The Four Fundamental Forces

Every force is a manifestation of one of the four ***fundamental forces*** of nature. They are (listed in order of decreasing strength):

(1) strong nuclear force

(2) electromagnetic force

(3) weak nuclear force

(4) gravitational force

Four Fundamental Interactions

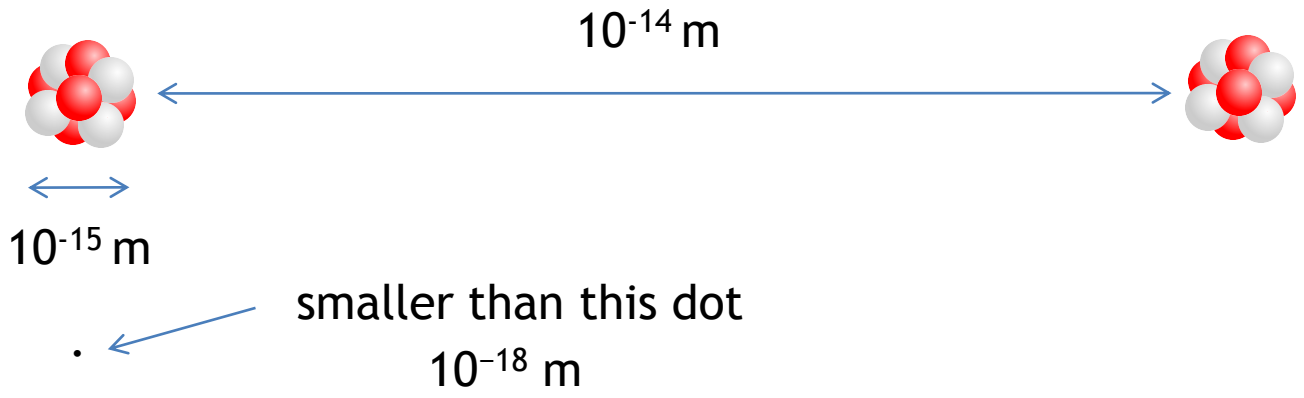
Interaction	Relative Strength	Range (m)	Particle(s) Affected	Exchange Particles	Masses of Exchange Particles (GeV/c^2)
strong	1	10^{-15} m	quarks	gluons (g)	0
electromagnetic	10^{-2}	∞	electrically charged	photon (γ)	0
weak	10^{-6}	10^{-18} m	quarks and leptons	W^+, W^-, Z^0	80.4, 80.4, 91.2
gravitational	10^{-43}	∞	all	graviton	0

Orders of magnitude

10^{-14} m: the distance between atoms in a substance.

10^{-15} m: The size of an atom, and the range of the strong nuclear force.

10^{-18} m: The range of the weak nuclear force.



*The **strong nuclear** force*

is a very ***strong***, ***attractive short-range*** (10^{-15} m) force that binds the protons and neutrons in the nuclei of atoms together. It is the strongest of the fundamental forces, but acts over a very short distance (10^{-15} m).

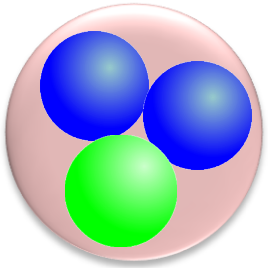
The strong force is what binds ***quarks*** in combinations so they can form protons and neutrons and many more exotic subatomic particles.

Quarks

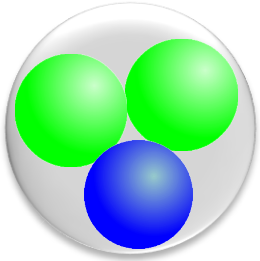
are a family of fundamental particles that comprise various types of matter, including protons and neutrons. Because of the strong force, quarks are always bound to other quarks.

A proton consists of two “up” quarks and a “down” quark, while a neutron consists of two “down” quarks and an “up” quark.

proton

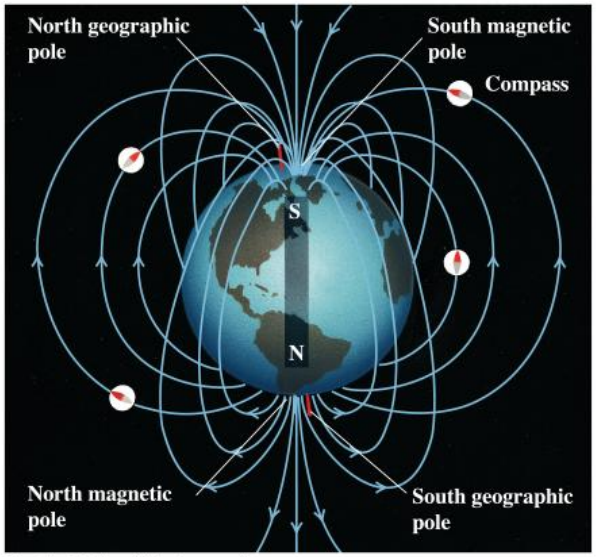


neutron

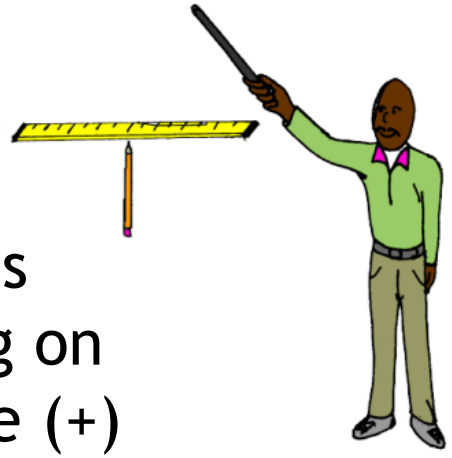


*The **electromagnetic** force*

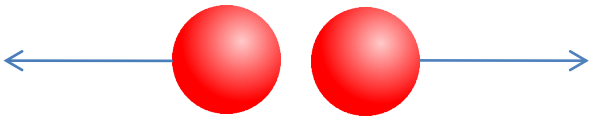
*is a very **strong**, **long-range** force with unlimited range that acts between any two objects possessing an electric charge*. It is the fundamental interaction that binds electrons to nuclei to form atoms and binds atoms together in molecules and solids.



