$E \approx mc^2 + \frac{1}{2}mv^2$ IF $v \ll c$

True: $E = \Gamma mc^2$ $\vec{p} = \Gamma m \vec{u}$

$p^0 = \frac{E}{c}$, $p^{1,2,3} = p_{x,y,z}$

$\sum_\mu p^\mu p_\mu = (p^0)^2 - \vec{p}^2 = m^2c^2$

IF $|\vec{u}| = c \rightarrow |\vec{p}| = \frac{E}{c} \Rightarrow 0$

$\Rightarrow m = 0!$

IF $m = 0 \Rightarrow |\vec{u}| = c$, E can be anything

$|\vec{p}| = \frac{E}{c}$ $E = |\vec{p}| \cdot c$

$E_\gamma = hf$ $p_\gamma = h\frac{f}{c} = \frac{h}{\lambda}$ γ = Photon

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

A) $v = 0.5 \cdot c$

$\gamma = 1.155$

B) $ct = \gamma$ $x = 0.5\gamma$

C) $1m^2$ D) $1m^2$

E) $\frac{1}{\gamma}m$

F) $ct = 0.5\gamma$ $x = \gamma$

G) $1m^2$

H) $1kg \cdot c$, $\vec{0}$

I) $\Gamma \cdot 1kg \cdot c$, $\Gamma \cdot 1kg \cdot 0.5c$, 0, 0

J) $E_{kin}/c = (\Gamma + 1)\,1kg \cdot c \Rightarrow (\Gamma+1)^2 - 0.5^2\Gamma^2 \cdot (1kg \cdot c)^2$

$(0.75\Gamma^2 + 2\Gamma + 1)(1kg \cdot c)^2$

$= 2.076\ kg$

Light $\rightarrow$ photons $= \gamma = m = 0$

Neutrinos $? = \nu$ X $m > 0$

Gluon G ✓ $m = 0$

Graviton g (✓) $m = 0$