

THE EIGHTFOLD PATH

Introduction

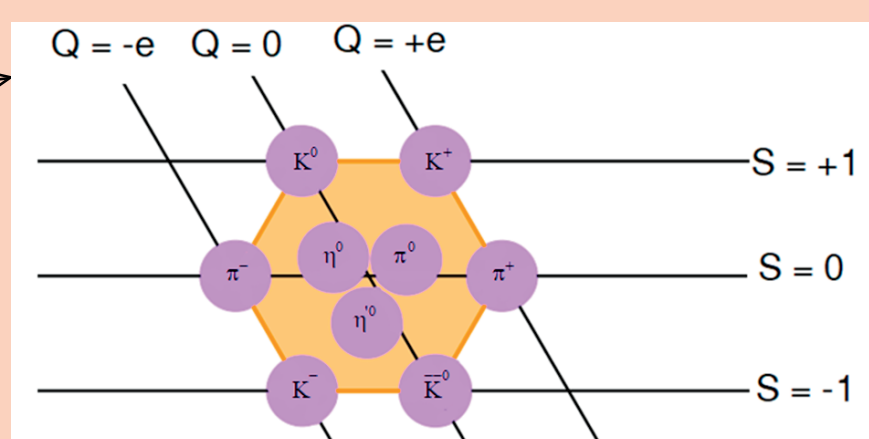


In my last year of studying physics education, inspired by games that use a deck of cards with elementary particles*, I decided to try my hand at designing new games with this deck, which could be related to aspects of elementary particle physics that are not already mentioned in existing games. So I came up with the idea of a game which utilises the concept of *The eightfold path* for baryons and mesons.

The eightfold path in physics

- **Property of symmetry** in the representation of baryons and mesons
- It was independently observed by **Murray Gell-Mann** and **Yu'val Ne'eman** in 1961**
- Such grouping often results in **sets of eight** (or more) hadrons

EXAMPLE



Hadrons can be represented in suitable symmetric groups according to their charge (Q) and strangeness (S) properties

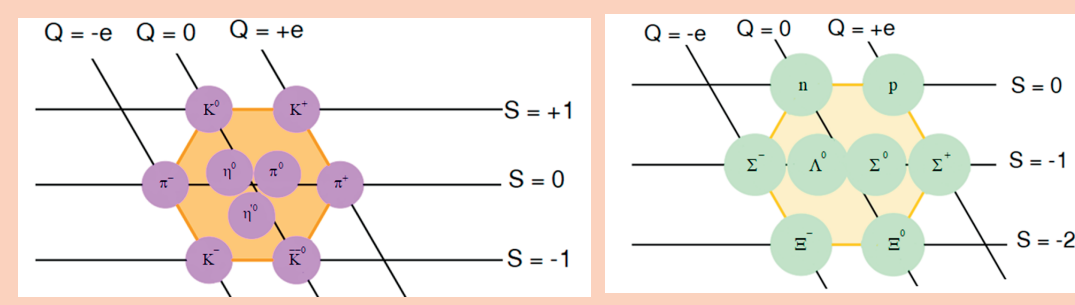
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Level 1: Beginner ★★☆☆☆

- Names of baryons and mesons **can be written on the boards**



- players **can** use following tables:

Particle name	Strangeness (S)	Electrical charge (Q/e)
u	0	+2/3
d	0	-1/3
s	-1	-1/3
u-bar	0	-2/3
d-bar	0	+1/3
s-bar	+1	+1/3
e ⁻ , μ ⁻	0	-1
e ⁺ , μ ⁺	0	+1
ν _e , ν _μ , ν _τ	0	0



