Question 1

Many times during this course you'll be asked to analyze a process involving particles you're not yet familiar with. To learn about the properties of particles you can resort to the **Particle Data Group** (PDG) web page: http://pdglive.lbl.gov/Viewer.action.

1. To familiarize yourselves with the PDG webpage, click the link above and look write down the mass, EM charge, and quark content for the following hadrons:
   (a) π^0 $=(u\bar{u}-d\bar{d})/\sqrt{2} \Rightarrow u\bar{u}$ or $d\bar{d} = 0,\ 135\,\text{MeV}$
   (b) K^- $= \bar{u}s = -\frac{2}{3}-\frac{1}{3} = -1,\ 493\,\text{MeV}$
   (c) B^+ $= u\bar{b} = \frac{2}{3}-(-\frac{1}{3}) = 1,\ 5.28\,\text{GeV}$
   (d) Ω^- $= sss = -\frac{1}{3}\cdot 3 \Rightarrow 1,\ 1.672\,\text{GeV}$
   (e) Λ^0 $= uds \Rightarrow Q_{EM} = 0,\ 1.115\,\text{GeV}$
   (f) Σ^0 $= uds \rightarrow +\frac{2}{3}-\frac{1}{3}-\frac{1}{3} = 0,\ 1.192\,\text{GeV}$
2. **(Optional)** In the PDG there are no hadrons containing a top quark. Explain why this is the case (i.e. why does the top quark not form any bound states)?

t כבד מסיבי (172GeV) שהוא דועך מהר מידי
(ל-b) כדי ליצור מצבים קשורים.

Question 2

1. The process $e^+e^- \rightarrow \gamma$ is forbidden in the SM. Show explicitly that this process can not conserve both the energy and momentum simultaneously.
2. Determine what is the minimal kinetic energy (in the center of mass frame) required for an electron in order for the process $e^+e^- \rightarrow \mu^+\mu^-$ to occur.

$$E^2 = m^2 + p^2$$

לפני — מרכז מסה $\rightarrow$

$$E^2 = (2m_e)^2 + P_i^2 \quad (P_i = 0)$$

אחרי

$$E^2 = P_f^2$$

$$\Rightarrow 2m_e = P$$

א) במע' מרכז המסה $P_i = P_f = 0$ סתירה! $m_e > 0$

ב) במע' מרכז המסה האנרגיה לפני $E_i = 2(E_k + m_e)$

הדרישה המינימלית היא שמיואונים יווצרו במנוחה: $E_f = 2m_\mu$

$$\Rightarrow E_k = m_\mu - m_e$$

Question 3

Determine whether the following processes are allowed in the SM. If the process is forbidden, list which conservation laws are violated.

1. $\Sigma^0 \to \Lambda^0 \pi^0$
2. $K^- \to \pi^- \pi^+ \pi^-$
3. $\tau^- \to \nu_\tau \mu^-$
4. $p \to e^+ \gamma$
5. $pp \to pppp\bar{p}$
6. $pe^- \to \nu_e \pi^0$
7. $n\bar{n} \to \pi^+ \pi^- \pi^0$ ✓
8. $\pi^+ n \to \pi^- p$ ✓

$\pi^+ \Lambda = u\bar{d}udd$

8) $\pi^- p = \bar{u}dudd$

7) $\pi^+ = u\bar{d}$, $\pi^- = \bar{u}d$, $\pi^0 = d\bar{d}/u\bar{u}$, $n = udd$, $\bar{n} = \bar{u}\bar{d}\bar{d}$

1) Forbidden, $B(\Sigma^0) = 1$, $B(\Lambda^0 \pi^0) = 1 + 1$

2) Forbidden, quark family - K^- has s, π^- have only u, d

3) Forbidden, $L(\tau^-) = 1$, $L(\nu_\tau \mu^-) = 2$

4) +5) Forbidden, conservation of 4-momentum

6) Forbidden, $B(pe^-) = 1$, $B(\nu_e \pi^0) = 0$