Three ideas to help understand relativity:

1. Throw a ball at speed \( \frac{\vec{V}}{V_b} \) relative to you while running at speed \( \frac{\vec{V}}{V_b} \) (w/r to person) \( \vec{V}_b + \vec{V} \). Ball goes at \( \frac{\vec{V}}{V_b + V} \) rel to ground.

   ![Diagram of a person running and throwing a ball]

2. Call at speed of sound while running \( \vec{V}_s \). Sound perceived by runner moving at \( \vec{V}_s - \vec{V} \).

   ![Diagram of a person running and making a call]

3. Light (a) moves at \( c \) w/r to ground, (b) moves at \( c \) w/r to person.
SOUND

still air

moves with velocity \( \vec{V}_s \), horizontal \( |\vec{V}_s| = V_s \)

runs horizontal velocity \( \vec{V} \), right to left \( |\vec{V}| = V \)

Speed of sound perceived by runner:

A: \( V_s + V \)

B: \( V_s \)

C: \( V_s - V \)
\[ v_e \]

\[ |v_e| = c = 3 \times 10^8 \text{ m/s} \]

relative to ground

Speed of light perceived by runner:

\[ \text{A) } c + v \]

\[ \text{B) } c \]

\[ \text{C) } c - v \]
How this is resolved

Time Dilation

"Clock" \[ \text{Mirror} \]

Flash \[ \text{"Ding"} \]

\[ \Delta t_0 = \frac{2L_0}{c} \]

AT REST, \[ c \Delta t_0 = 2L_0 \]

time between "Dings"

\[ L^2 = L_0^2 + \left( \frac{u \Delta t}{2} \right)^2 \] \text{Pythag}

\[ \Delta t = \frac{2L}{c} = \frac{2}{c} \sqrt{L_0^2 + \left( \frac{u \Delta t}{2} \right)^2} \] \text{SOLVE!}
\[
\left( \frac{c \Delta t}{2} \right)^2 = L_0^2 + \left( \frac{u \Delta t}{2} \right)^2
\]

\[
\frac{1}{4} \left[ (c \Delta t)^2 - (u \Delta t)^2 \right] = \left( \frac{c \Delta t_0}{2} \right)^2
\]

\[
(\Delta t)^2 (c^2 - u^2) = c^2 (\Delta t_0)^2
\]

\[
\Delta t = \frac{c \Delta t_0}{\sqrt{c^2 - u^2}} = \frac{\Delta t_0}{\sqrt{1 - (\frac{u}{c})^2}}
\]

\[
\beta = \frac{u}{c} \quad \gamma = \frac{1}{\sqrt{1 - (\frac{u}{c})^2}} = \frac{1}{\sqrt{1 - \beta^2}} > 1
\]

\[
\Delta t = \gamma \Delta t_0
\]

Longer time interval in the rest frame

\( \mu \) particles: \( \Delta t \approx 2.2 \times 10^{-6} \text{ s} \) \( (c \Delta t = 2200 \text{ ft} \) )

but: they travel 30,000 ft from