Exercise 1: QED Vertex

Explain why the QED vertex shown in figure cannot be a real process.

(Hint: use conservation of 4-momentum)

Exercise 2: Weak Decays

The $\Xi^-$ is a strange baryon whose quark content is $\Xi^- (ssd)$. After drawing the Feynman diagrams for the following weak decays, determine which is more likely:

a) $\Xi^- (ssd) \rightarrow \Lambda^0 (usd) + \pi^- (d\bar{u})$

b) $\Xi^- (ssd) \rightarrow n (udd) + \pi^- (d\bar{u})$

The $D^0 (c\bar{u})$ is a charmed meson. After drawing the Feynman diagrams for the following weak decays, determine which is more likely:

a) $D^0 (c\bar{u}) \rightarrow K^- (s\bar{u}) + \pi^+ (u\bar{d})$

b) $D^0 (c\bar{u}) \rightarrow \pi^- (d\bar{u}) + \pi^+ (u\bar{d})$

c) $D^0 (c\bar{u}) \rightarrow K^+ (\bar{s}u) + \pi^- (\bar{u}d)$
Exercise 3: Isospin conservation and strong decays

Consider the following strong processes.

a) $\pi^+ + p \rightarrow \pi^+ + p$ elastic scattering
b) $\pi^- + p \rightarrow \pi^- + p$ elastic scattering
c) $\pi^- + p \rightarrow \pi^0 + n$ charge exchange

The cross section is proportional to the square of the matrix element connecting initial and final states. Using Dirac notation of $\langle \psi_f | \text{ and } | \psi_i \rangle$ for the in and out states, one can write

$$\sigma \propto \langle \psi_f | O | \psi_i \rangle^2 = M^2$$

Where $O$ is an isospin operator equalling $O_{1/2}$ if it operates on initial and final states of isospin $I = 1/2$ and $O_{3/2}$ for states of $I = 3/2$. By conservation of isospin, there is no operator connecting initial and final states of different isospin. Let

$$M_{1/2} = \langle \psi_f | O_{1/2} | \psi_i \rangle$$
$$M_{3/2} = \langle \psi_f | O_{3/2} | \psi_i \rangle$$

The strong process a) involves the transition between two states of $I = 3/2$ and $I_z = +3/2$, therefore

$$\sigma_a = K |M_{3/2}|^2$$

Where $K$ is some constant. By using the decomposition law of angular momentum deduce the cross-section ratios

$$\sigma_a : \sigma_b : \sigma_c$$

In terms of $M_{1/2}$ and $M_{3/2}$.

In the same spirit of the previous calculation, determine the ratios of the cross sections of the strong processes

a) $\Sigma^*^0 (uds) \rightarrow \Sigma^+ (uus) + \pi^- (d\bar{u})$
b) $\Sigma^*^0 (uds) \rightarrow \Sigma^0 (dus) + \pi^0 (d\bar{d})$
c) $\Sigma^*^0 (uds) \rightarrow \Sigma^- (dds) + \pi^- (u\bar{d})$