Homework 1

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Exercise 1

***Introduction to Elementary Particles* (Griffiths, 2e) Exercise 1.1**

For a particle to be undeflected, $F_e = F_m$.

$$\begin{aligned} F_e &= F_m \\ qE &= qv \times B = qvB \\ v &= \frac{E}{B} \end{aligned} \tag{1}$$

Turning off the electric field:

$$\begin{aligned} F_m = qvB &= \frac{mv^2}{R} \\ \frac{q}{m} &= \frac{v}{RB} = \frac{E}{RB^2} \end{aligned} \tag{2}$$

Exercise 2

***Introduction to Elementary Particles* (Griffiths, 2e) Exercise 1.3**

By the position-momentum uncertainty relation:

$$\begin{aligned} \Delta x \Delta p &\geq \frac{\hbar}{2} \\ p_{\min} &= \frac{\hbar}{2\Delta x} \\ &= \frac{\hbar c}{2\Delta x}\frac{1}{c} \\ &= \frac{6.58212 \cdot 10^{-22}\ \text{MeVs} \cdot 3 \cdot 10^{8}\ \text{m/s}}{2 \cdot 10^{-15}\ \text{m}}\frac{1}{c} \\ &= 98.7318\ \text{MeV/c} \\ E &= \sqrt{m^2c^4 + p^2c^2} \end{aligned} \tag{3}$$

The corresponding energy is then:

$$\begin{aligned} E_{\min} &= \sqrt{\left(0.510999\ \text{MeV/c}^2\right)^2 c^4 + \left(98.7318\ \text{MeV/c}\right) c^2} \\ &= 98.7331\ \text{MeV} \end{aligned} \tag{4}$$

Exercise 3

***Introduction to Elementary Particles* (Griffiths, 2e) Exercise 1.7**

Part (a)

The decays where charge and strangeness are conserved are:

$$\begin{aligned}
\Delta^{++} &\to p^+ + \pi^+ \\
\Delta^- &\to n + \pi^- \\
&\to \Sigma^- + K^0 \\
\Sigma^{*+} &\to \Sigma^0 + \pi^+ \\
&\to \Lambda + \pi^+ \\
&\to \Xi^0 + K^+ \\
&\to p + \bar{K}^0 \\
&\to \Sigma^+ + \pi^0 \\
&\to \Sigma^+ + \eta \\
\Xi^{*-} &\to \Sigma^- + \bar{K}^0 \\
&\to \Xi^- + \pi^0 \\
&\to \Xi^- + \eta \\
&\to \Sigma^0 + K^- \\
&\to \Lambda + K^- \\
&\to \Xi^0 + \pi^-
\end{aligned} \tag{5}$$

Part (b)

The decays where the reactant mass exceeds the product mass are:

$$\begin{aligned}
\Delta^{++} &\to p^+ + \pi^+ \\
\Delta^- &\to n + \pi^- \\
\Sigma^{*+} &\to \Sigma^0 + \pi^+ \\
&\to \Lambda + \pi^+ \\
&\to \Sigma^+ + \pi^0 \\
\Xi^{*-} &\to \Xi^- + \pi^0 \\
&\to \Xi^0 + \pi^-
\end{aligned} \tag{6}$$

Exercise 4

***Introduction to Elementary Particles* (Griffiths, 2e) Exercise 1.8**

The decays where charge and strangeness are conserved are:

$$\begin{aligned} \Omega^- &\to \Xi^- + \bar{K}^0 \\ &\to \Xi^0 + \bar{K}^- \end{aligned} \tag{7}$$

However, both decays have the reactant mass exceeding the product mass and are therefore kinematically forbidden.

Exercise 5

Part (a)

	Reactants ($\pi^+ + p^+$)	Products ($K^+ + \Sigma^0$)
A	$0+1=1$	$0+1=1$
S	$0+0=0$	$1+-1=0$
L_μ	$0+0=0$	$0+0=0$
L_e	$0+0=0$	$0+0=0$
q	$1+1=2$	$1+0=1$
E	$139.570+938.272=1077.842$	$493.68+1192.64=1686.32$

Charge and energy are not conserved.

Part (b)

	Reactants ($\pi^- + p^+$)	Products ($\Lambda + \Sigma^0$)
A	$0+1=1$	$1+1=2$
S	$0+0=0$	$-1+-1=-2$
L_μ	$0+0=0$	$0+0=0$
L_e	$0+0=0$	$0+0=0$
q	$-1+1=0$	$0+0=0$
E	$139.570+938.272=1077.842$	$1115.68+1192.64=2308.32$

Baryon number, strangeness, and energy are not conserved.

Part (c)

	Reactants (π^-)	Products ($\mu^- + \nu_\mu$)
A	0	$0+0=0$
S	0	$0+0=0$
L_μ	0	$1+1=2$
L_e	0	$0+0=0$
q	-1	$-1+0=-1$
E	139.570	$105.659+0=105.659$

Muon number is not conserved.

Part (d)

	Reactants (p^+)	Products ($\Delta^{++} + \pi^-$)
A	1	$1+0=1$
S	0	$0+0=0$
L_μ	0	$0+0=0$
L_e	0	$0+0=0$
q	1	$2+-1=1$
E	938.272	$1232+139.570=1371.570$

Energy is not conserved.

Part (e)

	Reactants (μ^-)	Products ($e^- + \nu_\mu$)
A	0	$0 + 0 = 0$
S	0	$0 + 0 = 0$
L_μ	1	$0 + 1 = 1$
L_e	0	$1 + 0 = 1$
q	-1	$-1 + 0 = -1$
E	139.570	$105.659 + 0 = 105.659$

Electron number is not conserved.

Part (f)

	Reactants (K^0)	Products ($\pi^+ + \pi^-$)
A	0	$0 + 0 = 0$
S	1	$0 + 0 = 0$
L_μ	0	$0 + 0 = 0$
L_e	0	$0 + 0 = 0$
q	0	$1 + -1 = 0$
E	497.65	$139.570 + 139.570 = 279.140$

Strangeness is not conserved.

Exercise 6

Part (a)

Weak interactions do not need to conserve strangeness, so $K^0 \to \pi^+ + \pi^-$ is allowed.

Part (b)

Applying crossing symmetry and detailed balance to transform $p^+ \to \Delta^{++} + \pi^-$:

$$\begin{aligned} p^+ &\to \Delta^{++} + \pi^- \\ p^+ + \pi^+ &\to \Delta^{++} \\ \pi^+ &\to \bar{p}^- + \Delta^{++} \\ \pi^+ + \bar{\Delta}^{--} &\to \bar{p}^- \end{aligned} \tag{8}$$

	Reactants ($\pi^+ + \bar{\Delta}^{--}$)	Products ($\bar{p}^-$)
A	$0 + -1 = -1$	-1
S	$0 + 0 = 0$	0
L_μ	$0 + 0 = 0$	0
L_e	$0 + 0 = -$	0
q	$1 + -2 = -1$	-1
E	$1232 + 139.570 = 1371.570$	938.272

All quantities are conserved, so this process is allowed.