The four forces

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Forces between elementary particles

There are four forces which act between elementary particles. Gravity and the electromagnetic force are the two familiar forces, and in addition there are two nuclear forces, the strong interaction and the weak interaction.

Gravity

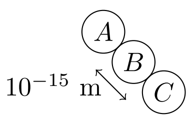
Gravity affects all particles which have   . It has an infinite range and is purely attractive. It governs the structure of stars, galaxies &c. and its exact strength will determine

Electromagnetism

This force affects all particles with   . It is much stronger than gravity and also of infinite range, but it tends to cancel in bulk matter as this normally comprises nearly exactly equal numbers of

Strong

The strong force is only felt by   , which are all made from   . The strong force is short range, and only affects nearest neighbours in the nucleus, as its range is the same as the diameter of a nucleon:



i.e. A and B are attracted by the strong force, as are B and C, but A and C are not.

The strong force is always attractive, and charge independent (the same for   ,   and   ).

Weak

When a neutron decays into a proton and an electron, an is formed. This is uncharged and does not feel the strong force, so another short range interaction must be involved. The weak interaction affects both and , and is usually associated with decays of various particles. Weak decays generally take place much more slowly than strong decays (the stronger the interaction, the quicker the decay).

When **strange** particles decay, they do so by the weak interaction, and is not conserved.

Modern explanation of the four forces

It was previously thought that a particle would create a field which exists throughout all space, and affects any particles in the field. The modern view, however, is that two particles exert a force on one another due to the transfer of a , which carries the force (this is known as second quantization). These particles are called exchange particles, and are .

The energy to create these particles comes from the Heisenberg uncertainty principle, which allows energy ΔE to be created for a time Δt, so long as

where $\hbar = \dfrac{h}{2\pi} = 1.05 \times 10^{-34}$ J s, known as the Planck constant.

The energy 'borrowed' creates the mass of the exchange particle, and therefore more massive exchange particles cannot exist for a long time, which puts an upper limit on how far they may travel, and thus the range of the forces produced. This suggests:

- The range of electromagnetic and gravitational forces is infinite, so .
- The range of the strong and weak are finite, so