



2.6 Quarks and antiquarks

We have seen that hadrons (mesons, baryons, antibaryons) consist of combinations of quarks. For example, a proton is made up of two up quarks and one down quark (uud). A neutron contains one up and two down quarks (udd). We also know that the relative charge on a proton $Q = +1$, and on a neutron $Q = 0$.

The table, below, shows the properties of individual quarks:

	quarks			antiquarks		
	u	d	s	$\bar{u}$	$\bar{d}$	$\bar{s}$
Q	$+\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{3}$	$-\frac{2}{3}$	$+\frac{1}{3}$	$+\frac{1}{3}$
S	0	0	-1	0	0	+1

The relative charge Q and strangeness number S are shown for the up, down and strange quark. Note that the strange quark has a strangeness number $S = -1$, and the anti-strange quark has a strangeness number $S = +1$.

If we work out the charge of a proton, we just add together the charge of the constituent quarks (uud). Therefore, charge $Q = \frac{2}{3} + \frac{2}{3} + \left(-\frac{1}{3}\right) = +1$.

(1) ✍️ Work out the charge of a neutron from its constituent quarks.

The proton and neutron don't contain a strange quark and so the strangeness number $S=0$ for both.

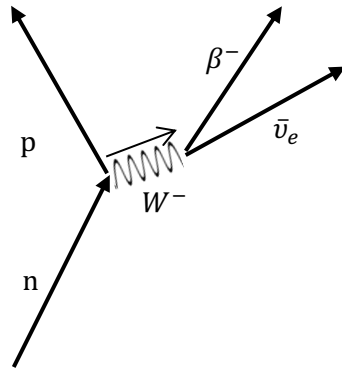
(2) ✍️ Complete the following table:

particle	Quark composition	Q	S
π^-	$\bar{u}d$		
π^0	$d\bar{d}$ or $u\bar{u}$		
$\bar{n}$	$\bar{u}\bar{d}\bar{d}$		
K^+	$u\bar{s}$		
K^-	$\bar{u}s$		
K^0			
π^+			

Remember that pions (pi mesons) don't contain a strange/anti-strange quark. Kaons contain a strange/anti-strange quark.

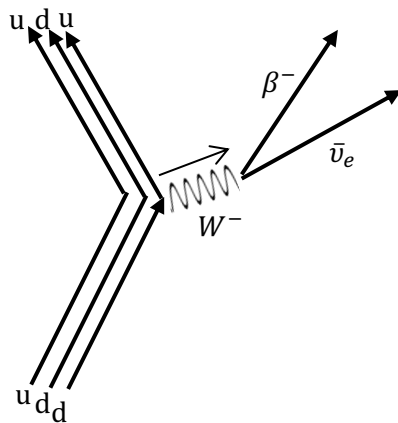
Beta decay

We have seen that a neutron changes to a proton during beta minus (β^-) decay. The Feynman diagram of this is shown below:



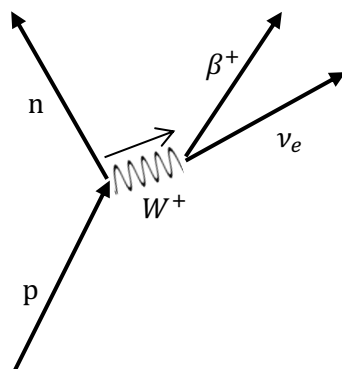
We can see that the neutron changes to a proton and emits a beta minus particle (an electron) as well as an anti-electron neutrino. A W^- boson is the exchange particle in this decay.

At the quark level, this is what is happening:



A down quark is changing to an up quark. The other two quarks remain unchanged. The result is that the neutron (udd) changes to a proton (uud).

During beta plus (β^+) decay, a proton changes to a neutron and emits a beta plus particle and an electron neutrino. The Feynman diagram of this is shown below:



(3) ✎ Draw a Feynman diagram for beta plus decay at a quark level.