direction according to this viewer? $\mathfrak{J}$
the direction in terms of the tangent
the x-axis.

given: $\omega = 2\pi \cdot 2000\,Hz$, $\vec{k} = \begin{pmatrix} k \\ 0 \\ 0 \end{pmatrix}$,

boost: $\Lambda = \begin{pmatrix} \gamma & 0 & 0 & \beta\gamma \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \beta\gamma & 0 & 0 & \gamma \end{pmatrix}$ where $\gamma =$

We want to discuss two ways of solving the

- Knowing the kinematic energy-momentu
can derive a four-vector k^μ which
and wave vector $\vec{k}$:

$$p^\mu = \begin{pmatrix} \frac{E}{c} \\ \vec{p} \end{pmatrix} \quad \text{with } E\text{: energy}, \vec{p}\text{:}$$

$$\Longrightarrow \quad k^\mu = \frac{p^\mu}{\hbar} = \begin{pmatrix} \frac{\omega}{c} \\ \vec{k} \end{pmatrix}$$

$$\vec{k}' = \begin{pmatrix} 0 \\ \gamma\beta\frac{\omega}{c} \end{pmatrix} \Longrightarrow \underline{\underline{\tan \theta}}$$

where θ is the angle to the x ax[...]
that photons have a linear dispersion rela[...]

- Another way of solving the problem is to [...]
points in four-space that are separat[...]
wave length λ:

$$x_1^{\mu} = (0,0,0,0) \quad , \quad x_2^{\mu} = (\lambda, \lambda, 0, 0)$$

$$\Longrightarrow \Delta x^{\mu} = x_2^{\mu} - x_1^{\mu} = (\lambda, \lambda, 0, 0)$$

The four-vector Δx^{μ} undergoes the boos[...]

$$\Delta x^{\mu'} = \Lambda \Delta x^{\mu} = \begin{pmatrix} \gamma & 0 & 0 & \beta\gamma \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \beta\gamma & 0 & 0 & \gamma \end{pmatrix} \begin{pmatrix} \lambda \\ \lambda \\ 0 \\ 0 \end{pmatrix}$$

The space part yields the angle θ to [...]

$$\underline{\underline{\tan \theta = \frac{\beta\gamma\lambda}{\lambda} = \gamma\beta}}$$

... scalar and especially ...
are invariant under boosts we can co...
following equation:

$$k_\mu x^\mu = 0 + k_x \cdot 2 + 0 + 0 = k'_\mu \ldots$$

$$\Longrightarrow k_x = k_x' = |\vec{k}'| \cos\theta = \frac{\omega'}{c} \cos\theta \ldots$$

$$= \frac{\omega'}{c} \cdot \sqrt{\frac{1}{1 + \tan^2\theta}} = \frac{\omega'}{c} \sqrt{\frac{\ldots}{1 + \ldots}}$$

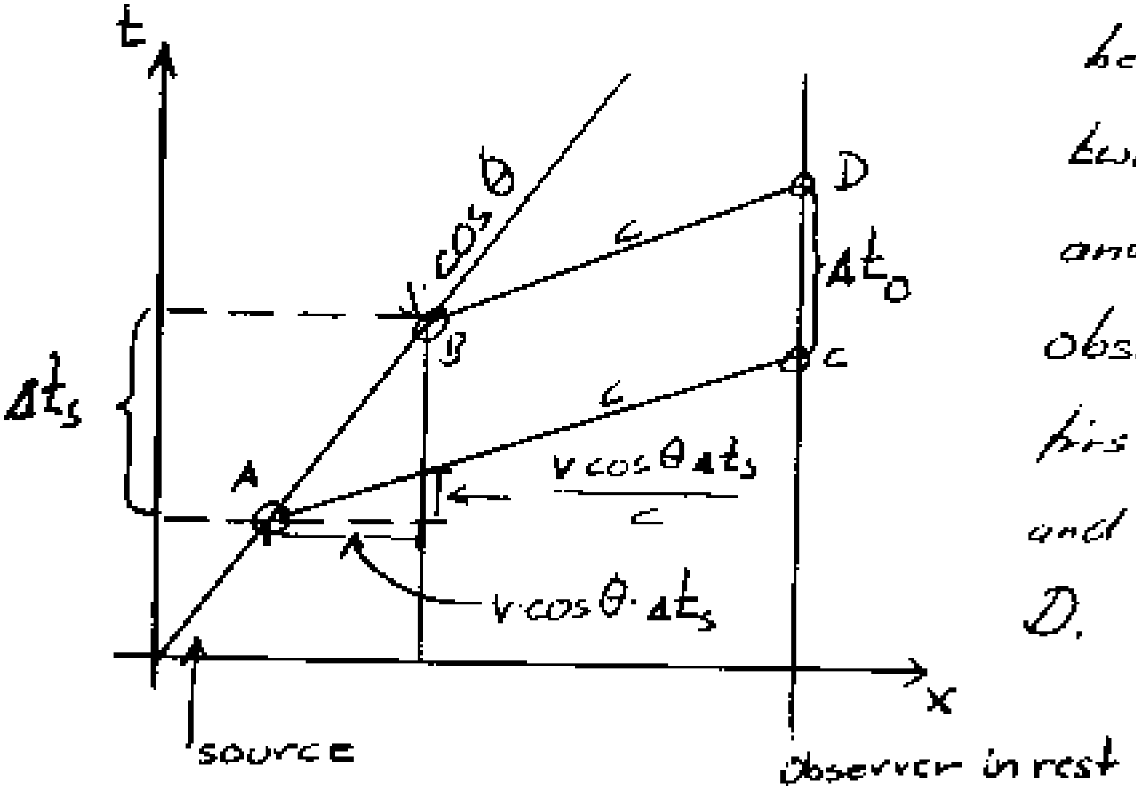
$$= \frac{\omega'}{c} \sqrt{\frac{1}{1 + \frac{\beta^2}{1-\beta^2}}} = \frac{\omega'}{c} \sqrt{\ldots}$$

$$= \frac{\omega'}{c} \sqrt{1 - \beta^2} = \frac{\omega'}{c} \cdot \frac{1}{\gamma} = k_x \ldots$$

with $k_x = k = \frac{\omega}{c}$ as $\vec{k} = (k, 0, \ldots$

$$\underline{\underline{\omega' = \gamma \cdot \omega}}$$

component of $\vec{v}$ which is parallel to t[...]
between source and observer is $v \cdot c$[...]
x axis be the line of sight. The [...]



