

# Standard Model of Elementary Particles

## Hadrons – quark based matter – they have internal structure – participates with the Strong Force

Subdivided into Baryons (3 quarks) and Mesons (1 quark and 1 anti-quark pair)

Quarks – elemental particles						
Families of increasing mass			Higher Mass			
	Lower Mass					
Name	Up	Anti-Up	Charm	Anti-Charm	Top	Anti-Top
Symbol						
Charge						
Baryon #						
Strangeness						
Mass – MeV c <sup>-2</sup>	1.7 – 3.1	1.7 – 3.1	1180 – 1340	1180 – 1340	172,000	172,000
Name	Down	Anti-Down	Strange	Anti-Strange	Bottom	Anti-Bottom
Symbol						
Charge						
Baryon #						
Strangeness						
Mass – MeV c <sup>-2</sup>	4.1 – 5.7	4.1 – 5.7	80 – 130	80 – 130	4130 – 4370	4130 – 4370

**Baryons consist of 3 quarks** ie. Proton is  $uud$ , and would have a charge of  $2/3 + 2/3 - 1/3 = +1$  and a Baryon number of  $1/3 + 1/3 + 1/3 = +1$

**Mesons consist of 1 quark & anti-quark pair** ie. Pion (pi plus) is  $u\bar{d}$ , and would have a charge of  $2/3 - 1/3 = +1/3$

Notes, diagrams and ideas:

Quark Confinement:

Baryon Number Conservation:

Worked Examples:

Keywords

Beta Positive Decay

Beta Negative Decay

Pion (meson) -  $\pi^0 (u:\bar{u})$  or  $(d:\bar{d})$        $\pi^+ (u:\bar{d})$        $\pi^- (d:\bar{u})$

Charge:

Kaon (meson) -  $k^0 (d:\bar{s})$        $k^+ (u:\bar{s})$        $k^- (s:\bar{u})$

Charge:

Strangeness:

**Leptons (no internal structure – considered elemental)**

Leptons – elemental particles						
Families of increasing mass		Lower Mass			Higher Mass	
Family	Electron Family		Muon Family		Tauon Family	
Name	Electron	Anti-Electron	Muon	Anti-Muon	Tau	Anti-Tau
Symbol						
Charge						
Lepton #						
Mass – $MeV c^{-2}$	0.511	0.511	106	106	1780	1780
Name	Electron-Neutrino	Anti-Electron-Neutrino	Muon-Neutrino	Anti-Muon Neutrino	Tau-Neutrino	Anti-Tau-Neutrino
Symbol						
Charge						
Lepton #						
Mass – $MeV c^{-2}$	$0.05 < m < 2 eV$	$0.05 < m < 2 eV$	$< 0.19$	$< 0.19$	$< 18$	$< 18$

Leptons are arranged in families – electron, muon, and tauon. Calculations for lepton number conservation stay within each family.

Notes, diagrams and ideas:

Lepton Number conservation:

Worked Examples:

**Exchange particles (elemental)**

Force	Particle	Range	Relative Strength	Acts On	
Gravitational					Binding planets, solar systems, etc.
Weak Nuclear					$[W^+, W^-]$ ; transmutation of elements
Electromagnetic					Binding atoms, proton-electron interaction, creating magnetic fields
Strong Nuclear					Binding atomic nuclei, fusion process in stars

Notes, diagrams and ideas:

Further Topics: (Not included in any of our assessments, IB or Ontario)

Quantum Chromodynamics (QCD)

Momentum of photons

Property called “Spin”: