Particle Properties

You don't have to remember this information! In an exam the masses of the particles are given on the constant sheet. Any other required information will be given to you.

What you should know, or be able to work out, is:

- the quantum numbers, and if they are conserved are or not
- the force responsible for a decay, from the lifetime
- the main decay modes, using a Feynman diagram
- that the $+, -$ and 0 superscripts correspond to the electric charge of the particles
- the relationship between a particle and its antiparticle.

Anti-particles are not named in the tables. Anti-particles have the same mass, same lifetime, opposite quantum numbers from the particle. Anti-particles decay into the anti-particles of the shown modes. For example, an anti-muon, μ^+, has a mass of 105.7 MeV$/c^2$ and a lifetime of 2.197×10^{-6} s. Its quantum numbers are $L_e = 0, L_\mu = -1, L_\tau = 0$ and $Q = +1$. Its main decay mode is $\mu^+ \to e^+ \nu_e \bar{\nu}_\mu$.

Quantum Numbers

The following quantum numbers are conserved in **all** reactions:

- Total quark number, $N_q = N(\mathrm{q}) - N(\bar{\mathrm{q}})$.
  - $N_q = +1$ for all quarks
  - $N_q = -1$ for all anti-quarks
  - $N_q = 0$ for all leptons and anti-leptons
  - $N_q = 3$ for baryons and $N_q = 0$ for mesons.
- The three lepton flavour quantum numbers:
  - Electron Number: $L_e = N(e^-) - N(e^+) + N(\nu_e) - N(\bar{\nu}_e)$
  - Muon Number: $L_\mu = N(\mu^-) - N(\mu^+) + N(\nu_\mu) - N(\bar{\nu}_\mu)$
  - Tau Number: $L_\tau = N(\tau^-) - N(\tau^+) + N(\nu_\tau) - N(\bar{\nu}_\tau)$
- Electric charge, Q.

There are six quantum numbers are used to describe quark flavour, which hadrons also carry:

- Up quark number $N_\mathrm{u} \equiv N(\mathrm{u}) - N(\bar{\mathrm{u}})$

- Down quark number, $N_{\mathrm{d}} \equiv N(\mathrm{d}) - N(\bar{\mathrm{d}})$
- Strange quark number $N_{\mathrm{s}} \equiv N(\mathrm{s}) - N(\bar{\mathrm{s}})$
- Charm quark number, $N_{\mathrm{c}} \equiv N(\mathrm{c}) - N(\bar{\mathrm{c}})$
- Bottom quark number, $N_{\mathrm{b}} \equiv N(\mathrm{b}) - N(\bar{\mathrm{b}})$
- Top quark number, $N_{\mathrm{t}} \equiv N(\mathrm{t}) - N(\bar{\mathrm{t}})$

These quark flavour quantum numbers are conserved in strong and electromagnetic interactions, but not in the weak interactions.

For historical reasons, quark quantum numbers are often re-formulated into similar quantum numbers called: strangeness $S = -N_{\mathrm{s}}$, charmness $C = N_{\mathrm{c}}$, bottomness $B = -N_{\mathrm{b}}$ topness, $T = N_{\mathrm{t}}$, strong isospin $|I, I_Z\rangle$ where $I_Z = \frac{1}{2}(N_{\mathrm{u}} - N_{\mathrm{d}})$ and baryon number, $\mathcal{B} = 1/3 N_{\mathrm{q}}$. The physics described by both sets of quantum numbers is identical.

Lepton	Symbol	Anti-particle	mass (MeV/c^2)	L_e	L_μ	L_τ	Q (e)	Lifetime (s)	Ma
electron	e^-	e^+	0.511	+1	0	0	-1	Stable	
muon	μ^-	μ^+	105.7	0	+1	0	-1	2.197×10^{-6}	
tau	τ^-	τ^+	1777	0	0	+1	-1	2.91×10^{-13}	$e^-\bar{\nu}_e\nu_\tau$, $\mu^-\bar{\nu}$
electron neutrino	ν_e	$\bar{\nu}_e$	~ 0	+1	0	0	0	-	
muon neutrino	ν_μ	$\bar{\nu}_\mu$	~ 0	0	+1	0	0	-	
tau neutrino	ν_τ	$\bar{\nu}_\tau$	~ 0	0	0	+1	0	-	

Table 1: The leptons of the Standard Model. The masses of the neutrinos are so small, that we can ignore them in most reactions. The concepts of lifetime and decay mode don't really make sense for the neutrinos.

Quark	Symbol	Anti-quark	N_u	N_u	N_s	N_c	N_b	N_t	$Q(e)$
down	d	$\bar{\mathrm{d}}$	1	0	0	0	0	0	$-1/3$
up	u	$\bar{\mathrm{u}}$	0	1	0	0	0	0	$+2/3$
strange	s	$\bar{\mathrm{s}}$	0	0	1	0	0	0	$-1/3$
charm	c	$\bar{\mathrm{c}}$	0	0	0	1	0	0	$+2/3$
bottom	b	$\bar{\mathrm{b}}$	0	0	0	0	1	0	$-1/3$
top	t	$\bar{\mathrm{t}}$	0	0	0	0	0	1	$+2/3$

Table 2: The quarks of the Standard Model. Quarks are always found in bound states, therefore it doesn't always make much sense to talk about the masses and lifetimes of the individual quarks.

