

QUARK AND LEPTON PROPERTIES

Quark Flavor	Symbol	Charge	Mass (MeV)	Baryon #	Strangeness	Charm	Bottomness or Beauty	Topness or Truth
UP	u	+2/3	5	+1/3	0	0	0	0
DOWN	d	-1/3	8	+1/3	0	0	0	0
CHARM	c	+2/3	1500	+1/3	0	1	0	0
STRANGE	s	-1/3	160	+1/3	-1	0	0	0
TOP	t	+2/3	>180,000	+1/3	0	0	0	1
BOTTOM	b	-1/3	~4250	+1/3	0	0	-1	0
ANTI-UP	u	-2/3	5	-1/3	0	0	0	0
ANTI-DOWN	d	+1/3	8	-1/3	0	0	0	0
ANTI-CHARM	c	-2/3	1500	-1/3	0	-1	0	0
ANTI-STRANGE	s	+1/3	160	-1/3	1	0	0	0
ANTI-TOP	t	-2/3	>180,000	-1/3	0	0	0	-1
ANTI-BOTTOM	b	+1/3	~4250	-1/3	0	0	1	0

Lepton Flavor	Symbol	Charge	Mass (MeV)	Electron #	Muon #	Tauon #
ELECTRON	e or e ⁻	-	0.511	1	0	0
MUON	μ or μ ⁻	-1	105.7	0	1	0
TAUON	τ or τ ⁻	-1	1777	0	0	1
ELECTRON NEUTRINO	ν _e	0	<15 eV	1	0	0
MUON NEUTRINO	ν _μ	0	<250 KeV	0	1	0
TAUON NEUTRINO	ν _τ	0	<50	0	0	1
ANTI-ELECTRON	e or e ⁺	1	0.511	-1	0	0
ANTI-MUON	μ or μ ⁺	1	105.7	0	-1	0
ANTI-TAUON	τ or τ ⁺	1	1777	0	0	-1
ELECTRON ANTI-NEUTRINO	ν̄ _e	0	<15 eV	-1	0	0
MUON ANTI-NEUTRINO	ν̄ _μ	0	<250 KeV	0	-1	0
TAUON ANTI-NEUTRINO	ν̄ _τ	0	<50	0	0	-1

Additional data may be found in the **Particle Properties Data Booklet**, available from:
 Technical Information Department - MS 90-2125 - Lawrence Berkeley Laboratory - Berkeley, CA 94720

BARYON PROPERTIES

Use the chart of "QUARK & LEPTON PROPERTIES" to determine the quark composition of the following baryons. A method for determining baryon composition is shown on the following page. Use your answers from this exercise to fill the appropriate circles on the "BARYON COMPOSITION" exercise that follows.

BARYON NAME BARYON	SYMBOL	CHARGE	MASS (MEV)	STRANGENESS	CHARM	SPIN	
NUMBER							
Proton	P	+1	938	0	0	1/2	+1
Antiproton	P	-1	938	0	0	1/2	-1
Neutron	N	0	940	0	0	1/2	+1
Antineutron	N	0	940	0	0	1/2	-1
Lambda	Λ^0	0	1116	-1	0	1/2	+1
Antilambda	Λ^0	0	1116	+1	0	1/2	-1
Charmed Lambda Plus	Λ_c^+	+1	2282	0	1	1/2	+1
Sigma Plus	Σ^+	+1	1189	-1	0	1/2	+1
Antisigma Minus	Σ^-	-1	1189	+1	0	1/2	-1
Sigma Zero	Σ^0	0	1192	-1	0	1/2	+1
Antisigma Zero	Σ^0	0	1192	+1	0	1/2	-1
Sigma Minus	Σ^-	-1	1197	-1	0	1/2	+1
Antisigma Plus	Σ^+	+1	1197	+1	0	1/2	-1
Xi Zero	Ξ^0	0	1315	-2	0	1/2	+1
Antixi Zero	Ξ^0	0	1315	+2	0	1/2	-1
Xi Minus	Ξ^-	-1	1321	-2	0	1/2	+1
Antixi Plus	Ξ^+	+1	1321	+2	0	1/2	-1
Omega Minus	Ω^-	-1	1672	-3	0	3/2	+1
Antiohga Plus	Ω^+	+1	1672	+3	0	3/2	-1
Delta Zero	Δ^0	0	1237	0	0	3/2	+1
Antidelta Zero	Δ^0	0	1237	0	0	3/2	-1
Delta Minus	Δ^-	-1	1239	0	0	3/2	+1
Delta Plus	Δ^+	+1	1235	0	0	3/2	+1
Delta Two Plus	Δ^{++}	+2	1233	0	0	3/2	+1
Sigma Star Plus	Σ^{*+}	+1	1382	-1	0	3/2	+1
Sigma Star Zero	Σ^{*0}	0	1385	-1	0	3/2	+1
Sigma Star Minus	Σ^{*-}	-1	1388	-1	0	3/2	+1
Xi Star Minus	Ξ^{*-}	-1	1530	-2	0	3/2	+1
Xi Star Zero	Ξ^{*0}	0	1530	-2	0	3/2	+1

DETERMINING BARYON COMPOSITION

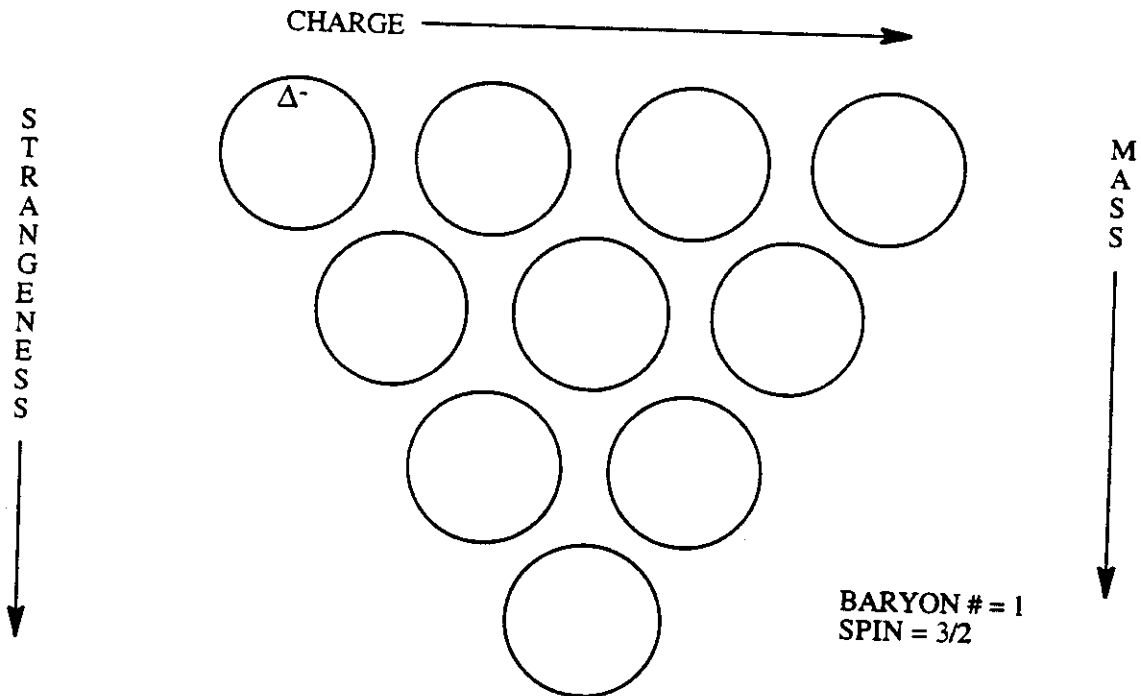
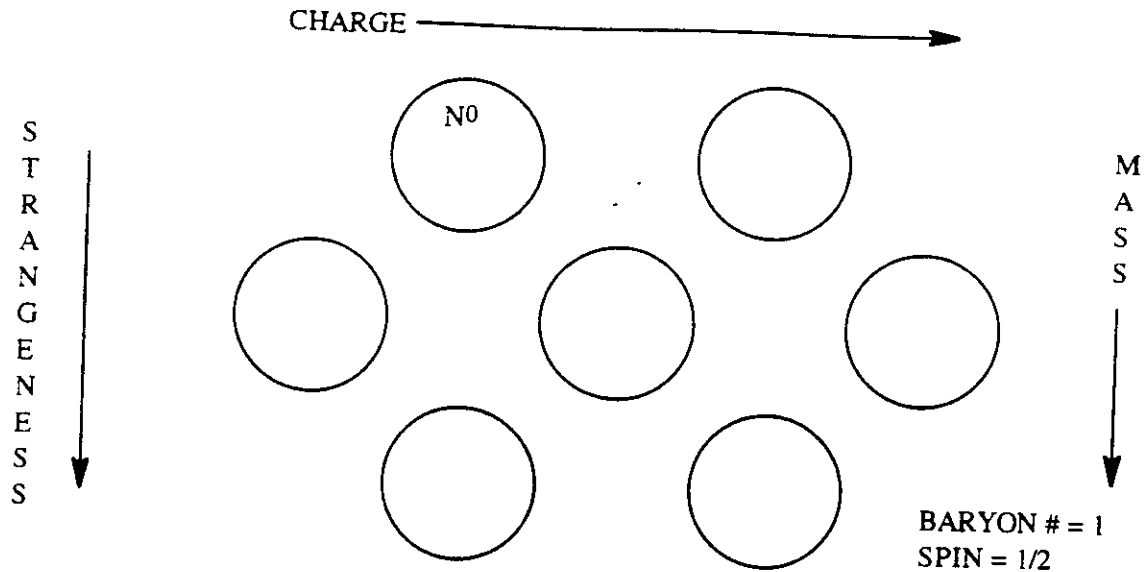
1. Baryons consist of three quarks.
 2. If the baryon number is +1, you have $\bar{Q}\bar{Q}\bar{Q}$.
 3. If the baryon number is -1, you have $Q\bar{Q}Q$.
 4. What is the charge on the baryon?
 5. What combinations of three quark charges ($\pm 2/3$, $\pm 1/3$) will yield the total charge on the baryon?
 6. What does the baryon mass indicate about possible quark combinations?
 7. A spin of $3/2$ will account for a larger mass.
 8. What do the strangeness, charm, beauty (bottomness), and truth (topness) numbers indicate?
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Example:

