

## Orders of Magnitude

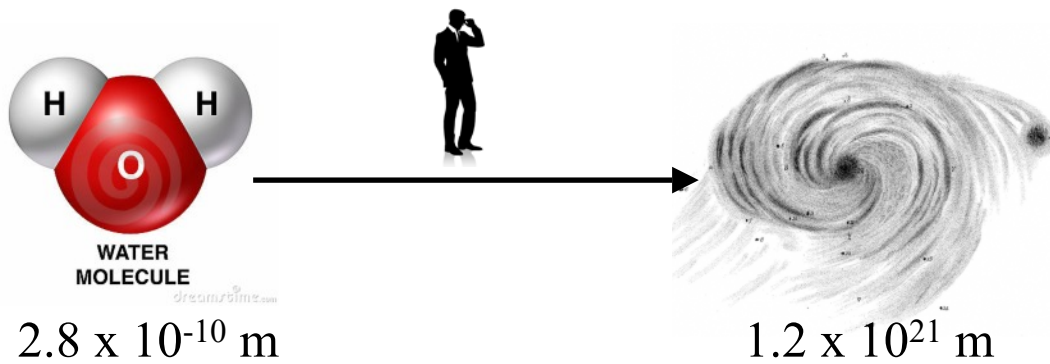
<http://goo.gl/kxy79>



The diameter of the Milky way is  $1.2 \times 10^{21}$  m. This is an enormous number.

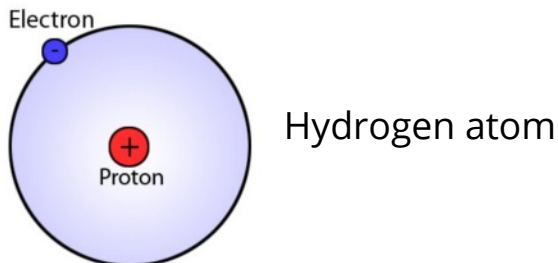
The diameter of a water molecule is  $2.8 \times 10^{-10}$  m

The range in the scale of size from a small molecule to a galaxy can only be expressed in what we call **ORDERS OF MAGNITUDE**.



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.....

.....  
.....



Hydrogen atom

.....



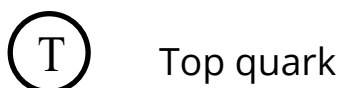
Uranium nucleus

.....



proton

.....



Top quark

## The Standard Model of Matter



<https://goo.gl/xhu2K>

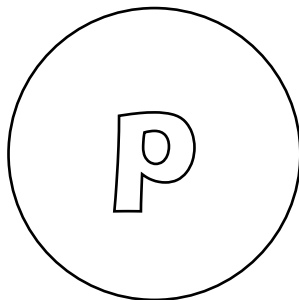
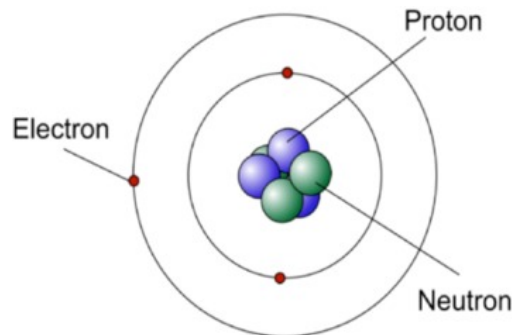


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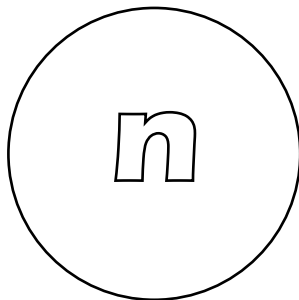


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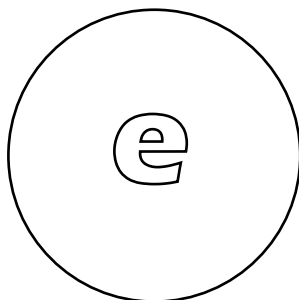
## Bohr Model of Atom



Name: proton  
Discovered: 1917 by Ernest Rutherford  
Mass:  $1.67 \times 10^{-27}$  kg  
Charge:  $+ 1.6 \times 10^{-19}$  C or +1



Name: neutron  
Discovered: 1932 by James Chadwick  
Mass:  $1.67 \times 10^{-27}$  kg  
Charge: 0



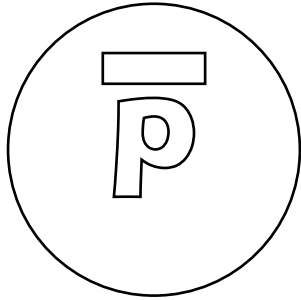
Name: electron  
Discovered: 1897 by J.J. Thompson  
Mass:  $9.11 \times 10^{-31}$  kg  
Charge:  $- 1.6 \times 10^{-19}$  C or -1

## Antimatter

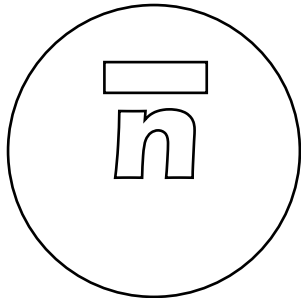


In 1928 Paul Dirac was trying to solve Einstein's equations. He arrived at a solution to the equations that predicted that there is antimatter.

