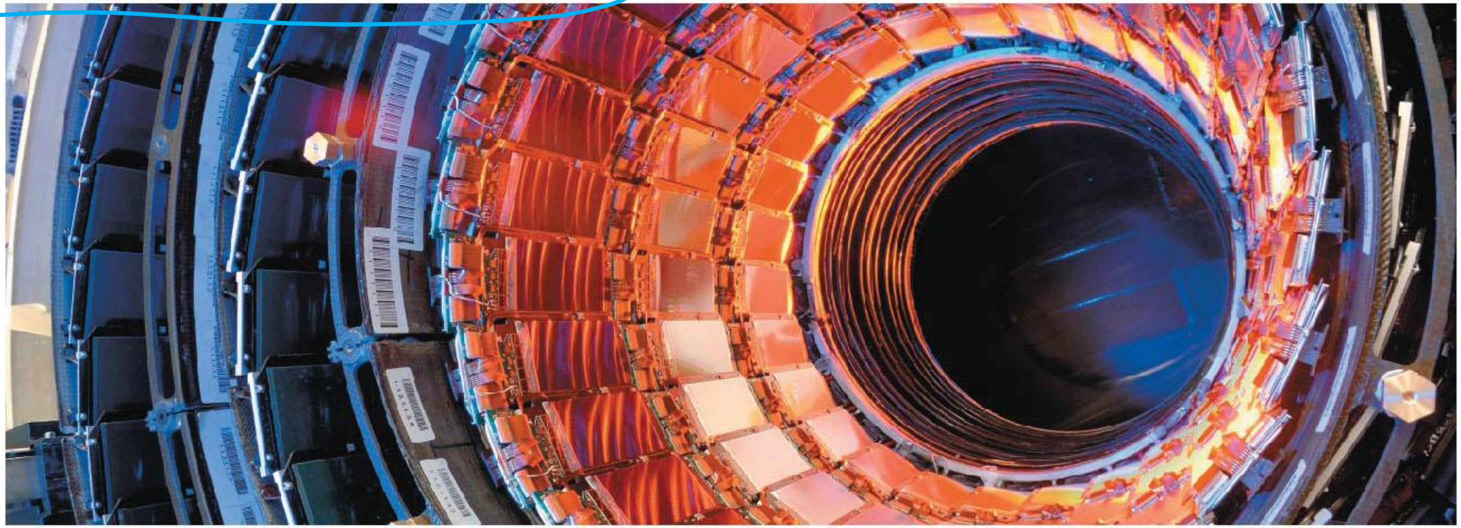
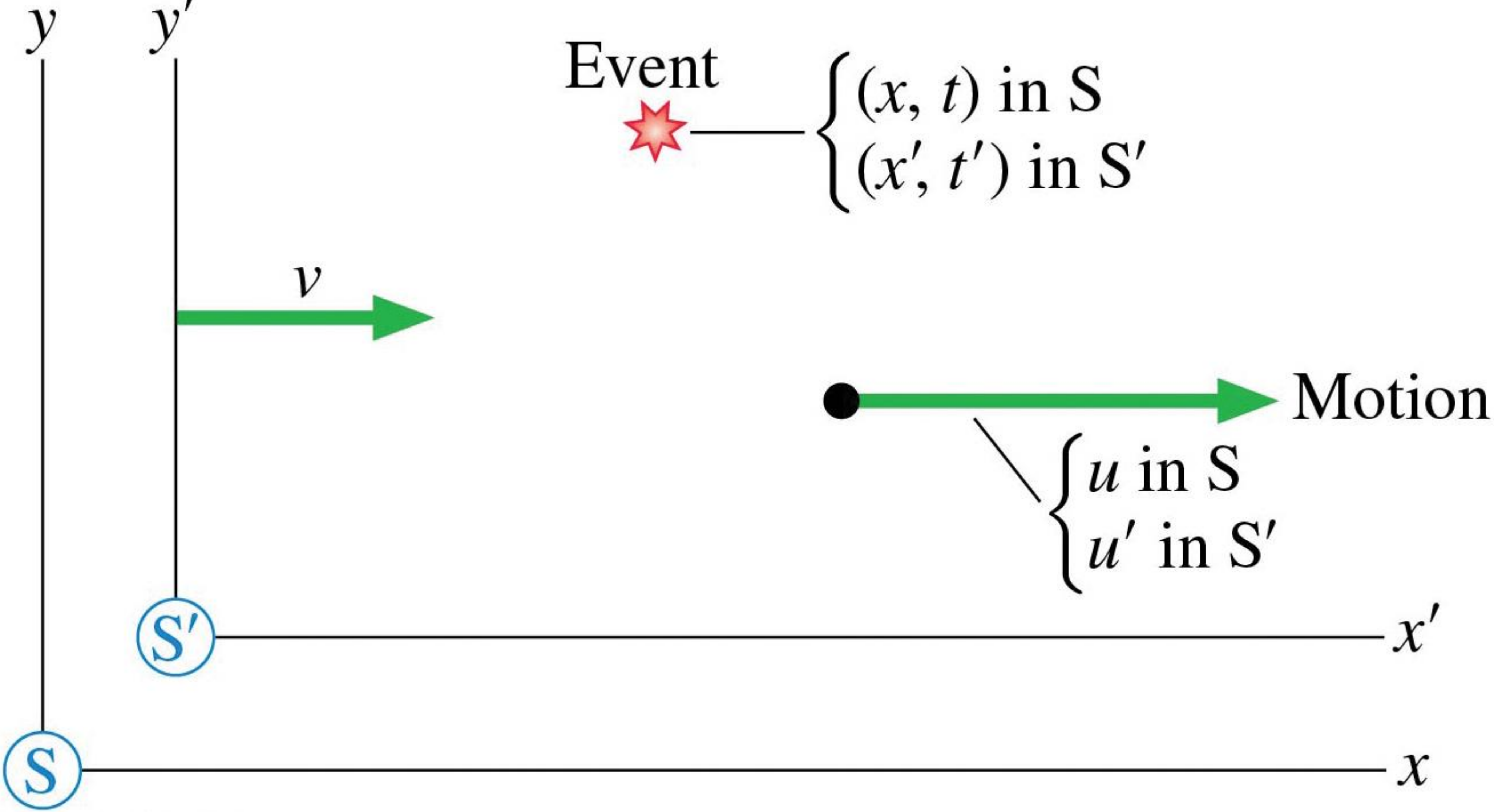