What is the quark composition of the Σ^0 ?

- a) The baryon number is +1. Therefore it consists of three quarks.
- b) The charge is zero. To get this total charge, the quarks must have charges of $+2/3$, $-1/3$, and $-1/3$ respectively. The $+2/3$ quark could be up, charm, or top. The $-1/3$ quarks could be down, strange, or bottom.
- c) The mass is 1192 MeV. This eliminates the more massive charm, bottom, and top quarks. Therefore the $+2/3$ quark must be up. The $-1/3$ quark could be either down or strange.
- d) The strangeness is -1. Therefore one, and only one, strange quark must be included.
- e) The composition is up, strange, down (**usd**).

BARYON COMPOSITION



The "Baryon Composition" sheet is designed to be used after the "Baryon Properties" sheet has been completed. It will show the relationships among the various baryons in terms of mass, charge, strangeness, and composition. Note that the upper set of baryons have a spin of 1/2, while the lower grouping has spin of 3/2. Use your answers from the "Baryon Properties" sheet to fill each circle with the name of the baryon and its quark composition. The circles should be filled in a pattern whereby charge increases from left to right, and both mass and strangeness increase from top to bottom.

MESON PROPERTIES

Use the chart of "QUARK & LEPTON PROPERTIES" to determine the quark composition of the following mesons. A method for determining meson composition is shown on the following page. Use your answers from this exercise to fill the appropriate boxes on the "MESON COMPOSITION" exercise that follows.