QUARK MATTER	BARYON	SYMBOL	QUARK MATTER	MESON	SYMBOL
uuu	Delta++	Δ ⁺⁺	u \bar{d}	Positive pion	π ⁺
uud	proton	p ⁺	d \bar{d}	Neutral pion	π ⁰
udd	Delta-	Δ ⁻	u \bar{u}	Negative pion	π ⁻
ddd	neutron	n ⁰	d \bar{s}	Positive kaon	K ⁺
ddu	Delta ⁰	Δ ⁰	u \bar{s}	Neutral kaon	K ⁰
uds	Delta ⁺	Δ ⁺	d \bar{s}	Neutral anti-kaon	K ^{0-bar}
udds	Lambda 0	Λ ⁰	s \bar{s}	Negative kaon	K ⁻
uds	Sigma 0	Σ ⁰	s \bar{d}	Eta meson	η ⁰
dds	Sigma ⁺	Σ ⁺			
uss	Xi 0	Ξ ⁰			
dds	Xi ⁻	Ξ ⁻			
sss	Omega ⁻	Ω ⁻			

Level 2: Intermediate ★★★★★

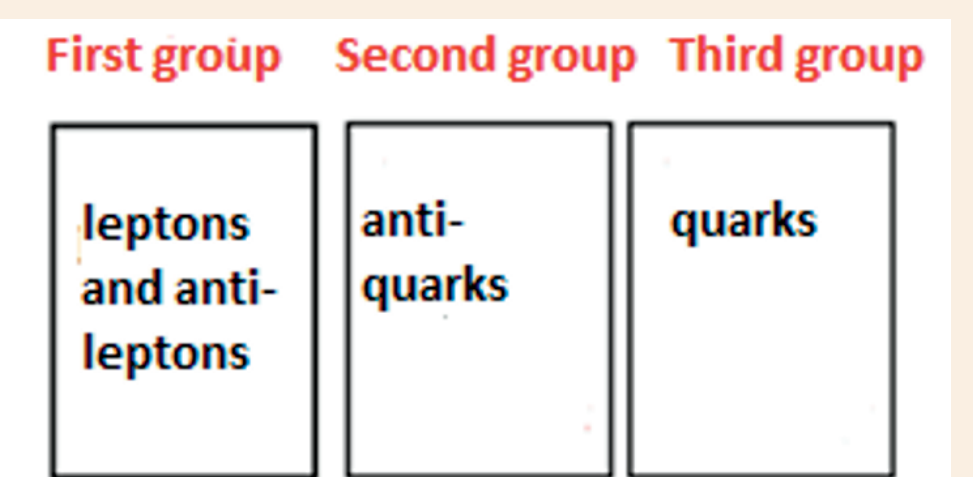
- Players **do not** have pre-written hadrons on the board
- Instead, they must place them on the board **themselves** based on their **Q** and **S**.

Players need to be familiar with the individual **S** and **Q** of **each elementary particle** in the deck, as the total strangeness and electric charge of each hadron (or group of leptons) is equal to the sum of **S** and **Q** of all individual particles that make it up.

- It is important to be **fast** and skilled at recognizing potential **opportunities** to assemble the appropriate hadron that is left unfilled on the board.

Rules and course of the game

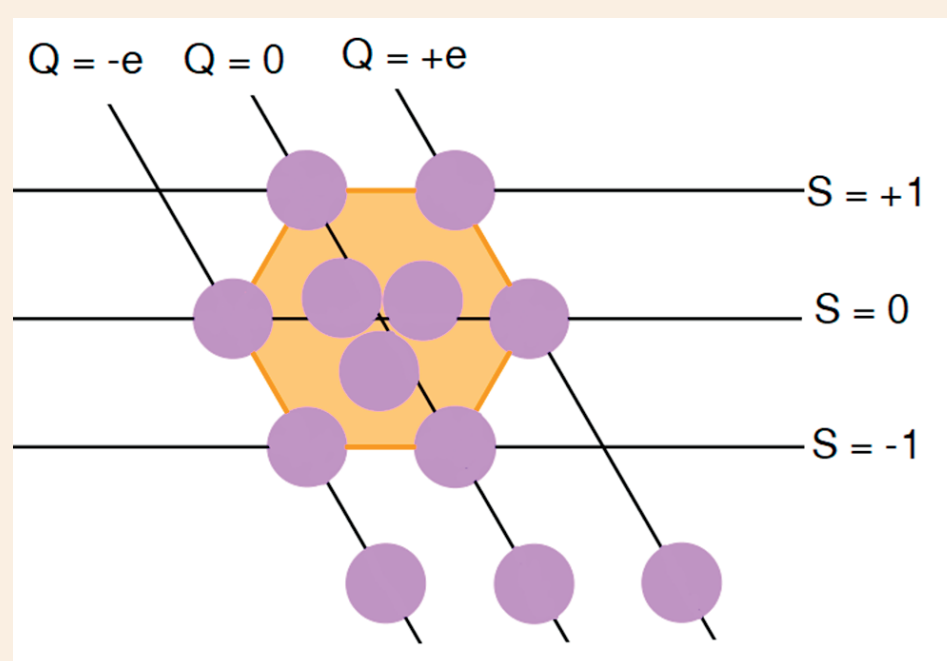
- The game is intended for **2 to 4 players**
- At the beginning, it is necessary to divide the cards from the deck into **three piles**
- Then, each player must take **two cards** from each pile
- Players hold their cards in their hands so that only they can see them.
- After that, the first part of the game begins!