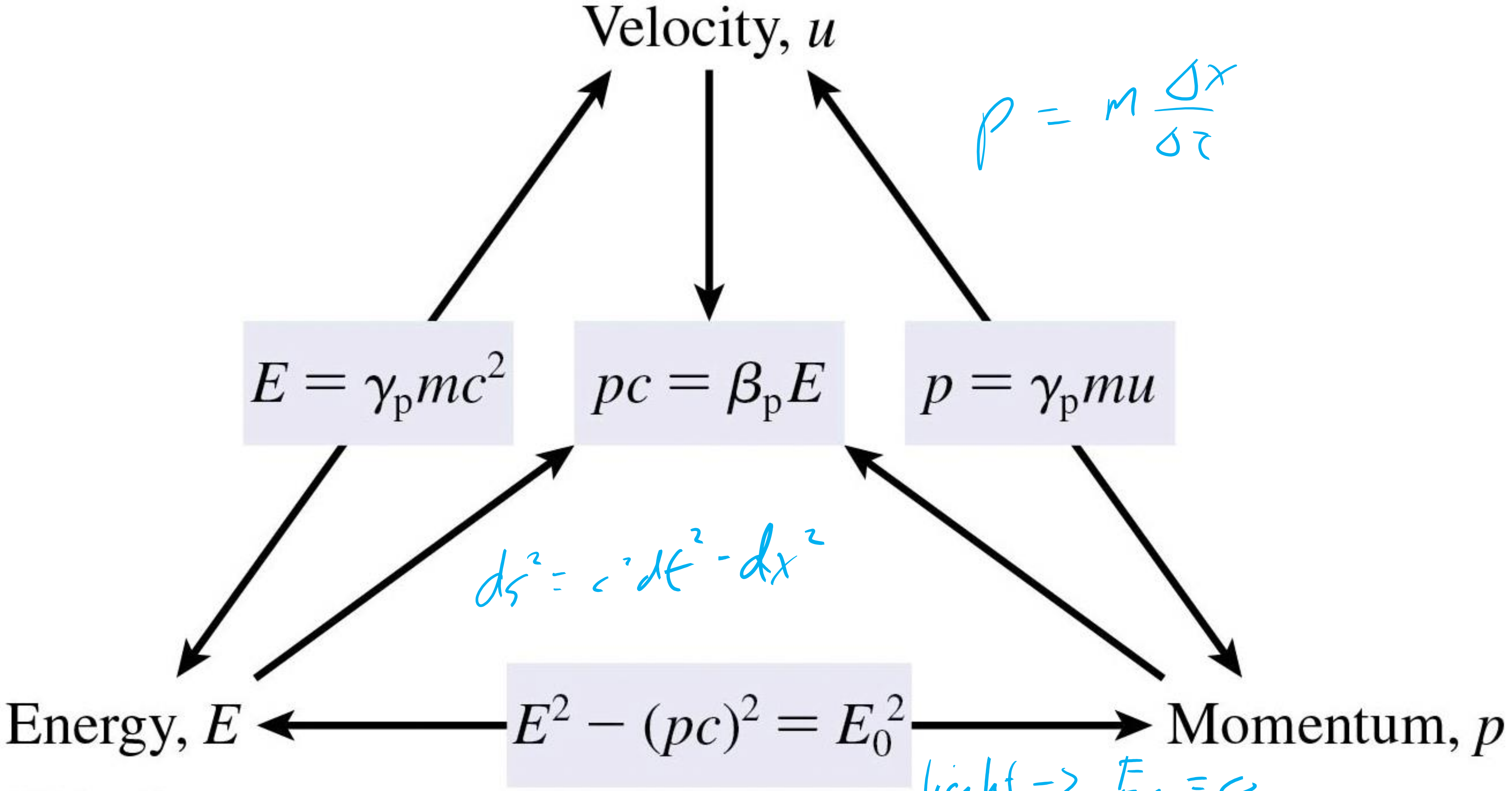
Chapter 36 – Relativity