Meson	Symbol	Anti-particle	quark composition	mass (MeV/c^2)	N_d	N_u	N_s	N_c	N_b	
Charged Pion	π^+	π^-	$\mathrm{u\bar{d}}$	139.6	-1	+1	0	0	0	2
Neutral Pion	π^0	Self	$(\mathrm{d\bar{d}} - \mathrm{u\bar{u}})/\sqrt{2}$	135.0	0	0	0	0	0	0.
Charged Kaon	K^+	K^-	$\mathrm{u\bar{s}}$	493.7	0	+1	-1	0	0	1
Neutral Kaon	K^0	$\overline{K}^0$	$\mathrm{d\bar{s}}$	-	+1	0	-1	0	0	
K-short	K^0_S	-	$(K^0 + \overline{K}^0)/\sqrt{2}$	497.7	-	0	-	0	0	0.
K-long	K^0_L	-	$(K^0 - \overline{K}^0))/\sqrt{2}$	497.7	-	0	-	0	0	5
Eta	η^0	Self	$(\mathrm{d\bar{d}} + \mathrm{u\bar{u}} - 2\mathrm{s\bar{s}})/\sqrt{6}$	547.5	0	0	0	0	0	
Eta-Prime	η'^0	Self	$(\mathrm{d\bar{d}} + \mathrm{u\bar{u}} - 2\mathrm{s\bar{s}})/\sqrt{6}$	957.8	0	0	0	0	0	
Charged Rho	ρ^+	ρ^-	$\mathrm{u\bar{d}}$	770	-1	+1	0	0	0	0
Neutral Rho	ρ^0	Self	$\mathrm{u\bar{u}}, \mathrm{d\bar{d}}$	770	0	0	0	0	0	0
Omega	ω^0	Self	$\mathrm{u\bar{u}}, \mathrm{d\bar{d}}$	782	0	0	0	0	0	0
Phi	ϕ	Self	$\mathrm{s\bar{s}}$	1020	0	0	0	0	0	2
D^+-meson	D^+	D^-	$\mathrm{c\bar{d}}$	1869	-1	0	0	+1	0	10
D^0-meson	D^0	$\overline{D}^0$	$\mathrm{c\bar{u}}$	1864.6	0	-1	0	+1	0	4
D_S-meson	D^+_S	D^-_S	$\mathrm{c\bar{s}}$	1969	0	0	-1	+1	0	4
J/Psi	J/ψ	Self	$\mathrm{c\bar{c}}$	3097	0	0	0	0	0	0
B^+-meson	B^+	B^-	$\mathrm{u\bar{b}}$	5279	0	+1	0	0	-1	1
B^0-meson	B^0_d	$\overline{B}^0_d$	$\mathrm{d\bar{b}}$	5279	+1	0	0	0	-1	1
B_S-meson	B^0_S	$\overline{B}^0_S$	$\mathrm{s\bar{b}}$	5370	0	0	+1	0	-1	1
Upsilon	Υ	Self	$\mathrm{b\bar{b}}$	9460	0	0	0	0	0	1

Table 3: Selected mesons. Notes: The neutral kaons mix with each other and appear physically as K^0_L and K^0_S. Decay modes are only shown for some the mesons.

Baryon	Symbol	quark composition	mass (MeV/c^2)	N_d	N_u	N_s	Lifetime (s)	Main Decay Modes
Proton	p	uud	938.272	1	2	0	Stable	-
Neutron	n	ddu	939.6	2	1	0	920	$pe^-\nu_e$
Lambda	Λ^0	uds	1115.6	1	1	1	2.6×10^{-10}	$p\pi^-$, $n\pi^0$
Sigma Plus	Σ^+	uus	1189.4	0	2	1	0.8×10^{-10}	$p\pi^0$, $n\pi^+$
Sigma Zero	Σ^0	uds	1192.5	1	1	1	6×10^{-20}	$\Lambda^0\gamma$
Sigma Minus	Σ^-	dds	1197.3	2	0	1	1.5×10^{-10}	$n\pi^-$
Delta	Δ^{++}	uuu	1232	0	3	0	0.6×10^{-23}	$p\pi^+$
Delta	Δ^+	uud	1232	1	2	0	0.6×10^{-23}	$p\pi^0$
Delta	Δ^0	udd	1232	2	1	0	0.6×10^{-23}	$n\pi^0$
Delta	Δ^-	ddd	1232	3	0	0	0.6×10^{-23}	$n\pi^-$
Cascade Zero	Ξ^0	uss	1315	0	1	2	2.9×10^{-10}	$\Lambda^0\pi^0$
Cascade Minus	Ξ^-	dss	1321	1	0	2	1.64×10^{-10}	$\Lambda^0\pi^-$
Omega Minus	Ω^-	sss	1672	0	0	3	0.82×10^{-10}	$\Xi^0\pi^-, \Lambda^0 K^-$
Lambda-C	Λ_c^+	udc	2281	1	1	0	2×10^{-13}	

Table 4: Selected baryons. Anti-baryons are symbolised by an overline, *e.g.* $\overline{\Sigma}^- = \bar{\mathrm{u}}\bar{\mathrm{u}}\bar{\mathrm{s}}$ is the antiparticle of Σ^+.