

THE FUNDAMENTAL SCHEME OF NATURE

LEPTONS (Fundamental particles that feel the Weak Force)		REST MASS	CHARGE	SPIN	MEAN LIFETIME (half-life / ln 2)	LEPTON NUMBER		
						L_e	L_μ	L_τ
ELECTRON	e^-	0.511	-1	$\frac{1}{2}$		1		
ELECTRON NEUTRINO	ν_e	$< 7.0 \times 10^{-6}$	0	$\frac{1}{2}$		1		
MUON (mu-minus)	μ^-	106	-1	$\frac{1}{2}$	2.2×10^{-6}		1	
MUON NEUTRINO	ν_μ	< 0.27	0	$\frac{1}{2}$			1	
TAU (tau-minus)	τ^-	1780	-1	$\frac{1}{2}$	3.4×10^{-13}			1
TAU NEUTRINO	ν_τ	< 31	0	$\frac{1}{2}$				1
ANTILEPTONS								
POSITRON	e^+	0.511	1	$\frac{1}{2}$		-1		
ELECTRON ANTINEUTRINO	$\bar{\nu}_e$	$< 7.0 \times 10^{-6}$	0	$\frac{1}{2}$		-1		
MUON (mu-plus)	μ^+	106	1	$\frac{1}{2}$	2.2×10^{-6}		-1	
MUON ANTINEUTRINO	$\bar{\nu}_\mu$	< 0.27	0	$\frac{1}{2}$			-1	
TAU (tau-plus)	τ^+	1780	1	$\frac{1}{2}$	3.4×10^{-13}			-1
TAU ANTINEUTRINO	$\bar{\nu}_\tau$	< 31	0	$\frac{1}{2}$				-1

The lepton numbers are conserved in weak interactions.

In the Standard Model, neutrinos are massless. The neutrino masses given are the experimental upper limits.

Charges are given in units of the proton charge e . Masses are given in MeV equivalents. Times are given in seconds.

Particles with half-integer spin are *fermions* and are subject to the Pauli Exclusion Principle. Hence all leptons are fermions.

QUARKS		REST MASS	CHARGE	SPIN	BARYON NUMBER	CHARM	STRANGE -NESS	TOPNESS	BOTTOM -NESS
UP	u	5	$+\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
DOWN	d	9	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	0
CHARM	c	1350	$+\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	1	0	0	0
STRANGE	s	175	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	-1	0	0
TOP	t	175000	$+\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	1	0
BOTTOM	b	4500	$-\frac{1}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	0	0	0	-1

Strangeness and bottomness are negative because the values were assigned to various strange particles before the quark model was adopted.

Antiquarks have opposite values of charge, baryon number, charm, strangeness, topness and bottomness.

CONSERVATION RULES									
FORCE		CHARGE	SPIN	BARYON NUMBER	CHARM	STRANGE -NESS	TOPNESS	BOTTOM -NESS	
Strong		Y		Y		Y			
Electromagnetic		Y		Y		Y			
Weak		Y		Y		± 1			

In strong interactions, the numbers of each type of quark are conserved.

In electromagnetic interactions, the numbers of quarks and leptons of each type are conserved.

In weak interactions, the total number of quarks is conserved and the total number of leptons is conserved but one quark may change from one type to another or one lepton may change from one type to another.

In strong interactions, quark/antiquark pairs may be created or destroyed.

In electromagnetic interactions, quark/antiquark pairs and/or lepton/antilepton pairs may be created or destroyed.

In weak interactions, quark/antiquark pairs and/or lepton/antilepton pairs may be created or destroyed.

FORCES	RANGE	STRENGTH	GAUGE BOSONS (Carriers of the force for quarks and leptons)		REST MASS	CHARGE	SPIN	OBSERVED ?
GRAVITY	Infinite	10^{-38}	GRAVITON	g	0	0	2	Conjectured
WEAK	< 1 am	10^{-5}	WEAK BOSONS	W^+	80200	1	1	Yes
				W^-	80200	-1	1	Yes
				Z^0	91200	0	1	Yes
ELECTROMAGNETISM	Infinite	10^{-2}	PHOTON	γ	0	0	1	Yes
STRONG	< 1 fm	1	GLUON	g	0	0	1	Permanently confined

Bosons are particles with zero or integer spin.

The range of the force is inversely proportional to the mass of the gauge boson.

The strength of the force, probed with interaction energies of 1 GeV, is in terms of the size of the strong force.

All the particles listed above are thought to be structureless and indivisible - time will tell!

HADRONS (Composite particles that feel the Strong Force)		REST MASS	CHARGE	SPIN	BARYON NUMBER	QUARKS	MEAN LIFETIME	TYPICAL DECAY	ANTI-PARTICLE
MESONS									
PION (pi-zero)	π^0	135.0	0	0	0	$u\bar{u}, d\bar{d}$	0.8×10^{-16}	$\gamma + \gamma$	Self
(pi-plus)	π^+	139.6	1	0	0	$u\bar{d}$	2.6×10^{-8}	$\mu + \nu_\mu$	π^-
KAON (K-plus)	K^+	493.7	1	0	0	$u\bar{s}$	1.2×10^{-8}	$\pi^+ + \pi^0$ or $\mu^+ + \nu_\mu$	K^-
(K-zero)	K_S^0	497.7	0	0	0	$d\bar{s}$	8.9×10^{-11}	$\pi^0 + \pi^0$	$\bar{K}_S^0$
(K-zero)	K_L^0	497.7	0	0	0	$d\bar{s}$	5.2×10^{-8}	$\pi^0 + \pi^0 + \pi^0$	$\bar{K}_L^0$
RHO (rho-zero)	ρ^0	769	0	1	0	$u\bar{u}, d\bar{d}$	$\approx 10^{-23}$	$\pi^0 + \pi^0$	Self
(rho-plus)	ρ^+	769	1	1	0	$u\bar{d}$	$\approx 10^{-23}$	π^+ or π^0	ρ^-
PHI	ϕ	1019.5	0	1	0	$s\bar{s}$	$\approx 10^{-21}$	K^+ or K^-	Self
J / PSI	J / Ψ	3096.6	0	1	0	$c\bar{c}$	$\approx 10^{-19}$	Any	Self
UPSILON	Υ	9460	0	1	0	$b\bar{b}$	$\approx 10^{-19}$	Any	Self

HADRONS (Composite particles that feel the Strong Force)									
BARYONS		REST MASS	CHARGE	SPIN	BARYON NUMBER	QUARKS	MEAN LIFETIME	TYPICAL DECAY	ANTI-PARTICLE
PROTON	p	938.3	1	$\frac{1}{2}$	1	uud	Stable		$\bar{p}$
NEUTRON	n	939.6	0	$\frac{1}{2}$	1	udd	898	$p + e^- + \bar{\nu}_e$	$\bar{n}$
LAMBDA (lambda-zero)	Λ^0	1116	0	$\frac{1}{2}$	1	uds	2.6×10^{-10}	$p + \pi^-$ or $n + \pi^0$	$\bar{\Lambda}^0$
SIGMA (sigma-plus)	Σ^+	1189	1	$\frac{1}{2}$	1	uus	0.8×10^{-10}	$p + \pi^0$ or $n + \pi^+$	$\bar{\Sigma}^+$
(sigma-zero)	Σ^0	1192	0	$\frac{1}{2}$	1	uds	7.4×10^{-20}	$\Lambda^0 + \gamma$	$\bar{\Sigma}^0$
(sigma-minus)	Σ^-	1197	-1	$\frac{1}{2}$	1	dds	1.5×10^{-10}	$n + \pi^-$	$\bar{\Sigma}^-$
XI (xi-zero)	Ξ^0	1315	0	$\frac{1}{2}$	1	uss	2.9×10^{-10}	$\Lambda^0 + \pi^0$	$\bar{\Xi}^0$
(xi-minus)	Ξ^-	1321	-1	$\frac{1}{2}$	1	dss	1.6×10^{-10}	$\Lambda^0 + \pi^-$	$\bar{\Xi}^-$
LAMBDA (lambda-plus)	Λ_c^+	2282	1	$\frac{1}{2}$	1	udc	2.3×10^{-13}	$\Lambda^0 + \text{anything}$	$\bar{\Lambda}_c^+$
DELTA (delta-minus)	Δ^-	1232	-1	$\frac{3}{2}$	1	ddd	$\approx 10^{-23}$	$(n \text{ or } p) + \pi$	
(delta-zero)	Δ^0	1232	0	$\frac{3}{2}$	1	udd	$\approx 10^{-23}$	$(n \text{ or } p) + \pi$	
(delta-plus)	Δ^+	1232	1	$\frac{3}{2}$	1	uud	$\approx 10^{-23}$	$(n \text{ or } p) + \pi$	
(delta-plus plus)	Δ^{++}	1232	2	$\frac{3}{2}$	1	uuu	$\approx 10^{-23}$	$(n \text{ or } p) + \pi$	
SIGMA (sigma-star plus)	Σ^{*+}	1385	1	$\frac{3}{2}$	1	uus	$\approx 10^{-23}$	$\Lambda^0 + \pi^0$	
XI (xi-star zero)	Ξ^{*0}	1530	0	$\frac{3}{2}$	1	uss	$\approx 10^{-23}$	$\Xi^0 + \pi^0$	
OMEGA (omega-minus)	Ω^-	1672	-1	$\frac{3}{2}$	1	sss	0.8×10^{-10}	$\Lambda^0 + K^-$	Ω^+

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QUESTI-ONS !!	
Are all leptons fermions?	
Are neutrinos massless?	
Are all quarks confined?	
Are photons bosons?	
Are all bosons massless?	
Are all mesons hadrons?	
Are all hadrons mesons?	
Are all baryons mesons?	
Are neutrons baryons?	
Are baryons ever neutral?	
Are all hadrons unstable?	
Can quark/antiquark pairs be created?	
Can lepton/antilepton pairs be created?	
Can quarks change from one type to another?	
Can leptons change from one type to another?	
Can bosons have half-integer spin?	
Do all fermions have half-integer spin?	
Do quark antiquarks pairs have equal mass?	
Do quark antiquarks pairs have equal charm?	
Do all quarks have the same spin?	
Do gluons have mass?	
Do all baryons have half-integer spin?	
Do mesons contain three quarks?	
Do all mesons have spin?	
Is baryon number always conserved?	
Is spin always conserved?	

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