$

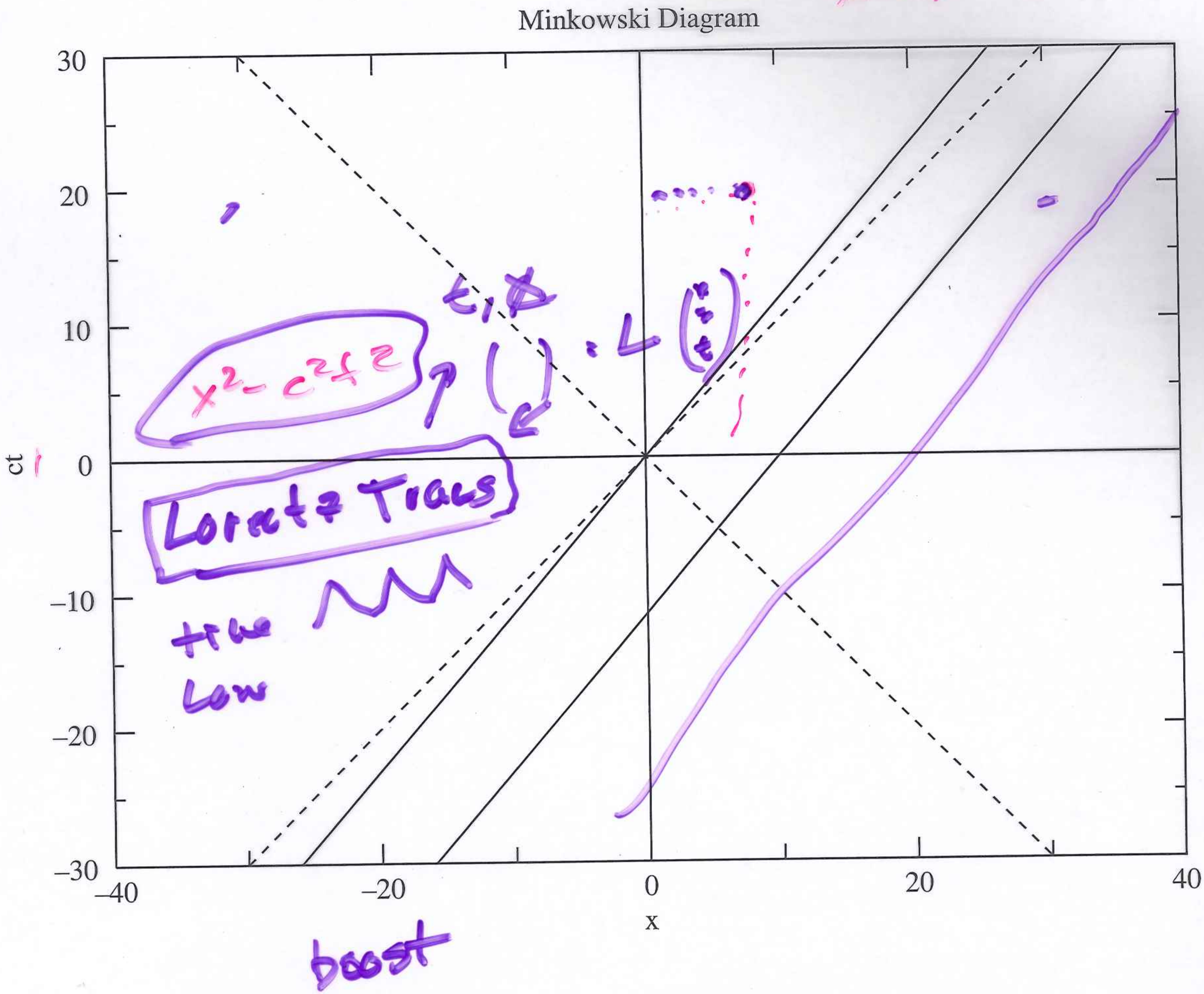
$$R^T = R^{-1}$$

$$\begin{pmatrix} \text{time} \\ \text{mass} \\ \text{Temp} \end{pmatrix}$$

