# PHYS 3317 Fall 2012
# Excercises on Elementary Particles

You may be needing masses of particles, etc.—just look them up online.

## 1. Forbidden reactions

The following reactions are forbidden. Determine a conservation law that each violates.

  **(a)** $p + \bar{p} \rightarrow \mu^+ + e^-$

  **(b)** $\pi^- + p \rightarrow p + \pi^+$

  **(c)** $p + p \rightarrow p + \pi^+$

  **(d)** $p + p \rightarrow p + p + n$

  **(e)** $\gamma + p \rightarrow n + \pi^0$

## 2. Energy threshold for reactions

Calculate the threshold for production of strange particles in the following reactions. Assume that the first particle is moving and the second is at rest.

  **(a)** $p + p \rightarrow n + \Sigma^+ + K^0 + \pi^+$

  **(b)** $\pi^- + p \rightarrow \Sigma^0 + K^0$

## 3. Is it possible?

For the following reactions, state whether each one is possible or impossible, according to the Standard Model. If the reaction is possible, state which interaction (strong, electromagnetic, or weak) is responsible for it. If the reaction is impossible, state which conservation law forbids it.

  **(a)** $\mu^- \rightarrow e^- + \gamma$

  **(b)** $p + p \rightarrow \pi^+ + \pi^0$

  **(c)** $\Sigma^0 \rightarrow \Lambda^0 + \gamma$

  **(d)** $\Sigma^0 \rightarrow \Lambda^0 + \pi^0$

  **(e)** $\Sigma^- \rightarrow n + \pi^-$

  **(f)** $e^- + e^+ \rightarrow \mu^- + \mu+$

  **(g)** $\mu^- \rightarrow e^- + \bar{\nu}_e$

  **(h)** $\Delta^+ \rightarrow p + \pi^-$

  **(i)** $e^- + p \rightarrow \nu_e + \pi^0$

  **(j)** $p + p \rightarrow \Sigma^+ + n + K^0 + \pi^+ + \pi^0$

**(k)** $p + p \rightarrow p + p + p + \bar{p}$

**(n)** $\text{J}/\psi \rightarrow \pi^+ + \pi^- + \pi^0 + K^+ + K^-$

**(l)** $\pi^+ + n \rightarrow \pi^- + p$

**(o)** $Y \rightarrow \tau^+ + \tau^-$

**(m)** $B^0 \rightarrow \pi^- + p$

**(p)** $Y \rightarrow \tau^+ + \bar{\nu}_\tau$

## 4. Feynman diagrams

Draw Feynman diagrams for the following processes:

**(a)** $D^0 \rightarrow K^- + \pi^+$ (weak interaction)

**(b)** $\Delta^+ \rightarrow p + \pi^0$ (strong interaction)

**(c)** $\pi^0 \rightarrow \gamma + \gamma$ (electromagnetic interaction)