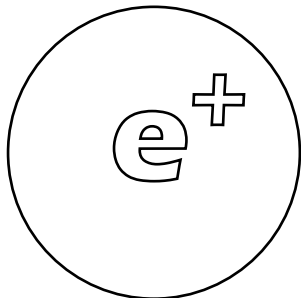
$$x^2 = 4$$



Name: Anti - proton  
 Discovered: 1955 by Owen Chamberlain et al  
 Mass:  $1.67 \times 10^{-27}$  kg  
 Charge:  $-1.6 \times 10^{-19}$  C or -1



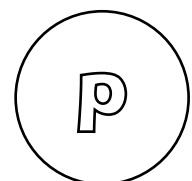
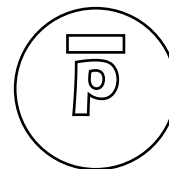
Name: Anti - neutron  
 Discovered: 1956 by Bruce Cork  
 Mass:  $1.67 \times 10^{-27}$  kg  
 Charge: 0



Name: Positron (Anti - electron)  
 Discovered: 1930 by Carl anderson.  
 Mass:  $9.11 \times 10^{-31}$  kg  
 Charge:  $+1.6 \times 10^{-19}$  C or +1

## Annihilation

No antimatter is detected in the universe. Just as well!  
 If matter meets antimatter then they both annihilate each other and the energy of the annihilation appears as two gamma rays going in opposite direction.



## The Neutrino: the little one

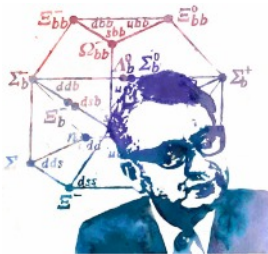


Enrico Fermi studied the radioactive decay of the carbon -14 atom. It decayed by emitting an electron from the nucleus of the carbon -14 atom.

This posed a problem because it looked like the law of conservation of momentum was being broken.

Enrico saved the day by indicating that another very very small particle was being emitted along with the electron.

This particle was called the anti- neutrino. Which meant that there must be a neutrino.



## The Particle Explosion!

By 1963 particle physicists couldn't stop discovering more and more particles. There were mesons and pions and all sort of short lived particles detected in the better detectors.

It was when another particle called the meson that was discovered that one physicist gave up and said, "Who ordered that?"

A particle physicist called Murray Gell - Mann spotted a pattern in all the particles that were being discovered.

He stated that all the particles were really made up from smaller particles called Quarks.

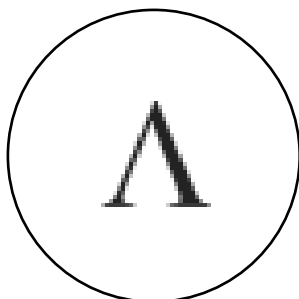
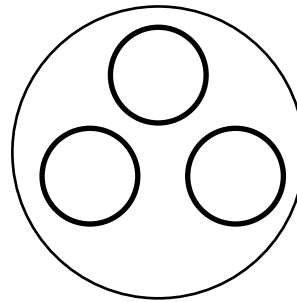
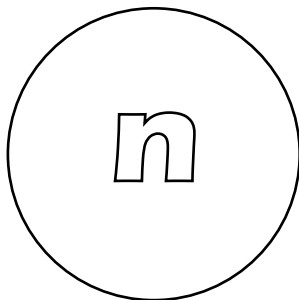
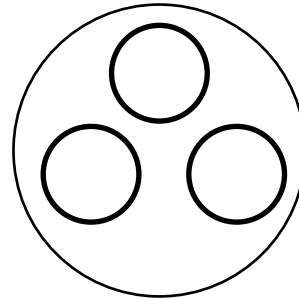
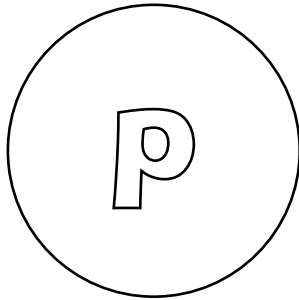
It was deduced that there were 6 quarks along with their antiquarks.

It was also deduced that these quarks could not be split into anything smaller.