$$\begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$

x, ϵ

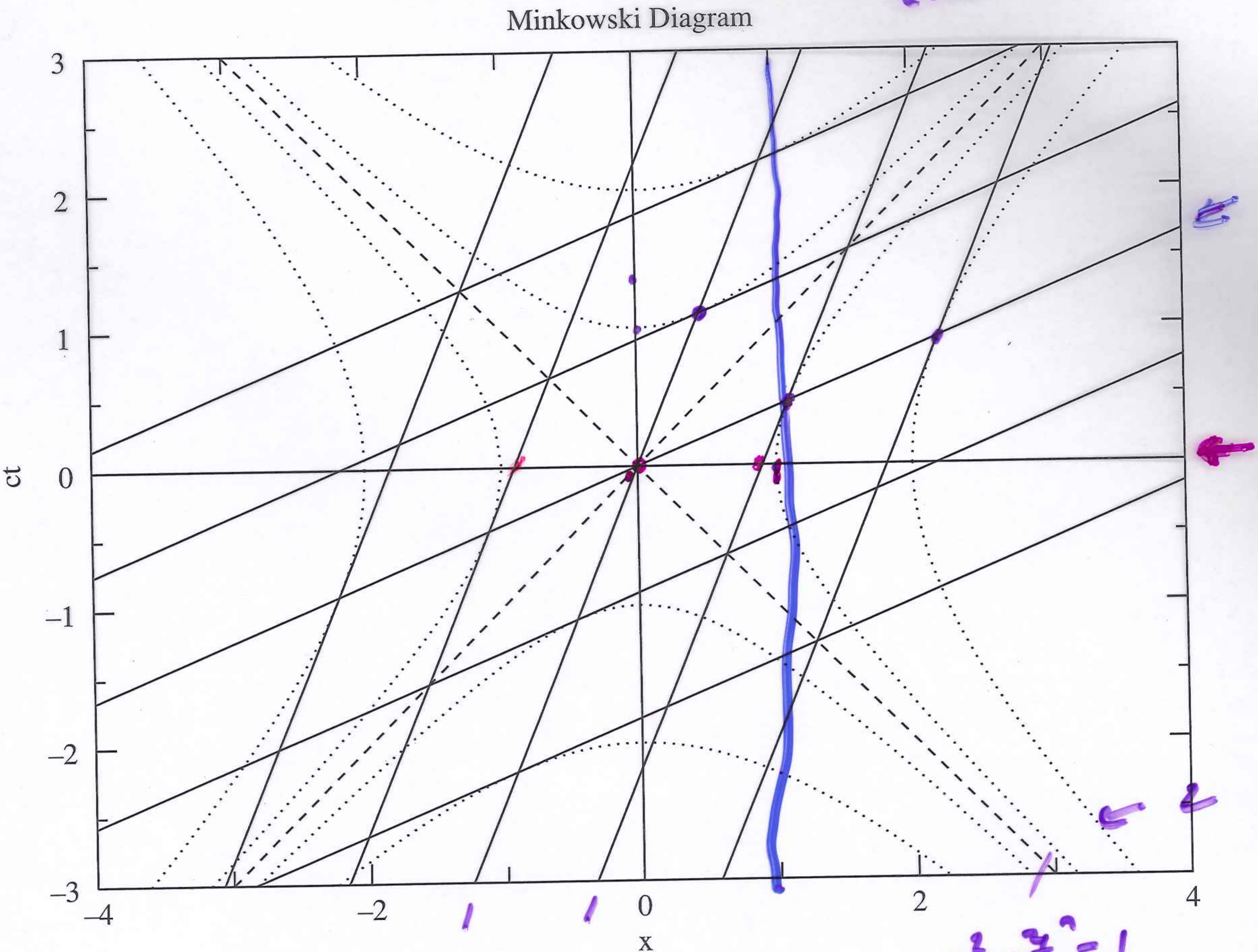
$x' = x - 4t$



