2.6 Quarks and antiquarks

videos

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**		
	$\boldsymbol{u}$	$\boldsymbol{d}$	$\boldsymbol{s}$	$\boldsymbol{\bar{u}}$	$\boldsymbol{\bar{d}}$	$\boldsymbol{\bar{s}}$
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.

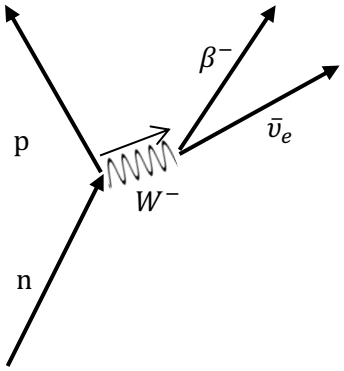
(2) Complete the following table:

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

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

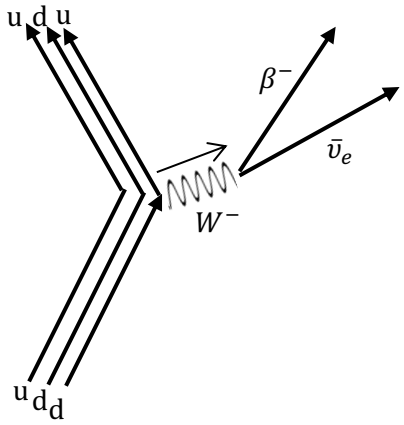
Beta decay

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



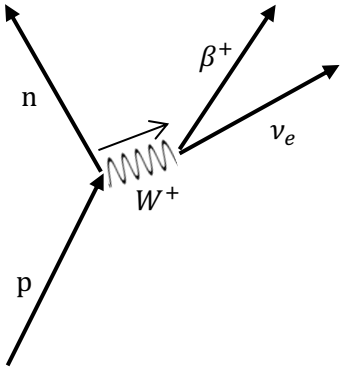
We can see that the neutron changes to a proton and emits a beta minus particle (an electron) as well as an anti-electron neutrino. A W^- boson is the exchange particle in this decay.

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.