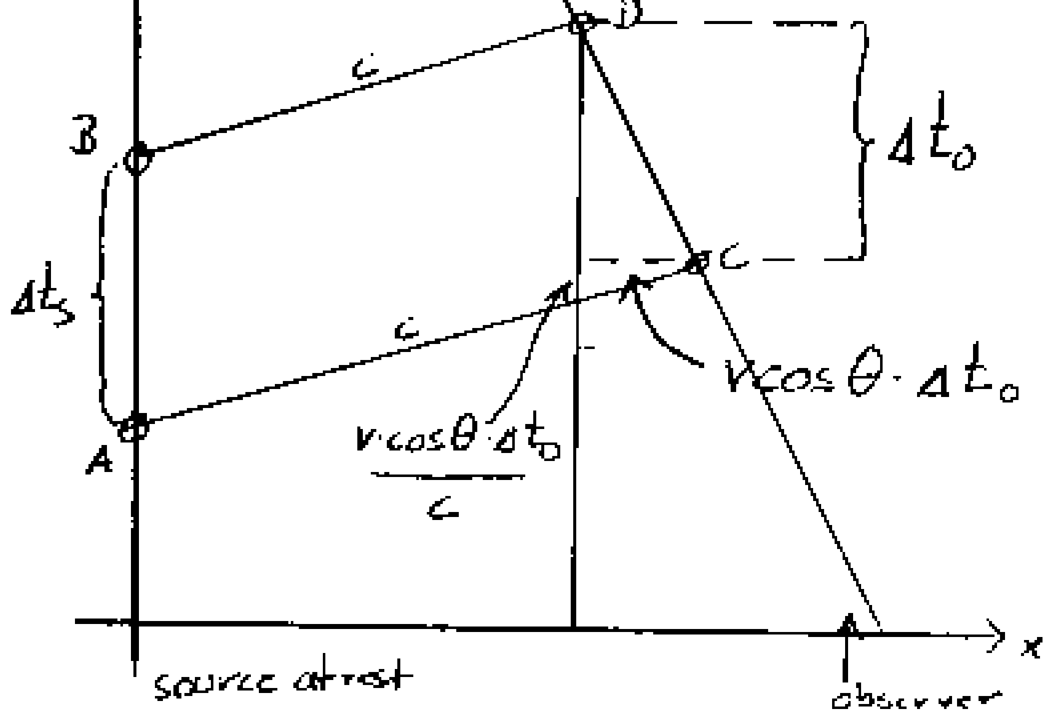
bell [...]
twice, [...]
and ev[...]
observer [...]
first st[...]
and the [...]
D.

Δt_0 is the time interval between D and [...]
Δt_s is the time interval between B and [...]

$$\Delta t_0 = \Delta t_s - \frac{v\cdot\cos\theta\,\Delta t_s}{c} = \left(1 - \frac{v}{c}\right.$$

The period between strikes corresponds to [...]
of the frequency ν:

$$\nu_0 = \frac{1}{1 - \frac{v\cos\theta}{c}}\,\nu_s$$



$$\Delta t_s = \Delta t_0 + \frac{v\cos\theta\,\Delta t_0}{c} = \left(1 + \frac{v}{c}\right.$$

$$\Longrightarrow \qquad \nu_s = \frac{1}{1+\frac{v}{c}\cos\theta}\,\nu_0$$

$$\Longrightarrow \qquad \underline{\underline{\nu_0 = \left(1+\frac{v}{c}\cos\theta\right)\nu_s}}$$

In our convention: $\theta < 90^\circ$ if distance between sour
becomes smaller.
$\theta > 90^\circ$ if distance between source
becomes larger.

The observer moves with velocity $\vec{v}$ in z-dir
of the source the lightray is described by k
$k^{\mu'}$ is the lightray in the observer's frame.

$$k^{\mu'} = \Lambda \cdot k^{\mu} = \begin{pmatrix} \gamma & 0 & 0 & \beta\gamma \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \beta\gamma & 0 & 0 & \gamma \end{pmatrix} \begin{pmatrix} \cdot \\ k_x \\ k_y \\ k_z \end{pmatrix}$$

$$\Longrightarrow \frac{\omega'}{c} = \gamma \frac{\omega}{c} + \beta\gamma\, k_z = \gamma \frac{\omega}{c} + \beta\gamma$$

$$= \gamma \frac{\omega}{c} + \beta\gamma \frac{\omega}{c} \cos\theta$$

where $\gamma = \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}}$, $\beta = \frac{v}{c}$, θ: angle
z-axe

$$\Longrightarrow \omega' = \omega \left(\frac{1 + \frac{v}{c}\cos\theta}{\sqrt{1 - \frac{v^2}{c^2}}} \right)$$

Note: Observations made at right angles ($\theta = 90°$)
of motion show the non-zero transverse Doppl
there should be no effect.