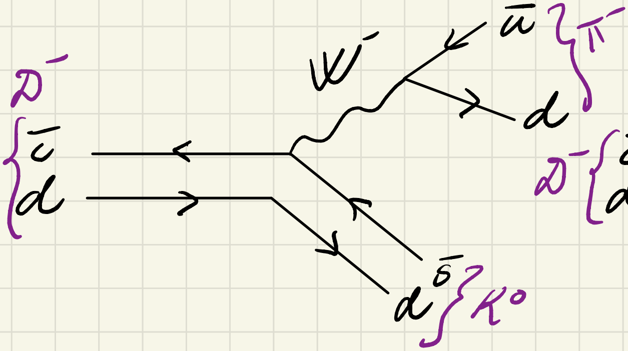
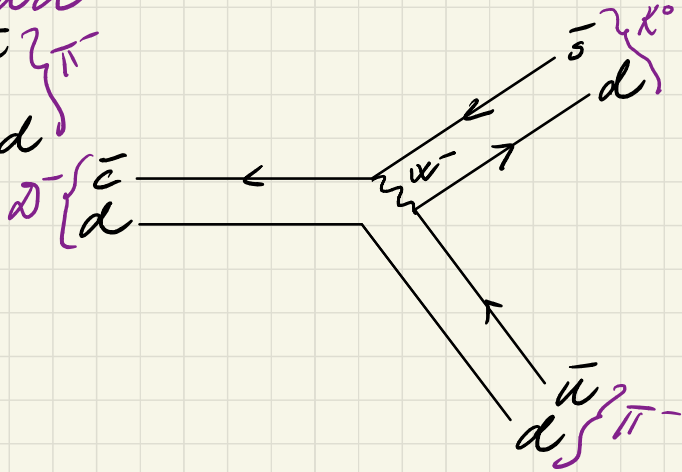
FYS3500 Solution 7

Problem 1 (Exercise 3.16)

a) $D^- \to K^0 + \pi^-$

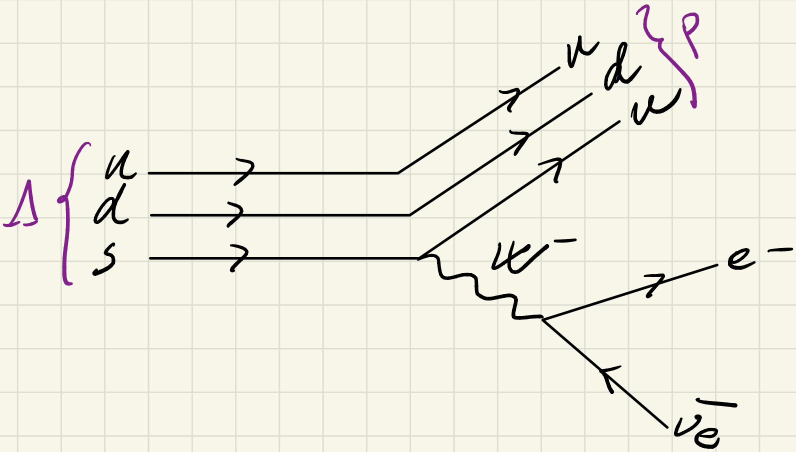
$\bar{c}d \qquad d\bar{s} \qquad \bar{u}d$





b) $\Lambda \to p + e^- + \bar{\nu}_e$

$uds \qquad uud$



Problem 2 (Exercise 3.13 in M&S)

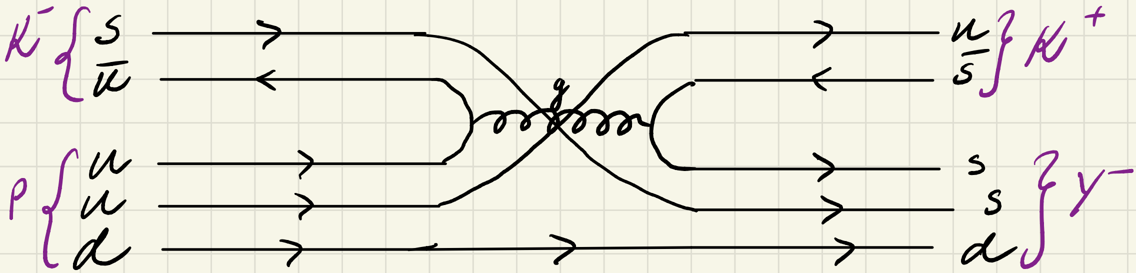
In the strong interaction, baryon nr B and individual quark numbers must be conserved.

