Further four forces notes

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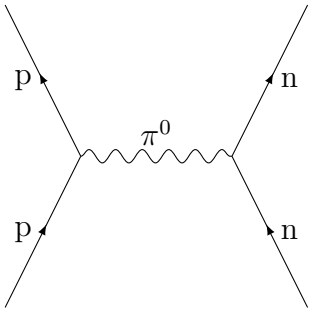
The strong interaction

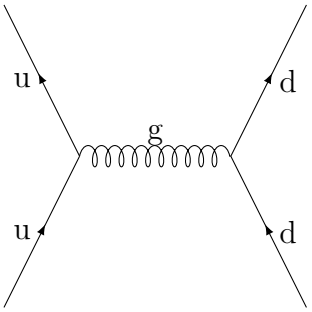
Protons and neutrons are held together by the strong force (which acts on all hadrons). As the range of the strong force is 10^{-15} m, and assuming the exchange particle has a speed close to that of light, it must exist for $\sim 10^{-23}$ s. This allows the mass of the exchange particle to be calculated, and it is found that the particle is the pi-meson or pion.

It can be shown as:



The direction of the paths does not show the direction of the particles, only of the interaction.

At a deeper level, the quarks themselves in the hadrons are held together by gluons:



The pion can be seen to exist to carry the gluons between the hadrons.

The weak interaction

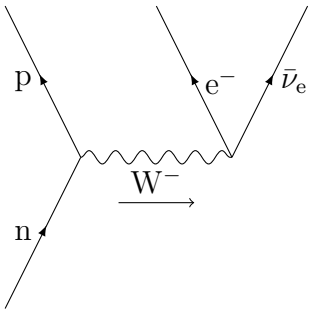
The weak interaction is very short range which suggests the exchange particle is massive. One of the characteristics of the weak force is that it is responsible for decays of particles. The weak force causes a change in the quark structure of a hadron.

There are three particles which can carry the weak force, W^+, W^- and Z^0, and these act on leptons and hadrons.

The most common weak interaction is beta decay. In this, a neutron decays into a proton, and into an electron and anti-electron neutrino through the weak interaction:

$$n \longrightarrow p + e^- + \bar{\nu}_e,$$

which is shown as:



The W^- is the carrier of the weak force. It needs to be negative to conserve charge.

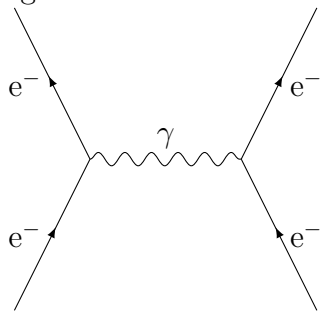
The weak force is the only force which acts on neutrinos (other than gravity), and this is why they are weakly interacting.

Weak force is responsible for the changing of a strange quark into a non-strange quark, and this is why strangeness is changed in a weak decay.

Electromagnetism

The electromagnetic force is exerted between any charged particles, and is described by the theory known as **quantum electrodynamics (QED)**. As the range of the force is infinite, the exchange particle is massless, and is a virtual photon.

e.g. electron–electron scattering:



Gravity

The particle responsible for the gravitational interaction is postulated to be the graviton. It ought to have zero mass and zero charge, but has not yet been detected.

Unification

It is believed that all four forces can be theoretically united, to show that they are all different aspects of one force. There has been some success already, namely the unification of the electromagnetic with the weak interactions, and it is an aim of modern physics to unite the others in a unified theory (sometimes known as a 'grand unified theory' or 'theory of everything'...)