The cards are shuffled and arranged according to the type of elementary particles, but they are faced down, so the players **cannot** see them

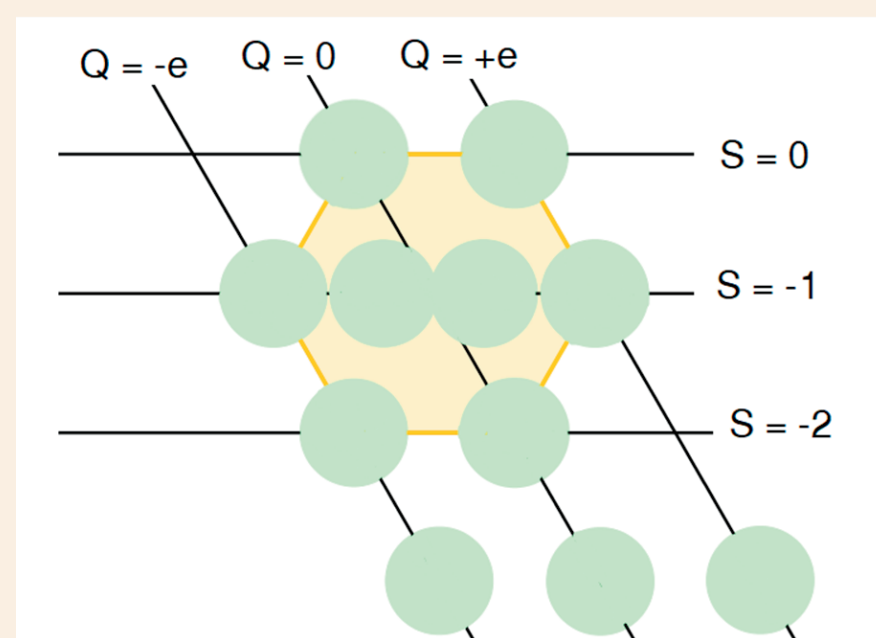
This is a board (card) game!

- Boards can be drawn on a large piece of paper/cardboard or printed according to this **template**:



First board - Meson hexagon

- For the three mesons located in the center of the hexagon, their properties of total strangeness (S) and total electric charge (Q) are such as if they were at the very center of the hexagon, where **S=0** and **Q=0**.



Second board - Baryon hexagon

- For the two baryons located in the center of the hexagon, their properties of **S** and **Q** are such as if they were at the very center of the hexagon, where **S=-1** and **Q=0**

- Boards correspond to the baryon and meson hexagons according to the eightfold path with **three additional circles** at the bottom.

