Quarks

Smaller Scattering

In 1968, a group of physicists conducted an experiment to Rutherford's gold foil experiment, but on nucleons, with a beam of electrons. This yielded similar results, such as deflections of varying angles, proving that nucleons were made of something smaller, which came to be known as quarks, currently accepted to be the smallest indivisible particle.

Quarks

There are 6 different quarks, although this course only cares about 3:
up: u, down: d, and strange: s. Their properties are below:
Quark	Charge	Baryon Number	Strangeness
u	+2/3	+1/3	0
d	-1/3	+1/3	0
s	-1/3	+1/3	-1
Each quark has a counterpart; anti-quarks have essentially the same properties, but just reversed, so anti-up has a charge of -2/3, for example.

Quarks cannot be on their own, due to their fractional properties.

Quark-based particles are called hadrons, which can be broken into two separate groups: mesons, containing a quark and antiquark, and baryons, containing 3 quarks or 3 antiquarks.

Hadrons

Mesons

- quark / anti-quark pair
- 8 needed to memorise for the course

Meson	Symbol	Quarks	Charge	Strangeness
Pion +	π^+	$u\bar{d}$	+1	0
Pion -	π^-	$\bar{u}d$	-1	0
Pion 0	π^0	$d\bar{d}$	0	0
Anti-Pion 0	π^0	$u\bar{u}$	0	0

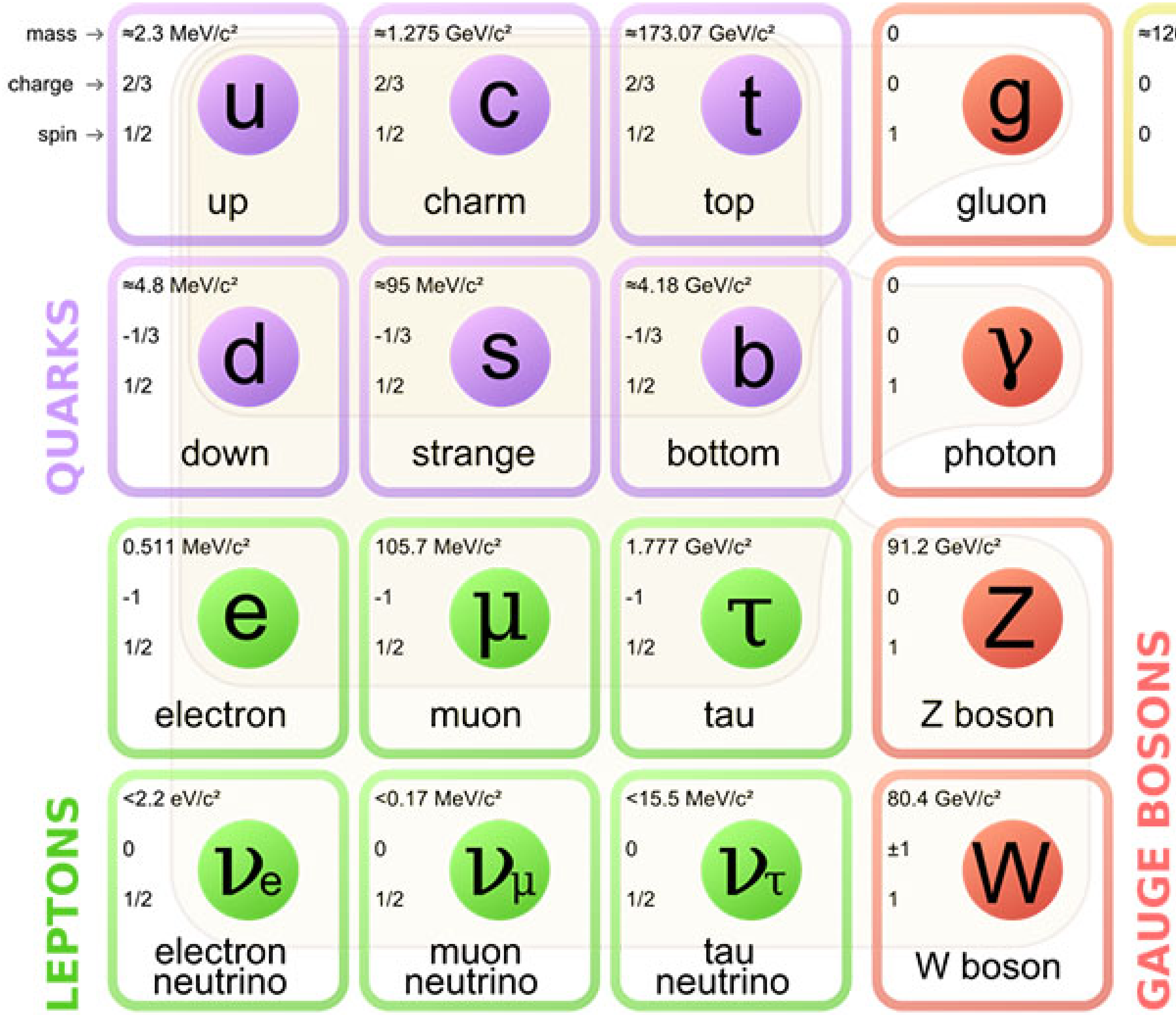
Meson	Symbol	Quarks	Charge	Strangeness
Kaon +	K^+	$u\overline{s}$	+1	+1
Kaon -	K^-	$\overline{u}s$	-1	-1
Kaon 0	K^0	$d\overline{s}$	0	+1
Anti-Kaon 0	$\overline{K}^0$	$\overline{d}s$	0	-1

Baryons

- 3 quarks OR 3 anti-quarks
- 4 needed to know for course

Baryon	Symbol	Quarks	Charge	Strangeness	Baryon Number
proton	p	uud	+1	0	+1
neutron	n	udd	0	0	+1
anti-proton	$\overline{p}$	$\overline{uud}$	-1	0	-1
anti-neutron	$\overline{n}$	$\overline{udd}$	0	0	-1

Standard Model of Elementary Particles.



Fundamental Forces

The Photoelectric Effect

Basics

When light of high enough energy is incident on a metal plate, it was observed that electrons were released from the surface of the plate. When the intensity of light was increased, the number of electrons emitted increased. If the frequency of light was lowered past some threshold, no electrons were emitted.

When this was discovered, light was believed to act as a wave. These observations contradicted this model, as if light acted as a wave, increasing the intensity of light should have increased the energy of the light, and the energy of the light should have released the electrons slowly, rather than instantly.

Photon

Because of the observations in Basics, Max Planck had the idea that light could be small packets of energy, which Einstein developed further, giving them the name photons. The energy of a photon was found to be $E = hf$.

Technical Explanation

Einstein went on to develop the photoelectric effect, and suggested that each photon interacts with a single electron in the metal. The energy of the photon would then be absorbed by the electron, where it uses some to break the bonds keeping it to the metal, then stored the rest as kinetic energy.

$$\text{The formula derived for this is: } hf = \phi + E_k$$

The ϕ is the work function of the metal, meaning how much energy is required to remove the electron from the metal.

A key term to learn is the threshold frequency, f_0, which is the lowest frequency of photon that can still release an electron. This means the electron will have no kinetic energy. A formula can be found through rearrangement:

$$f_0 = \frac{\phi}{h}$$

Graph

If we graph kinetic energy against frequency, we get a graph that describes the formula derived in Technical Explanation, as shown below:

$$y = mx + c \Rightarrow E_k = hf - \phi$$

When plotted, this graph will have a gradient of Planck's constant, and if extrapolated below 0, a y-intercept of the work function: