1. In the lab frame, a gamma ray with energy $E_\gamma$ is incident upon a particle $A$ with mass $M$ that is at rest. The gamma ray is absorbed, creating a new, unstable particle $B$. A detector is set up to register the decay products of $B$ so that scientists can determine how far it traveled before decaying.

a) Determine the mass of particle $B$. (15 Points)

b) If particle $B$ has a lifetime $\tau$ (in its own frame), determine the distance particle $B$ will have traveled in the lab frame before decaying. (15 Points)
2. Let $p^\mu = (10, -3, 2, 4)$ and $k^\mu = (6, 0, 5, 1)$ be four-vectors, and let $g_{\mu\nu}$ be the Minkowski metric tensor. Evaluate the following. (5 Points Each)

a) $g^{\mu\nu}k_\mu k_\nu$

b) $k^\mu p_\nu p_\nu$

c) $g_{\mu\nu}(p^\mu + k^\mu)p^\nu$

d) $g^\nu k^\sigma(k_\rho + p_\rho)(k_\lambda - p_\lambda)g^\rho g^\lambda g_{\mu\sigma} k_\alpha$
3. For each process, determine whether it is possible or impossible. If possible, state which interaction allows it. If impossible, state which conservation law prohibits it. (5 Points Each)

a) $\eta \rightarrow \gamma + \gamma$

b) $\Sigma^+ + n \rightarrow \Sigma^- + p$

c) $\mu^- \rightarrow e^- + \bar{\nu}_e$

d) $n \rightarrow p + e^- + \bar{\nu}_e$

e) $\Omega^- \rightarrow \Delta + \Xi^-$

f) $\Sigma^+ \rightarrow p + \pi^0$
4. A neutral pion can be created via the photoproduction reaction given below. If the initial proton is at rest in the lab frame, determine the minimum necessary energy of the incident gamma ray in order to trigger this reaction. Take the masses of the particles as given. (20 Points)

\[ \gamma + p \rightarrow p + \pi^0 \]
★ Bonus! ★ (5 Points)

On the first homework, you showed that a light signal sent after a particle accelerating away from the origin with a constant proper acceleration $\alpha$ will never reach the particle so long as the particle has a head start that is at least $T = c/\alpha$.

Imagine this scenario from the perspective of the particle. How can the light fail to catch up? Or does it? Explain.