MESON NAME	SYMBOL	CHARGE	MASS (MEV)	STRANGENESS	CHARM	BEAUTY/ BOTTOMNESS	TRUTH/ TOPNESS
Pi Zero	π^0	0	135	0	0	0	0
Pi Minus	π^-	-1	140	0	0	0	0
Pi Plus	π^+	+1	140	0	0	0	0
Rho	ρ^0	0	776	0	0	0	0
Eta	η^0	0	549	0	0	0	0
K Zero	K^0	0	498	+1	0	0	0
Anti K Zero	\bar{K}^0	0	498	-1	0	0	0
K Plus	K^+	+1	494	+1	0	0	0
K Minus	K^-	-1	494	-1	0	0	0
D Zero	D^0	0	1865	0	+1	0	0
Anti D Zero	\bar{D}^0	0	1865	0	-1	0	0
D Plus	D^+	+1	1869	0	+1	0	0
D Minus	D^-	-1	1869	0	-1	0	0
F Plus	F^+	+1	1971	+1	+1	0	0
F Minus	F^-	-1	1971	-1	-1	0	0
J/Psi	J/Ψ	0	3097	0	0	0	0
B Zero	B^0	0	5274	0	0	+1	0
Anti B Zero	\bar{B}^0	0	5274	0	0	-1	0
B Plus	B^+	+1	5271	0	0	+1	0
B Minus	B^-	-1	5271	0	0	-1	0
Phi	ϕ	0	1020	0	0	0	0
Upsilon	Ψ	0	9460	0	0	0	0

DETERMINING MESON COMPOSITION

1. Mesons consist of a quark and an antiquark ($Q\bar{Q}$).
2. What is the charge on the meson?
3. What combinations of quark and antiquark charges ($\pm 2/3, \pm 1/3$) will yield the total charge on the meson?
4. What does the meson mass indicate about possible quark/antiquark combinations?
5. What do the strangeness, charm, beauty (bottomness), and truth (topness) numbers indicate?

Example:

What is the composition of D^- ?

- a) It is a meson, so we have $Q\bar{Q}$.
- b) The charge is -1 . Therefore the quark/antiquark charges must be $-1/3$ and $-2/3$. We must have a quark charge of $-1/3$ (down, strange, or bottom) and an antiquark charge of $-2/3$ (antiup, anticharm, or antitop).
- c) The mass is 1869 MeV . This eliminates the bottom and antitop.
- d) The charm is -1 . This requires the anticharm.
- e) The strangeness is zero. This eliminates the strange quark.
- f) We are left with the down/anticharm ($d\bar{c}$) combination for the D^- .

MESON COMPOSITION

The "Meson Composition" sheet is designed to be used after the "Meson Properties" sheet has been completed. It will show the quark composition relationships among the various mesons. In the table below insert the names of the known mesons formed from each quark/antiquark combination.

	\bar{u}	\bar{d}	\bar{c}	\bar{s}	\bar{t}	\bar{b}
u	π^0 ρ^0 η^0					
d		π^0 ρ^0 η^0				
c						
s						
t						
b						

MESON PROPERTIES AND MESON COMPOSITION ANSWER KEYS

MESON NAME	COMPOSITION QUARK/ANTIQUARK		MESON NAME	COMPOSITION QUARK/ANTIQUARK	
Pi Zero	u/d	\bar{u}/\bar{d}	D Plus	c	\bar{d}
Pi Minus	d	\bar{u}	D Minus	d	\bar{c}
Pi Plus	u	\bar{d}	F Plus	c	\bar{s}
Rho	u/d	\bar{u}/\bar{d}	F Minus	s	\bar{c}
Eta	u/d	\bar{u}/\bar{d}	J/Psi	c	\bar{c}
K Zero	d	\bar{s}	B Zero	d	\bar{b}
Anti K Zero	s	\bar{d}	Anti B Zero	b	\bar{d}
K Plus	u	\bar{s}	B Plus	u	\bar{b}
K Minus	s	\bar{u}	B Minus	b	\bar{u}
D Zero	c	\bar{u}	Phi	s	\bar{s}
Anti D Zero	u	\bar{c}	Upsilon	b	\bar{b}

	\bar{u}	\bar{d}	\bar{c}	\bar{s}	\bar{t}	\bar{b}
u	π^0 ρ^0 η^0	π^+ ρ^+	\bar{D}^0	K^+		B^+
d	π^- ρ^-	π^0 ρ^0 η^0	D^-	K^0		B^0
c	D^0	D^+	J/ Ψ	F^+		
s	K^-	\bar{K}^0	F^-	ϕ		
t						
b	B^-	\bar{B}^0				Ψ