	K^- ($\bar{u}s$)	+	p (uud)	$\rightarrow$	K^+ ($u\bar{s}$)	+	Y^-
baryon nr B	0		1		0		1
strangeness S	-1		0		+1		-2
charm nr C	0		0		0		0
bottom nr $\tilde{B}$	0		0		0		0

$\Rightarrow$ from conservation of quark nr, deduce Y^-'s q. nr

Y^- must consist of two strange-quarks to conserve strangeness. To conserve charge, last quark must be d (cannot be b, as bottom nr was 0 before)

Y^- : ssd



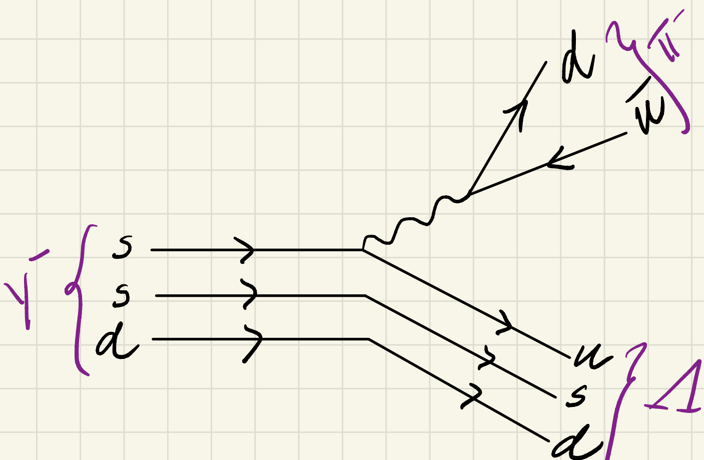
Decay:

$$Y^- \to \Lambda + \pi^-$$

ssd uds $\bar{u}d$

As strangeness is not conserved, this must be a weak interaction

$\Rightarrow$ W.I. lifetime $10^{-7} - 10^{-13}$ s



Problem 3 M&S 3.11

Parity

$$\hat{P}(\underset{u\bar{d}}{\pi^+}) = (-1)^{\overset{\text{because lowest energy level}}{l=0}} \underbrace{P(u)}_{+1} \underbrace{P(\bar{d})}_{-1} = -1$$

$$\hat{P}(\underset{d\bar{u}}{\pi^-}) = (-1)^{l=0} P(d) \cdot P(\bar{u}) = -1$$

$$\hat{P}(\pi^0) = (-1)^{l=0} P\underbrace{(u)\, P(\bar{u})}_{\text{alternatively: } d\bar{d}} = -1$$

First excited: $l=0$, $s=1$

$$\hat{P}(\rho^+) = (-1)^l P(u) P(\bar{d}) = -1$$

$$\hat{P}(\rho^-) = (-1)^l P(d) P(\bar{u}) = -1$$

$$\hat{P}(\rho^0) = (-1)^l P(u) P(\bar{u}) = -1$$

Charge conjugation

Only particles that are their own anti-particle have defined $C \Rightarrow \pi^0, \rho^0$

$$\hat{C}(\pi^0) = (-1)^{\overset{=0}{l}+\overset{=0}{s}} = 1$$

$$\hat{C}(\rho^0) = (-1)^{\overset{=0}{l}+s^{=1}} = -1$$

Why $\pi^{\pm}$ has longer lifetime than $\rho^{\pm}$:

For $\rho^{\pm}$ there exists a meson with lower mass, but the same quark configuration (which is $\pi^{\pm}$, definition of excited state).

So decay of $\rho^{\pm}$ can go through the strong interaction, giving short lifetime.

$\pi^{\pm}$ is the «ground state», the lowest mass configuration with these quark flavours. Since the strong force conserved quark flavour, $\pi^{\pm}$ must decay through the weak interaction, giving a much longer lifetime

$\rho^0 \to \pi^+\pi^-$

$l=0$ $\quad s=0 \Rightarrow$ orbital ang. mom must be $l=1$ to conserve total momentum

$s=1$

$\rho^0 \to \pi^0 \pi^0$

↳ both pions have $S=0$ & need total symmetric wave function $\Psi = \psi_{spin} \cdot \psi_{space}$

ψ_{spin} is symmetric, $S=0$

Need $l=1$ to conserve ang. mom,

but then ψ_{space} is anti-sym; and thus also Ψ is anti-sym

$\Rightarrow$ not allowed, decay not observed)

(see solution of M&S 1.3 from last week for more details)

Problem 4 (M&S 3.21)

In the simple quark model, mesons are made up by $q\bar{q}$ and baryons by qqq.

For mesons, $q\bar{q}$

$C=0$ $(c\bar{c}, u\bar{d}, d\bar{u} \dots) \Rightarrow Q = -1, 0, 1$

$C=1$ $(c\bar{d}, c\bar{b}, c\bar{u}, c\bar{t}) \Rightarrow Q = 0, 1$

$C=-1$ $(\bar{c}d, \bar{c}b, \bar{c}u, \bar{c}t) \Rightarrow Q = 0, -1$

For baryons, qqq

$C=3$ $(ccc) \Rightarrow Q = +2$

$C=2$ $(ccu, ccd, ccs, \dots) \Rightarrow Q = +2, +1$

$C=1$ $(cuu, cud, \dots) \Rightarrow Q = +2, +1, 0$

$C=0$ $(uuu, uud, \dots) \Rightarrow Q = +2, +1, 0, -1$

If we find another combination of the C and Q quantum numbers, then this would imply that we have quark combinations like $qq\bar{q}\bar{q}$ & $qqqq\bar{q}$ which are not included in the simple quark model, and are thus called exotic.