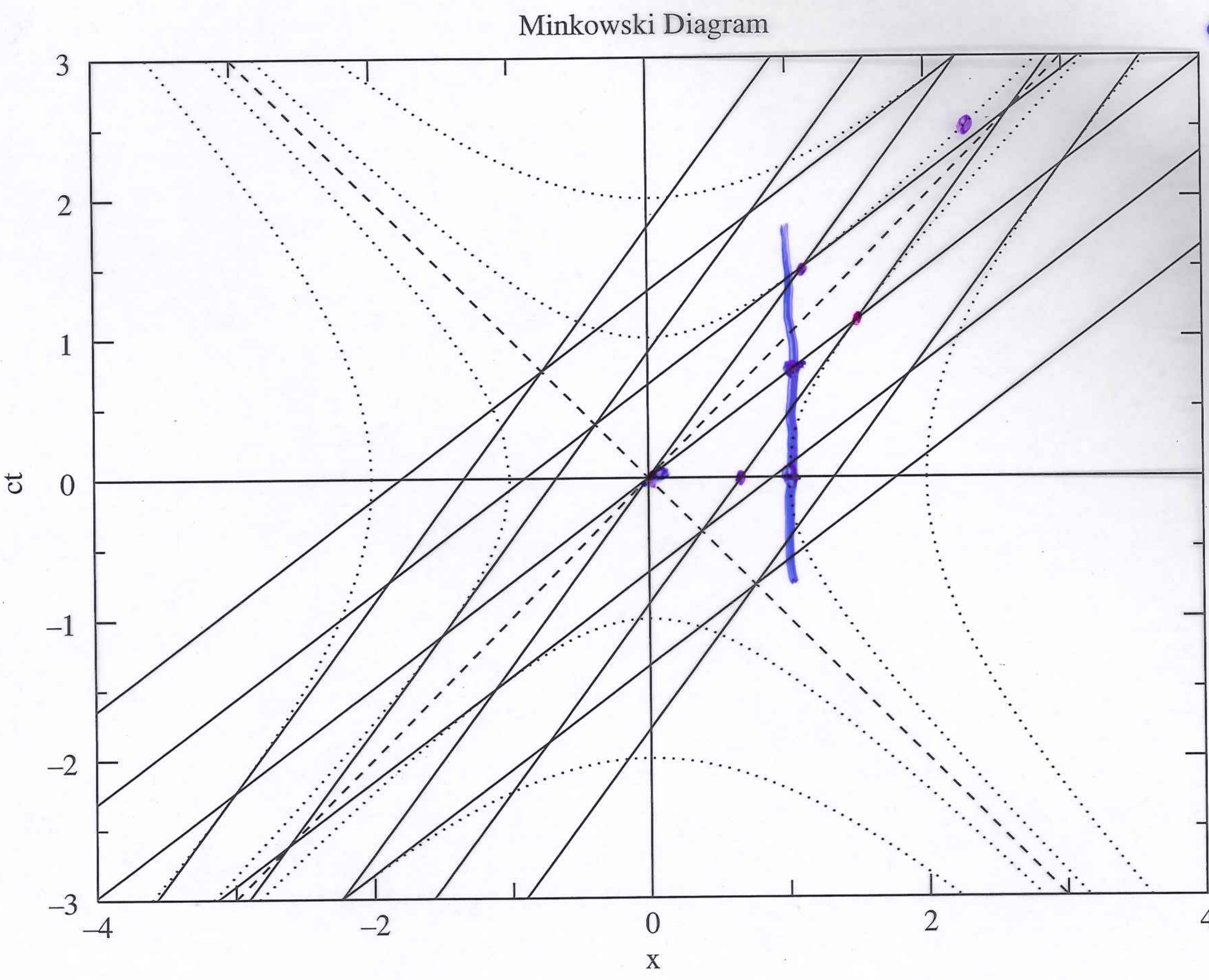
Minkowski Diagram
ct
x
30
20
10
0
−10
−20
−30
−40
−20
0
20
40
$x^2 - c^2t^2$
Lorentz Trans
the Law
boost