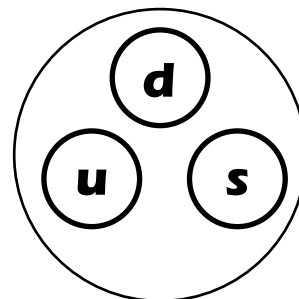
Quark	Symbol	Charge
Up	u	$+\frac{2}{3}$
Down	d	$-\frac{1}{3}$
Top	t	$+\frac{2}{3}$
Bottom	b	$-\frac{1}{3}$
Strange	s	$-\frac{1}{3}$
Charm	c	$+\frac{2}{3}$

## It looks a lot simpler now!

Protons and neutrons are made up of quarks. Quarks can only exist in groups of three. Other combination of quarks are short lived particles.



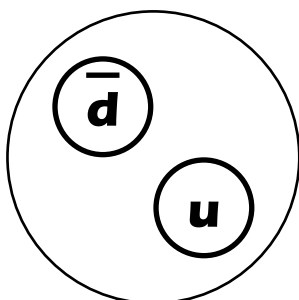
lambda



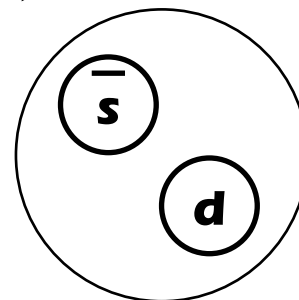
**Baryons**



**Mesons**



pion



Kaon<sup>0</sup>

## Leptons

There are other particles that cannot be broken down into smaller particles. These are called the **leptons**. Leptons is a word meaning light and thin but don't be misled, some leptons are heavier than a proton.

There are 6 leptons and also 6 anti leptons. The matter leptons are in the table below.

$e$ Electron	$\mu$ Muon	$\tau$ Tau
$\nu_e$ Electron neutrino	$\nu_\mu$ Muon neutrino	$\nu_\tau$ Tau neutrino

Leptons belong to the **Fermion Family**. These are particles which has a property called half spin.

## The Lego Box of Particles

Particle physicists now are of the firm belief that all matter made up of two types of families: Quarks and Leptons

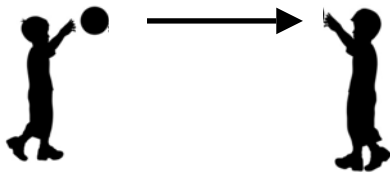
Don't forget their **anti-particle cousins!**

<b>Quarks</b>	↑	Up <b>u</b>	Charm <b>c</b>	Top <b>t</b>
	↓	Down <b>d</b>	Strange <b>s</b>	Bottom <b>b</b>
<b>Leptons</b>	↑	$e$ Electron	$\mu$ Muon	$\tau$ Tau
	↓	$\nu_e$ Electron neutrino	$\nu_\mu$ Muon neutrino	$\nu_\tau$ Tau neutrino

## The Fundamental Forces and Bosons

Besides the matter particles there are **four** fundamental forces in nature. Three of the forces are in the Standard Model. Gravity **is not in the standard model**.

Particle physicists believe that these forces in nature are really caused by the exchange in a type of particle called a **Boson**.



Imagine two children throwing a ball at each other. The ball is exchanged keeping the two children together in the game!

### 1. Electromagnetic force

This force affects any particles that have electric charge. Protons, electrons. The exchange particle is called the **photon**.

This force acts over an infinite range. The photon has no mass nor charge.



### 2. Strong force

This force holds together the quarks to make mesons and baryons.

The particle responsible for the strong force is called the **gluon**.

A kind of left over strong force is responsible for keeping together the protons in a nucleus.

The strong force only acts over the distance of the nucleus  $1 \times 10^{-15}\text{m}$



### 3. Weak Force

This is responsible for beta decay from the nucleus. This force acts on quarks and leptons. It can cause one lepton to change into another lepton and also cause quarks to change as well.

This weak force is caused by a few particles;  $W^+$   $W^-$  and the Z bosons.

The weak force acts over a range the size of proton  $1 \times 10^{-18}\text{m}$



Summary so far!

Standard Model

## Fermions

### Quarks

Come in six flavours.

Up and down,  
charm and strange,  
top and bottom.

### Leptons

These consist of the:  
electron and electron neutrino  
muon and muon neutrino  
Tau and tau neutrino.

### mesons

These are particles made up of a quark and anti quark

Held together by the strong force caused by the gluons

### baryons

These are particles made up of 3 quarks

Held together by the strong force caused by the gluons

### Hadrons

Mesons and baryons are called hadrons meaning that they are made up of quarks that are held together by the strong force.

They interact via

Photons in the em force

They also interact with the  $W^+$   $W^-$  and Z bosons in the weak force

The Weak force causes beta decay. That is an electron being emitted from the nucleus. Only can happen if neutron can change into a proton.

Leptons do not experience the strong force

## Bosons

These are the particles that cause the forces

### photon

Electromagnetic force.

### gluon

Strong Force

### W and Z

Weak force.