Part 1 - Assembling leptons, antileptons and mesons

- The game is played **in rounds** (for example, in clockwise order)
- In each round, each player has **two possible choices**:

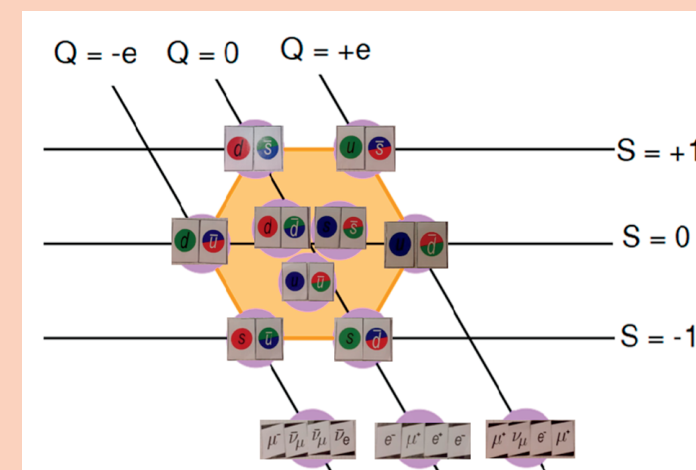
- To discard one of their own cards and draw a new card from one of the piles
- OR
- To place cards (correctly) in an empty circle within the hexagon!

- For a correctly filled circle, **1 point** is awarded...and there are also penalties!

Detailed explanations of the rules for the first part of the game can be found here



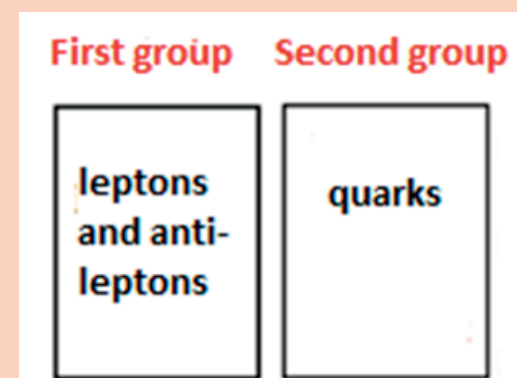
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Correctly filled board at the end

Part 2 - Assembling leptons, antileptons and baryons

- After the first part is finished, players must **return** all the cards and make **two piles**:



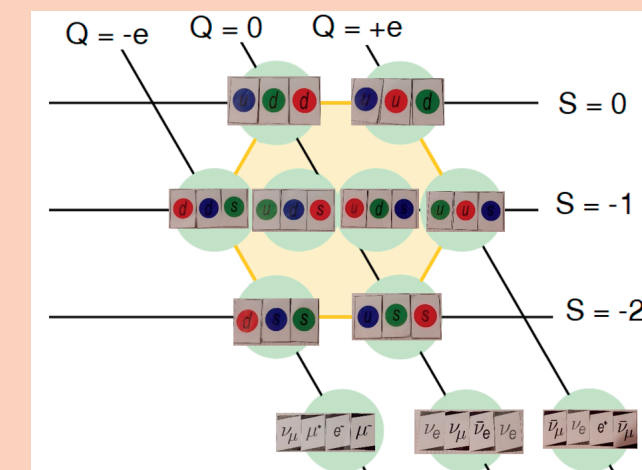
The cards are shuffled and arranged according to the type of elementary particles, face down. However, in this part of the game, the pile with antiquarks is **not** used

- Rules, choices and scoring are **very similar** to the first part of the game!

Detailed explanations of the rules for the second part of the game can be found here



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Correctly filled board at the end

What is the main goal?

To fill the designated circles in hexagons with the corresponding cards, so that within each circle, the total strangeness (S) and electrical charge (Q) are equal to the markings

- By doing that, players are **arranging hadrons**
- Players also must consider that all hadrons (baryons and mesons) must be **color neutral**
- The three lower circles (located outside the hexagon) must be filled with **4 lepton/anti-lepton cards** so that the total **Q** and **S** also correspond to the markings

HADRONS

BARYONS	quark + quark + quark
ANTIBARYONS	anti-quark + anti-quark + anti-quark
MESONS	quark + anti-quark or anti-quark + quark

Conclusion

For whom is the game intended, and what can we learn from it?



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- Various ideas and concepts of particle physics (which may seem very **complicated** at first), can be brought closer to players of different ages and backgrounds through **fun** and **social interactions**

- In addition to existing games, there is a particularly interesting and significant possibility of creating **new** and **diverse** games centered around the existing deck of cards

- As a result, these games can continue to be developed **in parallel with new physical discoveries** and theories