GCE Physics Unit 1.7 Particles and Nuclear Structure

Matter is composed of atoms, but within the atoms there are sub atomic particles. Therefore, **all matter is composed of quarks and leptons.**

	leptons		quarks	
particle (symbol)	electron (e-)	electron neutrino (ν_e)	up (u)	down (d)
charge (e)	-1	0	$+\frac{2}{3}$	$-\frac{1}{3}$

This table of information will be given on the **data booklet**, but it is important to know how to use this information.

Note that these are the first generation of leptons and quarks, there are **three generations** but questions will only be asked about the first.

Antiparticles :

Each of the particles has an equivalent antiparticle. Each antiparticle has the **same properties** as its equivalent particle **except opposite charge**.

	antileptons		antiquarks	
particle (symbol)	Antielectron **or** positron (e+)	Antielectron neutrino ($\bar{\nu}_e$)	antiup ($\bar{u}$)	antidown ($\bar{d}$)
charge (e)	+1	0	$-\frac{2}{3}$	$+\frac{1}{3}$

When a particle and its antiparticle meet, they annihilate each other, often energy in the form of photons, γ.

Leptons always exist separately. Their important features are:

- Charge: electrons have a charge of -1e, neutrinos have no charge.
- Lepton number: leptons have lepton number = 1, antileptons = -1

Hadrons:

Quarks don't exist in isolation; they are always bound into particles made up of more than one quark. They are known as hadrons and there are 3 types.

- **Baryon** – combination of 3 quarks. For example, a neutron.
- **Antibaryon** – combination of 3 antiquarks. For example, an antiproton.
- **Meson** – 1 quark – antiquark pair.

Baryons and antibaryons:

All quarks have baryon number = $+\frac{1}{3}$ and all antiquarks have baryon number = $-\frac{1}{3}$. This means that all baryons must have baryon number = 1 and antibaryons = - 1.

Two baryons you must be familiar with are protons and neutrons.

	proton	neutron
charge /e	+1	0
baryon number	1	1
quark composition	uud	udd

You must also be able to work out the quark made up of less familiar baryons, for example Δ++ = uuu.

Mesons:

There are 4 mesons that can be made up of the first-generation quarks and antiquarks, they are known as pions. As they are made of quark antiquark pairs their baryon number = 0.

	u	d
$\bar{u}$	$u\bar{u}$ π^0	$\bar{u}d$ π^-
$\bar{d}$	$u\bar{d}$ π^+	$d\bar{d}$ π^0
The charge of each pion is shown by the symbol.		

Forces:

There are 4 fundamental forces involved in interactions between particles.

Interaction	Experienced by	Range	Comments
gravitational	all matter	infinite	very weak – negligible except between large objects such as planets
weak	all leptons, all quarks	very short	only significant when the e-m and strong interactions do not operate
electromagnetic (e-m)	all charged particles	infinite	also experienced by neutral hadrons, as these are composed of quarks
strong	all quarks	short	

Interactions:

In all interactions there are conservations laws that must be true.

- Conservation of charge.
- Conservation of baryon number.
- Conservation of lepton number.

Strong interactions (lifetime 10^{-24}s)

- Only involve hadrons.
- No change in quark flavour, (the same number of u and d quarks before and after).
- Typically involved in collision between particles.

Electromagnetic interactions (lifetime 10^{-12}-10^{-18} s)

- The particles must be charged or have charged components.
- No change in quark flavour.
- One or more photons may be emitted.

Weak interactions (lifetime 10^{-10} s)

- Neutral leptons are involved.
- There may be a change in quark flavour.