- Reference frames, events, measurements, space-time diagrams
- Postulates of special relativity, impact on simultaneity
- Time dilation, space contraction, and Lorentz transformations
- Relativistic momentum and energy





y
y′
Event
(x, t) in S
(x′, t′) in S′
v
Motion
u in S
u′ in S′
S′
x′
S
x

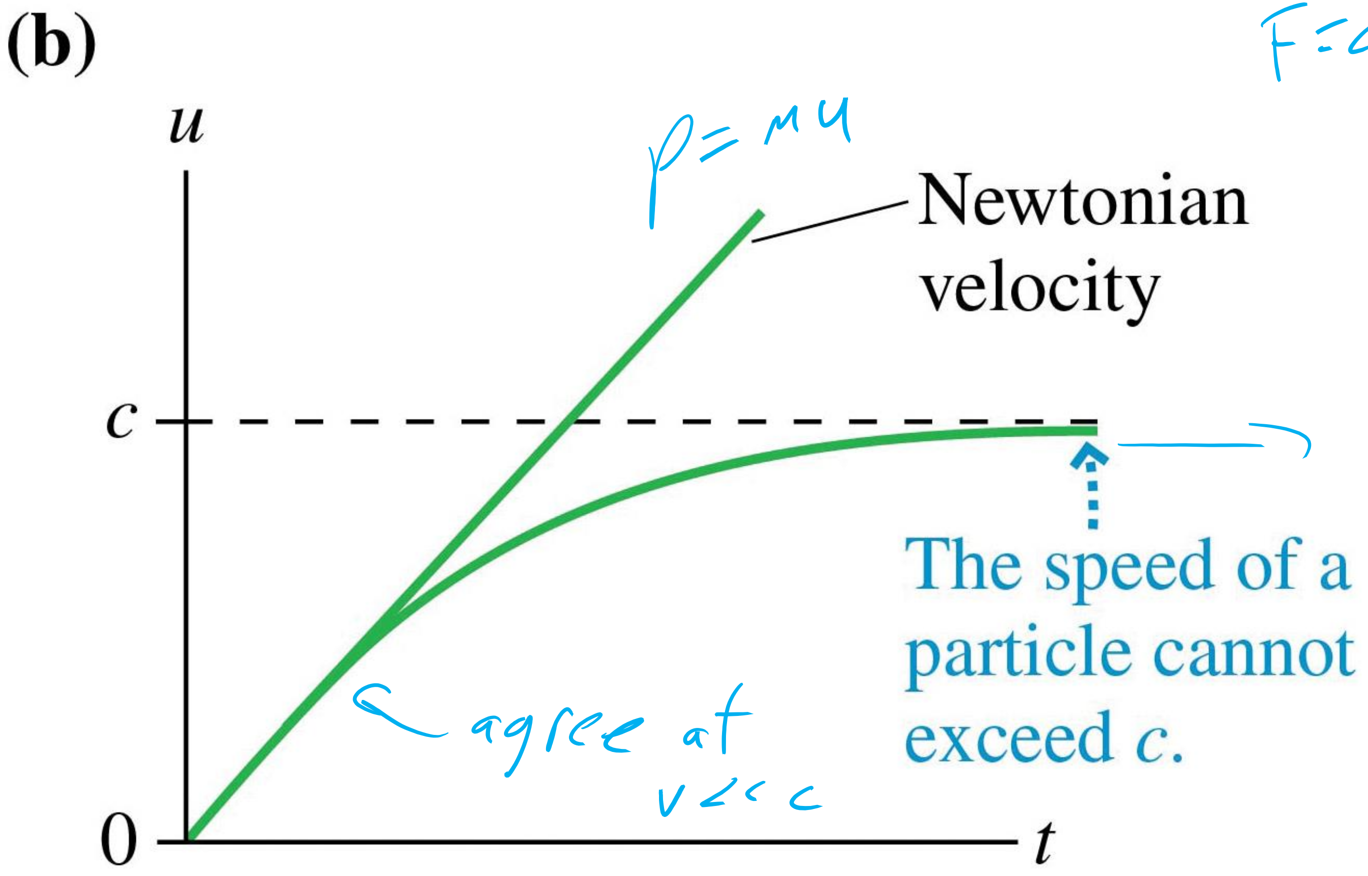


$p = m \frac{\Delta x}{\Delta \tau}$

$ds^2 = c^2 dt^2 - dx^2$

light $\rightarrow E_0 = 0$

Constant force



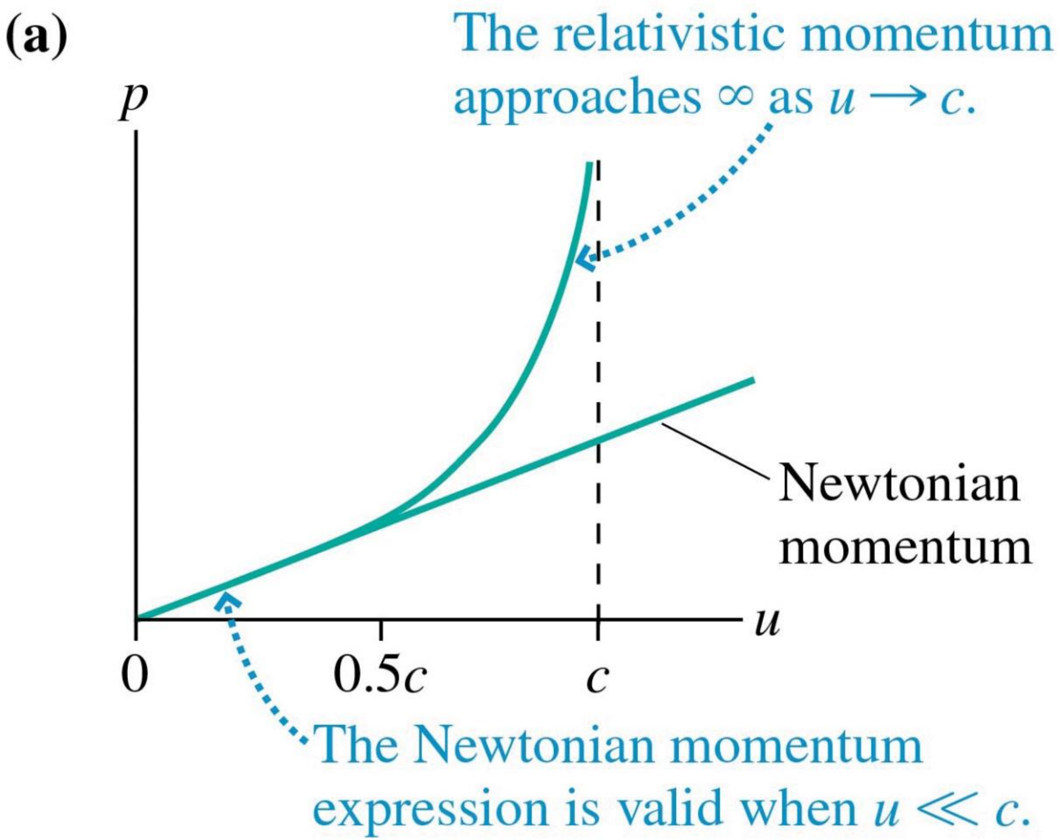
$p = mu$

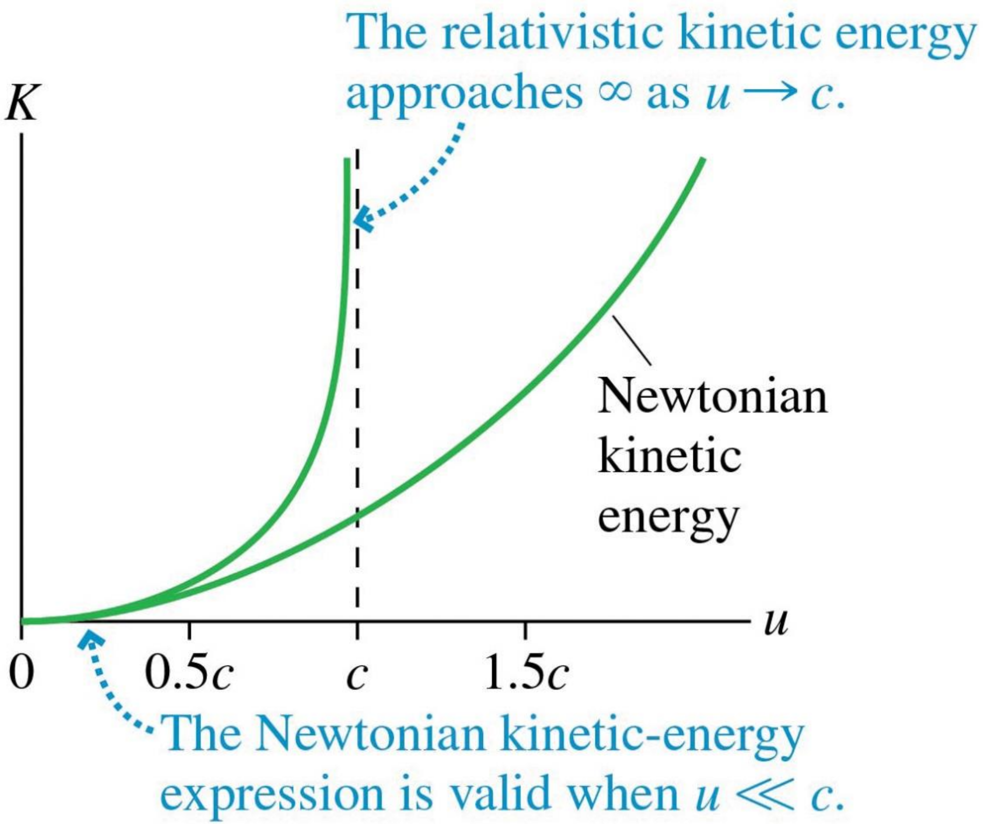
agree at $v \ll c$

$F = \text{constant} = \frac{dp}{dt}$

$p \propto At$

$p = \gamma_p m u_p$





$$\gamma = (1-\beta^2)^{-1/2}$$

$$\gamma \simeq 1 + \tfrac{1}{2}\beta^2$$

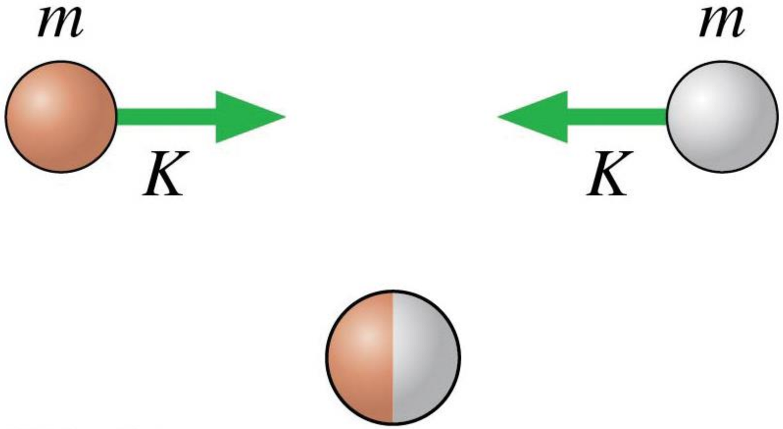
Kinetic energy

$$\boxed{K = (\gamma - 1)mc^2}$$

$$E = \gamma mc^2 \simeq \left(1 + \tfrac{1}{2}\beta^2\right)mc^2 \simeq mc^2 + \tfrac{1}{2}\left(\tfrac{v}{c}c\right)^2 m$$

