**Why it is that** mass equals Energy

**Pythagorean Theorem’s proof** & its invariance under Cartesian-coordinate rotation. ALGEBRA invented \( \Rightarrow \) rotational-invariance EQUATION: 
\[
d\alpha^2 + d\beta^2 = ds^2 = dx^2 + dy^2
\]
Then, 3D, & then, ALGEBRA let us SUBTRACT a FOURTH term! THAT explained TIME:
CONSTANT-motion invariance: 
\[
(d\alpha^2 + d\beta^2 + dy^2) - dt^2 = (dx^2 + dy^2 + dz^2) - dt^2
\]

**Example:** twice, \( \heartsuit \) snaps her fingers — as ♠, and then ♠, see \( \heartsuit \) move \( dx \) at constant \( v \):

\( d\tau^2 = dt^2 - dx^2 \): \( \heartsuit \)'s time slows! But \( dx = v \, dt \) and so 
\( d\tau^2 = dt^2(1 - v^2) \) and \( v \leq 1 \)

Photons (and gluons) move at \( v = 1 \) light-year/year : \( d\tau = 0 \) so, for them, NO time passes.

Cars move at \( v = 0.000,000,089 \) (= 60 mph) 
\[
\left( \frac{dt}{d\tau} \right)^2 = \frac{1}{1-v^2} = 1 \quad \text{if} \quad v = 0, \quad \text{but} \quad \to \infty \quad \text{as} \quad v \to 1
\]

\[
\left( \frac{dv}{d\tau} \right)^2 = \frac{1}{1-v^2} - \frac{v^2}{1-v^2} \quad \text{Multiply through by} \quad \heartsuit \text{'s mass}^2 \quad m^2 = \left( \frac{m}{\sqrt{1-v^2}} \right)^2 - \left( \frac{mv}{\sqrt{1-v^2}} \right)^2 \equiv E^2 - p^2
\]

\[
E = \frac{m}{\sqrt{1-v^2}} \left( = m + \frac{1}{2}mv^2 + \cdots \right) \quad \text{and} \quad p = \frac{mv}{\sqrt{1-v^2}} \left( = mv + \cdots \right)
\]

if \( \heartsuit \) doesn’t move, \( v = 0 \), and \( \heartsuit \)'s \( p = 0 \) BUT \( \heartsuit \) still retains Energy \( E = \text{mass} \, m \)

\[
ds^2 = dx^2 + dy^2 + dz^2 - dt^2 \quad \text{explains Newton's} \quad E = \frac{1}{2}mv^2, \quad p = mv; \quad \text{and gives} \quad E = mc^2
\]

We invented algebra as a convenience—but ALGEBRA seems to understand the Universe!