*The **electric** force,*

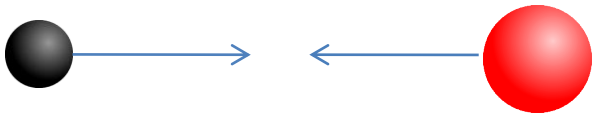


an aspect of the electromagnetic force, is either ***attractive*** or ***repulsive*** depending on whether the charges involved are positive (+) or negative(-).



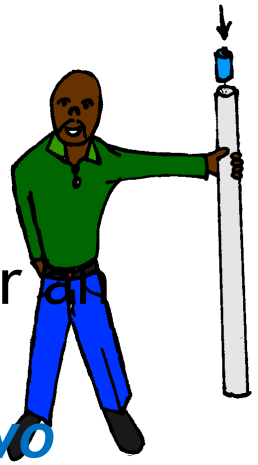
Two positive charges will ***repel*** each other

Two negative charges will ***repel*** each other

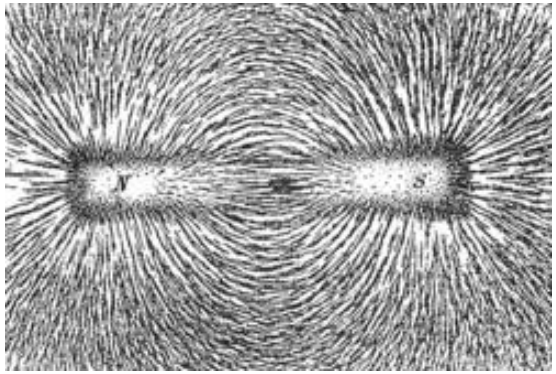


A positive and a negative charge will ***attract*** each other.

The magnetic force,



an aspect of the electromagnetic force, is either an ***attractive*** or a ***repulsive depending on the interaction of the magnetic fields between two charged objects.***



Two magnetic north poles will ***repel*** each other

Two magnetic south poles will ***repel*** each other

A magnetic north and a magnetic south pole will ***attract*** each other.

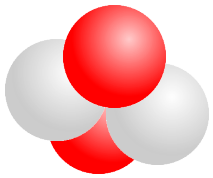
The weak nuclear force

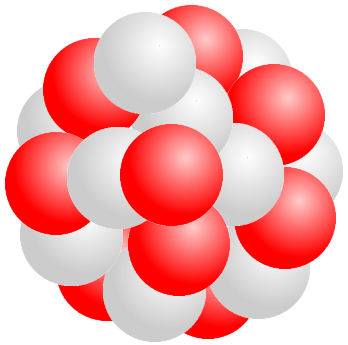
is an extremely short-range (10^{-18} m) force that acts on the quarks that make up protons and neutrons. It is much weaker than the electric and the strong forces (but still much stronger than gravity at short distances), acts over an extremely tiny distance, and is the cause for beta decay in atoms.

Without it, the sun would not shine because it allows protons to change into neutrons, allowing for nuclear fusion.

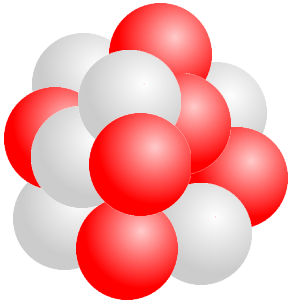
Radioactivity – alpha decay

alpha particle





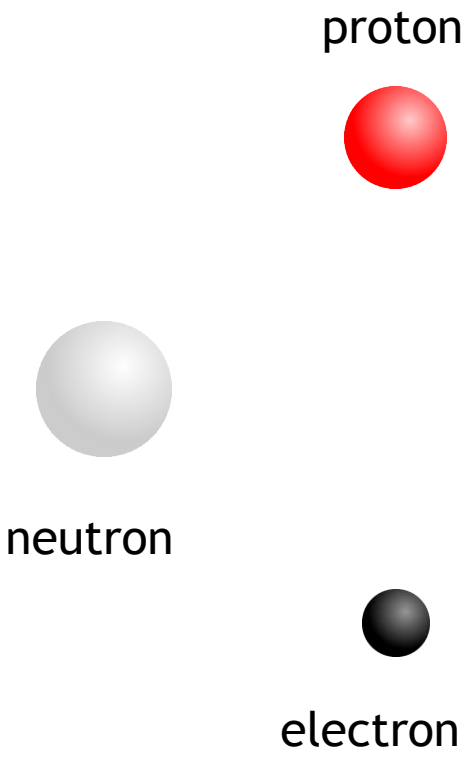
parent nucleus



daughter nucleus

Electric forces try to break the nucleus apart, while the strong nuclear force tries to bind the nucleus together. In larger atoms, the electric force of repulsion may break the nucleus apart, resulting in a form of radiation called alpha decay.

Radioactivity – beta decay



The weak nuclear force is responsible for a form of radioactivity called beta decay. Beta decay occurs when a neutron breaks apart into an electron and a proton. The electron gets kicked out of the nucleus as radioactivity, while the proton remains in the nucleus, changing the original atom into a different element.

The gravitational force

is a very ***weak***, ***attractive long-range*** force of unlimited range that exists between any two objects possessing mass. It is the weakest of all the fundamental forces.