$x^2 - c^2t^2$

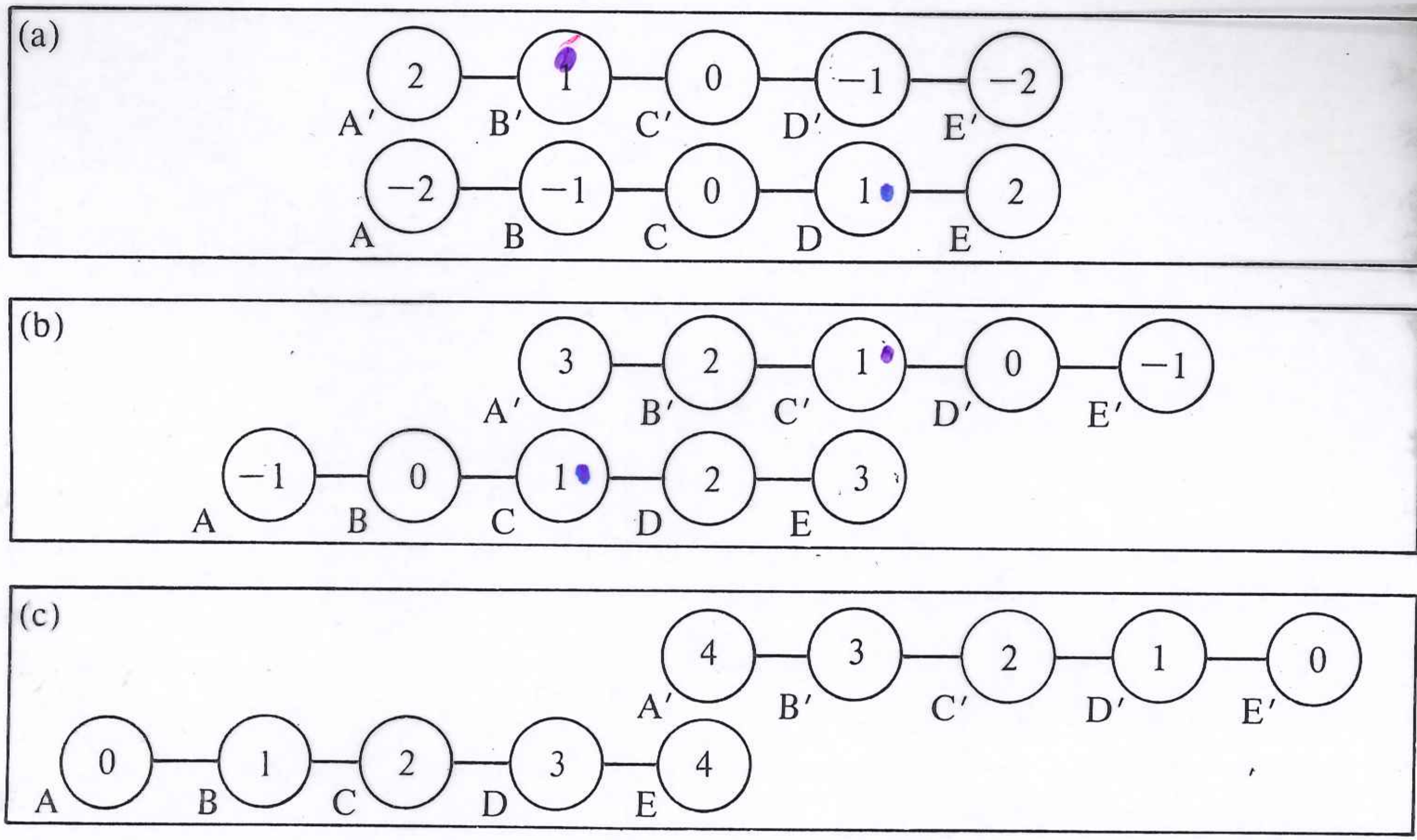
$(ct)^2 - x^2$



$x^2 - c^2t^2 = 1.$



$t'=0$


(a)
2 1 0 −1 −2
A′ B′ C′ D′ E′
−2 −1 0 1 2
A B C D E
(b)
3 2 1 0 −1
A′ B′ C′ D′ E′
−1 0 1 2 3
A B C D E
(c)
4 3 2 1 0
A′ B′ C′ D′ E′
0 1 2 3 4
A B C D E

$A_x B_x + A_y B_y =$

$A'_x B'_x + A'_y B'_y$

$x^2 - (ct)^2 = 1 = x'^2 - (ct')^2$