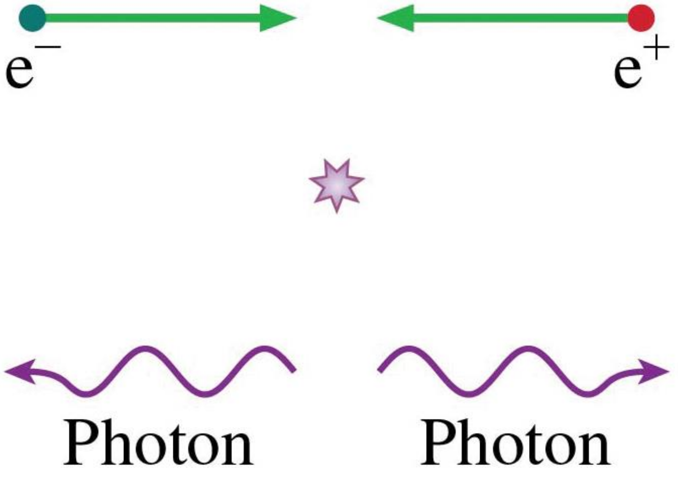
$$= mc^2 + \tfrac{1}{2}mv^2$$

$$\simeq mc^2 + K$$



$$E_i = 2mc^2 + 2K$$

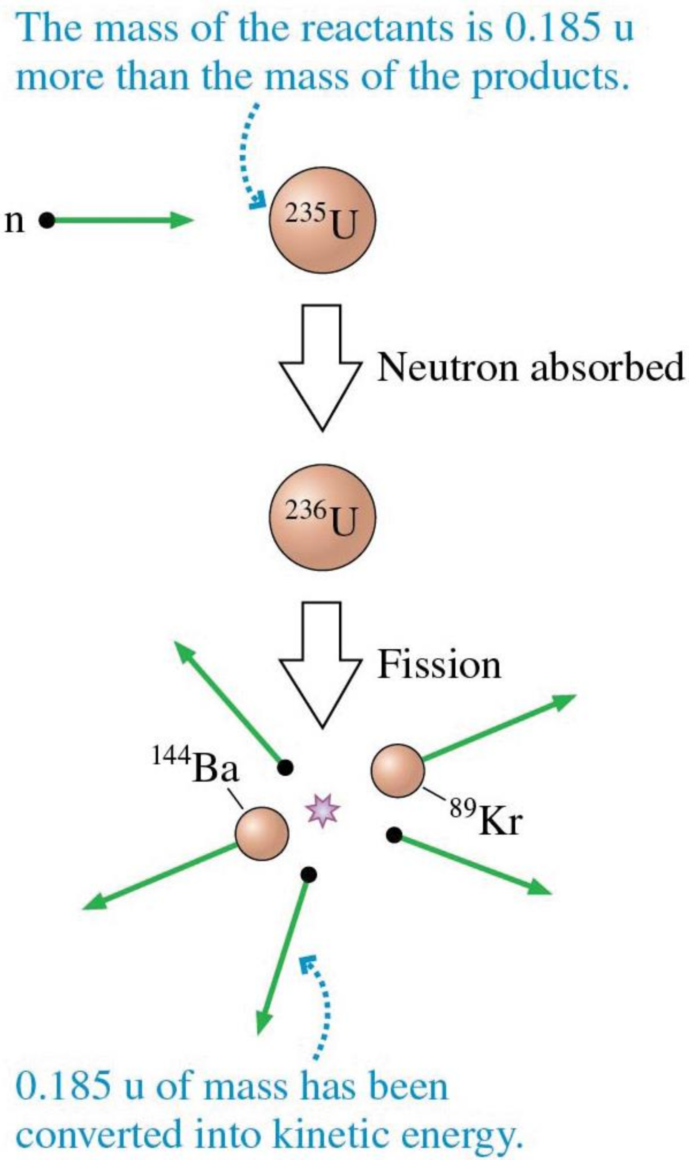
$$E_f = 2mc^2 ?$$



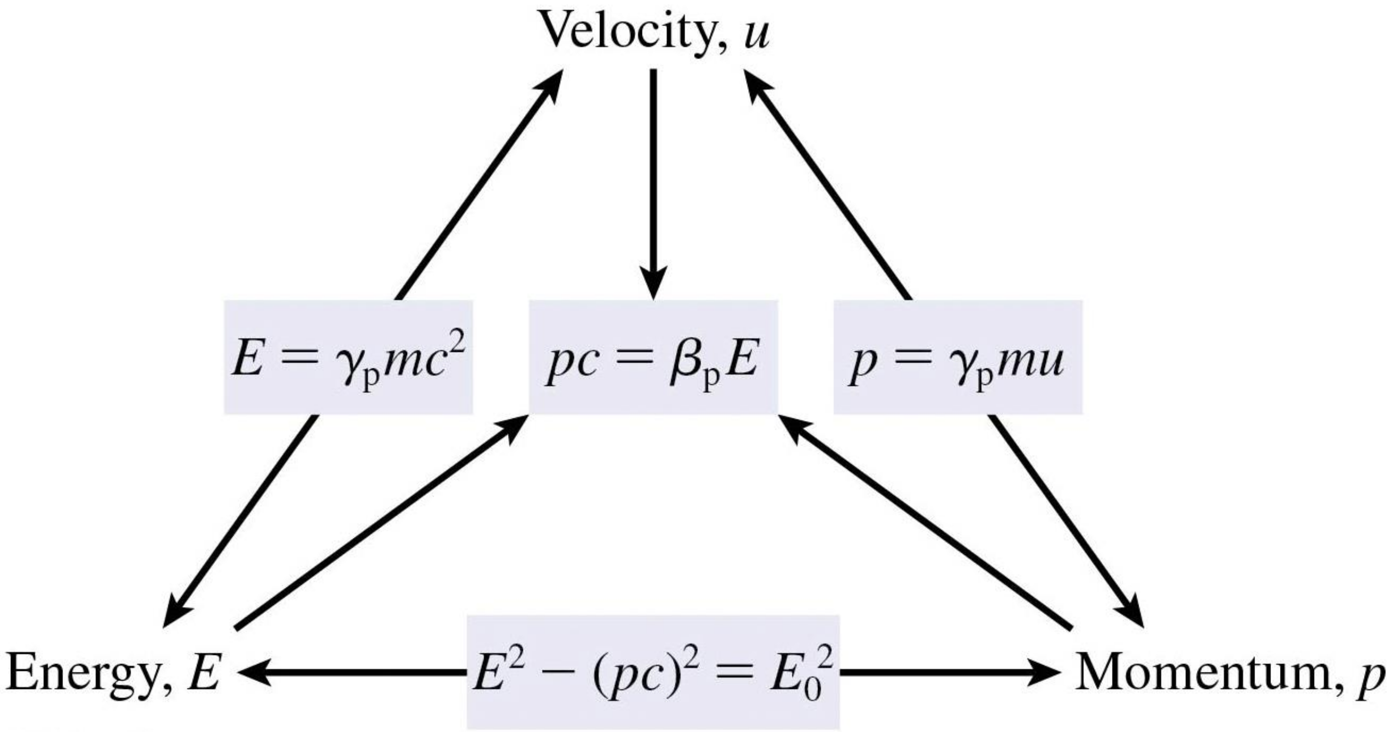
An electron and a positron meet.

They annihilate.

The energy equivalent of the mass is transformed into two gamma-ray photons.



Team Up questions



$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} = \frac{1}{\sqrt{1 - \beta^2}}$$

$$u' = \frac{u - v}{1 - uv/c^2} \quad \text{and} \quad u = \frac{u' + v}{1 + u'v/c^2}$$

