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 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:

- Baryon Number, $\mathcal{B}$. $\mathcal{B} = +1/3$ for quarks and $\mathcal{B} = -1/3$ for antiquarks. Therefore $\mathcal{B} = 1$ for baryons and $\mathcal{B} = 0$ for mesons.
- The three lepton flavour quantum numbers: L_e, L_μ, L_τ.
- Electric charge, Q.

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

- Strangeness, $S \equiv N(\bar{\mathrm{s}}) - N(\mathrm{s})$
- Charm, $C \equiv N(\mathrm{c}) - N(\bar{\mathrm{c}})$
- Bottomness, or beauty, $B \equiv N(\bar{\mathrm{b}}) - N(\mathrm{b})$
- Topness, $T \equiv N(\mathrm{t}) - N(\bar{\mathrm{t}})$
- Isospin, I, and the third component of the isospin, I_Z (or I_3): $-I < I_Z < I$. For single quarks, the isospin quantum number give information about the number of up and down quarks, with the third component (I_Z) used to differentiate between up and down. In hadrons, isospin combines in the same way as spin: using Clebsch-Gordan coefficients.

The first four quantum numbers is conserved in strong and electromagnetic interactions, but not in the weak interactions. Isospin is conserved in strong interactions, but not in electromagnetic and weak interactions.

Lepton	Symbol	Anti-particle	mass (MeV/c^2)	L_e	L_μ	L_τ	Q (e)	Lifetime (s)	Main Decay Modes
electron	e^-	e^+	0.511	$+1$	0	0	-1	Stable	-
muon	μ^-	μ^+	105.7	0	$+1$	0	-1	2.197×10^{-6}	$e^-\bar{\nu}_e\nu_\mu$
tau	τ^-	τ^+	1777	0	0	$+1$	-1	2.91×10^{-13}	$e^-\bar{\nu}_e\nu_\tau$, $\mu^-\bar{\nu}_\mu\nu_\tau$, hadrons + ν_τ
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	I	I_Z	S	C	B	T	$Q(e)$
down	d	$\bar{\text{d}}$	1/2	$-1/2$	0	0	0	0	$-1/3$
up	u	$\bar{\text{u}}$	1/2	1/2	0	0	0	0	$+2/3$
strange	s	$\bar{\text{s}}$	0	-	-1	0	0	0	$-1/3$
charm	c	$\bar{\text{c}}$	0	-	0	$+1$	0	0	$+2/3$
bottom	b	$\bar{\text{b}}$	0	-	0	0	-1	0	$-1/3$
top	t	$\bar{\text{t}}$	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)	I	S	C	B	Lifetime (s)	Main Decay Modes
Charged Pion	π^+	π^-	$\mathrm{u\bar{d}}$	139.6	1	0	0	0	2.60×10^{-8}	$\mu^+\nu_\mu$
Neutral Pion	π^0	Self	$(\mathrm{d\bar{d}} - \mathrm{u\bar{u}})/\sqrt{2}$	135.0	1	0	0	0	0.83×10^{-16}	$\gamma\gamma$
Charged Kaon	K^+	K^-	$\mathrm{u\bar{s}}$	493.7	1/2	+1	0	0	1.24×10^{-8}	$\mu^+\ \nu_\mu, \pi^+\pi^0$
Neutral Kaon	K^0	$\overline{K}^0$	$\mathrm{d\bar{s}}$	-	1/2	+1	0	0	-	-
K-short	K^0_S	-	$(K^0 + \overline{K}^0)/\sqrt{2}$	497.7	-	0	0	0	0.89×10^{-10}	$\pi^+\pi^-, 2\pi^0$
K-long	K^0_L	-	$(K^0 - \overline{K}^0))/\sqrt{2}$	497.7	-	0	0	0	5.2×10^{-8}	$\pi^+e^-\nu_e$
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	$< 10^{-18}$	$\gamma\gamma$, $3\pi^0$
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	$< 10^{-20}$	$\pi^+\pi^-\eta$, $\rho^0\gamma$, $\pi^0\pi^0\eta$
Charged Rho	ρ^+	ρ^-	$\mathrm{u\bar{d}}$	770	1	0	0	0	0.4×10^{-23}	$\pi^+\pi^0$
Neutral Rho	ρ^0	Self	$\mathrm{u\bar{u}}, \mathrm{d\bar{d}}$	770	1	0	0	0	0.4×10^{-23}	$\pi^+\pi^-$
Omega	ω^0	Self	$\mathrm{u\bar{u}}, \mathrm{d\bar{d}}$	782	0	0	0	0	0.8×10^{-22}	$\pi^+\pi^-\pi^0$
Phi	ϕ	Self	$\mathrm{s\bar{s}}$	1020	0	0	0	0	20×10^{-23}	$K^+\,K^-$, $K^0\,K^0$
D^+-meson	D^+	D^-	$\mathrm{c\bar{d}}$	1869	1/2	0	+1	0	10.6×10^{-13}	
D^0-meson	D^0	$\overline{D}^0$	$\mathrm{c\bar{u}}$	1864.6	1/2	0	+1	0	4.2×10^{-13}	
D_S-meson	D_S^+	D_S^-	$\mathrm{c\bar{s}}$	1969	0	+1	+1	0	4.7×10^{-13}	
J/Psi	J/ψ	Self	$\mathrm{c\bar{c}}$	3097	0	0	0	0	0.8×10^{-20}	$e^+e^-, \mu^+\mu^-$...
B^+-meson	B^+	B^+	$\mathrm{u\bar{b}}$	5279	1/2	0	0	+1	1.7×10^{-12}	K^++ something
B^0-meson	B^0_d	$\overline{B}^0_d$	$\mathrm{d\bar{b}}$	5279	1/2	0	0	+1	1.5×10^{-12}	
B_S-meson	B^0_S	$\overline{B}^0_S$	$\mathrm{s\bar{b}}$	5370	0	-1	0	+1	1.5×10^{-12}	D_S^- + something
Upsilon	Υ	Self	$\mathrm{b\bar{b}}$	9460	0	0	0	0	1.3×10^{-20}	$e^+e^-, \mu^+\mu^-$, $B^0_d, \overline{B}^0_d$

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

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

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