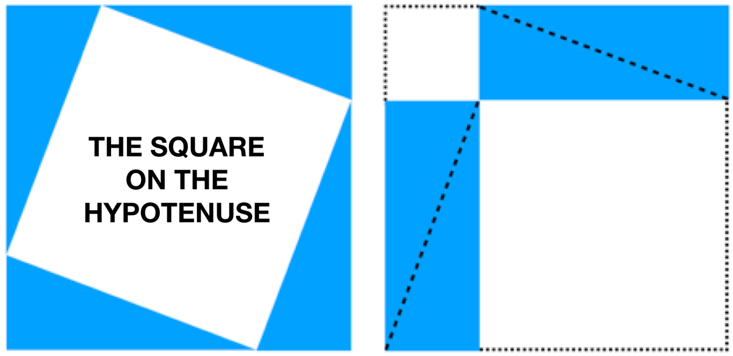
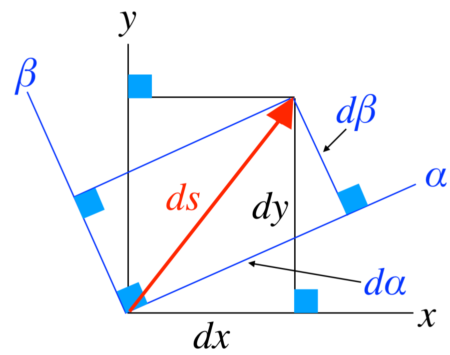
Why it is that ***mass* *equals* *Energy***





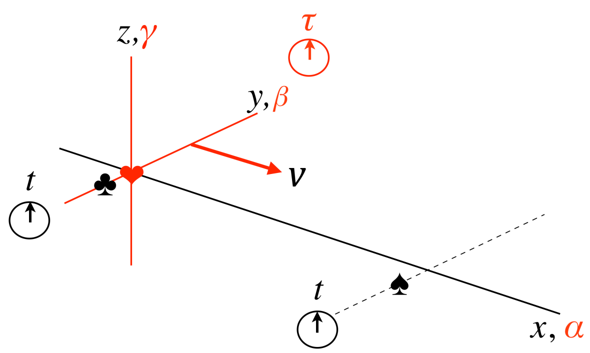
Pythagorean Theorem's proof & its invariance under Cartesian-coordinate **rotation.**

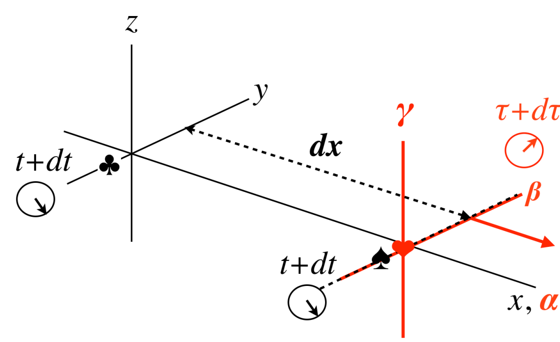
ALGEBRA invented ⟹ **rotational**-invariance **EQUATION:** $d\alpha^2 + d\beta^2 = ds^2 = dx^2 + dy^2$

Then, *3D*, & then, **ALGEBRA** let us **SUBTRACT** ***a*** **FOURTH term *!*** **THAT explained TIME :**

CONSTANT–motion invariance: $\boldsymbol{(d\alpha^2 + d\beta^2 + d\gamma^2) - d\tau^2 = (dx^2 + dy^2 + dz^2) - dt^2}$

Example: **twice,** ❤ snaps her fingers — as ♣, and then ♠, see ❤ move ***dx*** at constant ***v*** :





❤***-moves*** at ***v*** ⟹ $\boldsymbol{0 + 0 + 0 - d\tau^2 = dx^2 + 0 + 0 - dt^2}$ ⟸ ♠ *&* ♣ both ***stationary*** in ***x, y, z***

$\boldsymbol{d\tau^2 = dt^2 - dx^2}$ ∴ ❤**'s time *slows!*** But $\boldsymbol{dx = v\,dt}$ and so $\boldsymbol{d\tau^2 = dt^2(1 - v^2)}$ and $\boldsymbol{v}$ ∴$\leq$ **1**

Photons (and gluons) move at $\boldsymbol{v = 1}$ light-year/year ∴ $\boldsymbol{d\tau} = 0$ so, for *them*, **NO** time passes.

Cars move at $\boldsymbol{v} = 0.000{,}000{,}089$ (= 60 *mph*) $\left(\frac{dt}{d\tau}\right)^2 = \frac{1}{1-v^2} = 1$ if $v = \mathbf{0}$, but → ∞ as $v \to \mathbf{1}$

$\left(\frac{d\tau}{d\tau}\right)^2 = \frac{1}{1-v^2} - \frac{v^2}{1-v^2}$ Multiply through by ❤'s *mass*² $m^2 = \left(\frac{m}{\sqrt{1-v^2}}\right)^2 - \left(\frac{m\,v}{\sqrt{1-v^2}}\right)^2 \equiv E^2 - p^2$

$$\boldsymbol{E = \frac{m}{\sqrt{1-v^2}} \quad \left(= m + \frac{1}{2}mv^2 + \cdots \right)} \qquad \textbf{– and –} \qquad \boldsymbol{p = \frac{mv}{\sqrt{1-v^2}} \quad (= mv + \cdots)}$$

if ❤ ***doesn't move***, $v = \mathbf{0}$, and ❤'s $\boldsymbol{p = 0}$ **BUT** ❤ still retains **Energy** $\boldsymbol{E = mass\ m}$

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

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