Team Up questions

1) $p = mc$, $u=?$ 2) $v=0.8c$, $K=?$ 3) $M \to 2m$, $u=0.8c$, $m=?$

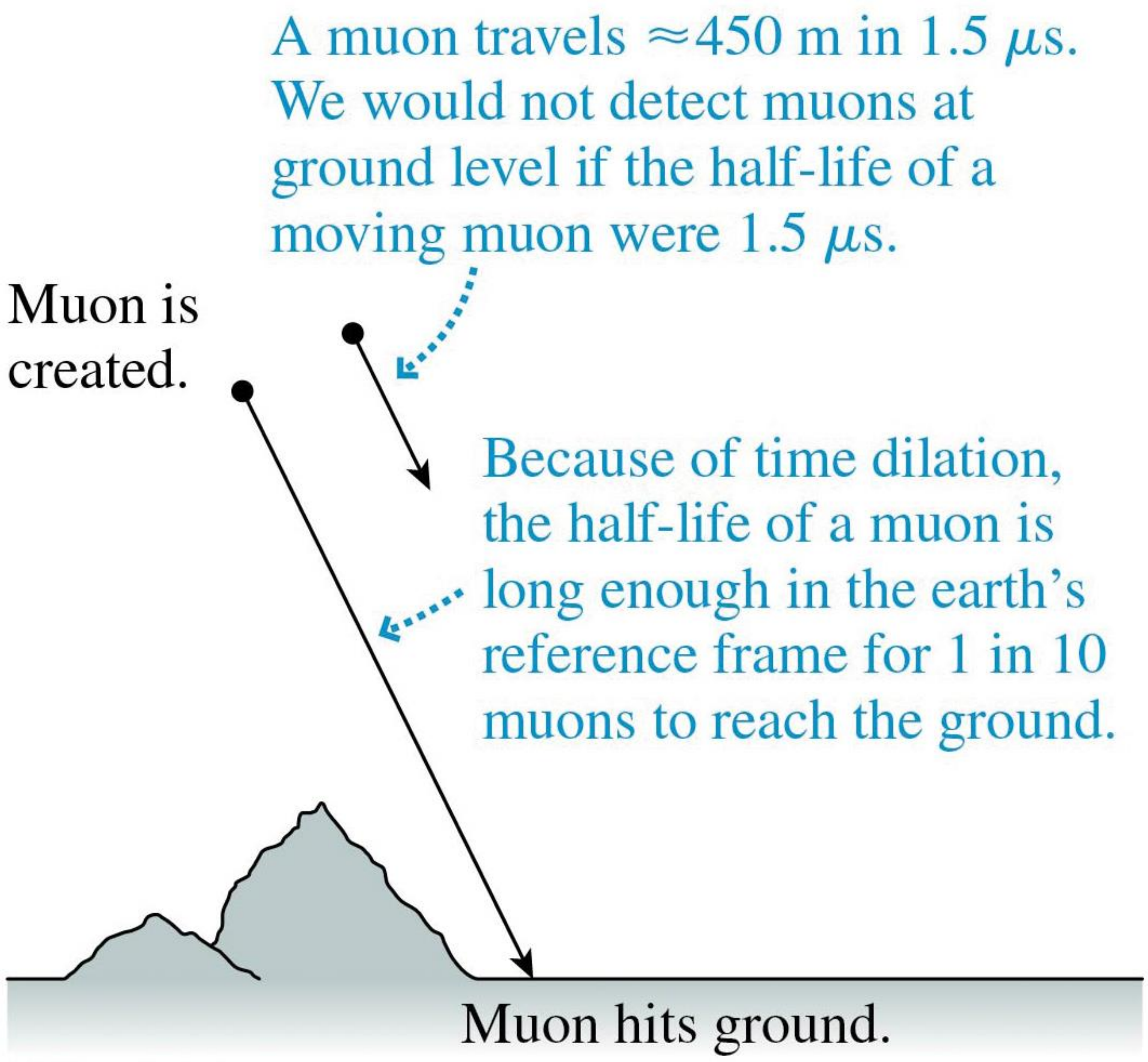
$\gamma_p \cancel{m} u = \cancel{m} c$

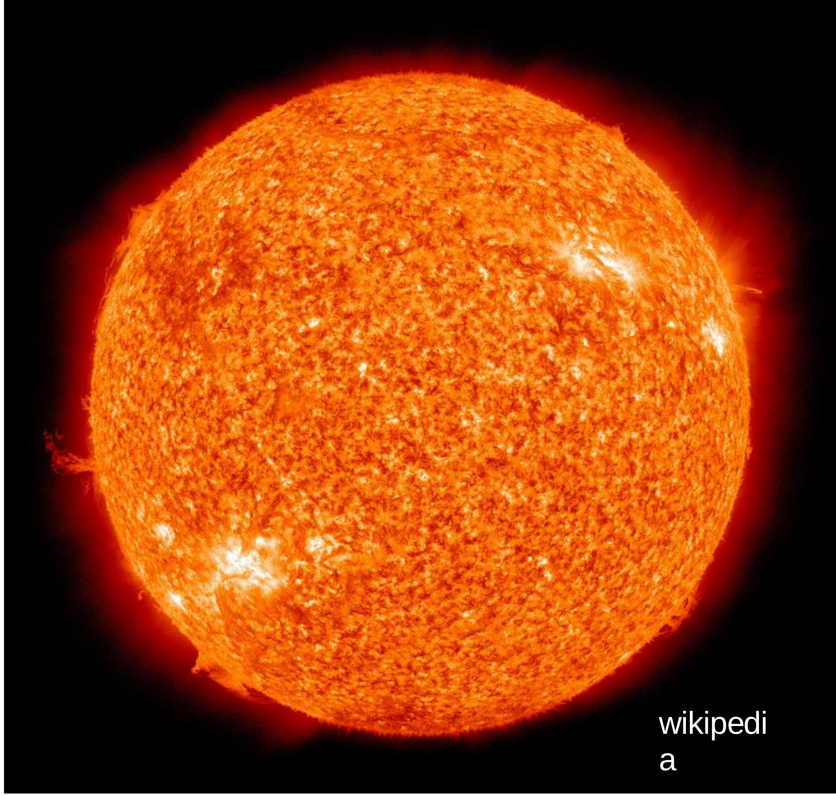
$\gamma_p \beta \cancel{c} = \cancel{c}$

$\gamma \beta = 1$

$K = (\gamma_p - 1) mc^2$

$\underbrace{\gamma}_{=1} Mc^2 = 2\gamma_p mc^2$


A muon travels ≈450 m in 1.5 μs. We would not detect muons at ground level if the half-life of a moving muon were 1.5 μs.
Muon is created.
Because of time dilation, the half-life of a muon is long enough in the earth's reference frame for 1 in 10 muons to reach the ground.
Muon hits ground.


wikipedia


GPS
100m
Main Rd
Speed
40
Menu
Arrival
6:51
NAVIGATION SYSTEM