

INTERACTIONS OF ELEMENTARY PARTICLES

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 where four fundamental forces could be mentioned.

The beginning of the game

- The game is intended for **2 to 4 players**
- Firstly, players need to choose **one card**
- That card must represent **a particle**
- The remaining 65 cards should be thoroughly **shuffled** and then placed **in a circle** around the central card facing downwards



- Then, each player draws **4 cards** from the circle. The drawn cards are held by the players in their hands so only they can see them.
- **After that, the game begins!** Players must take turns placing one card of their choice (from the cards they hold in their hands) on the central card, while **naming the interaction** according to the following rules!

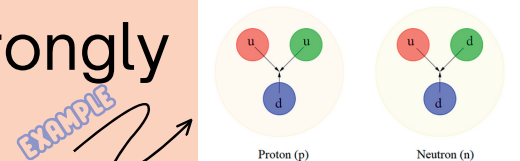
Rules of card placement

Placing *particles* on the central card

Rules correlate with the elementary particle interactions for each of the four fundamental forces

Strong interaction

- Due to the short range of this force, it is assumed that only quarks **within the same baryon** can interact strongly
- During this interaction, there is an **exchange of color** between them, while maintaining the overall color neutrality of the baryon.



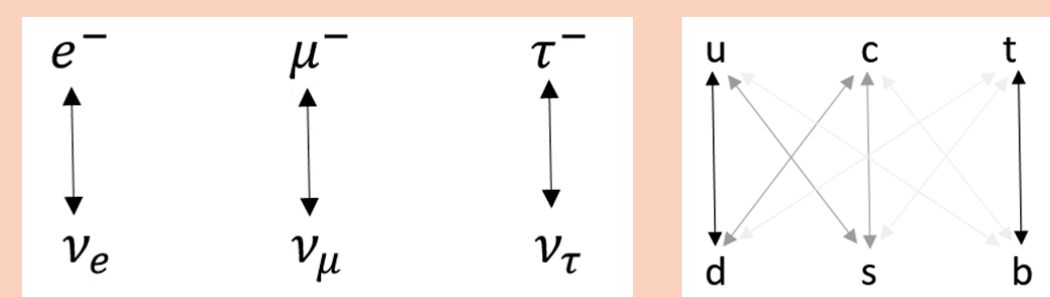
As a result, the following moves are allowed:

On each quark (u, c, or d) it is possible to put any other quark (u, c or d) provided that they **differ in color**.

(The fact that quarks placed on the given quark must be different color reflects color exchange in a baryon!)

Weak interaction

- Particles that can interact:



- As a result, the following moves are allowed:

Leptons

- e^- can be placed on ν_e and vice versa
- μ^- can be placed on ν_μ and vice versa

Quarks

- An "u" quark can have a "d" quark or "s" quark placed on it, but only if they are of the same color as the "u" quark.
- A "d" quark can have only an "u" quark of the same color placed on it.
- An "s" quark can have only an "u" quark of the same color placed on it.

(The fact that quarks must be the same color reflects the observation that the weak force can change the flavor but not the color of the quark!)

Electromagnetic interaction

- The fundamental property of this force is that only two **electrically charged** particles can interact with it.
- As a result, the following moves are allowed:

Any electrically charged particle (u, s, or d quark of any color, electron or muon) can be placed on **any other** electrically charged particle!

Gravitational interaction

- Through this interaction, all massive particles can interact with each other.
- However, this interaction between elementary particles is **extremely weak** (due to their small masses)
- This situation can be **very intriguing** as it may change the course of the game and give a **significant advantage** to the player who utilizes it at the right moment.

Only once during the game (but not when the player has only one card left, and all the cards from the central circle have been taken), the player can take advantage of the opportunity for "gravitational interaction" and place **any particle card** on the central one.

Rules of card placement

Placing *antiparticles* on the central card

Cards representing antiparticles can be placed on the central card only if they truly represent the **antiparticle** of the central card!

- In that situation, the player must say **"Annihilation"**!
 - By doing that, the player can (in the same move) place **any other** card on the table
 - That intentionally changes the course of the game
- useful & strategic move**

Additional rules and game ending

- In order to make the game even more **interesting** and **dynamic**, additional rules have been designed.
- This way, players can gain an **extra advantage**, but also deepen their knowledge of interactions of elementary particles, and even learn about **neutrino oscillations!**



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GAME OVER



- Game is over when all cards from the central pile have been taken, and one of the players has **run out of all cards** representing particles
- That player is the **winner**, and the other players are ranked according to the number of cards representing particles they have left in their hands (with the player holding the most cards being ranked last.)

Conclusion

For whom is the game intended?



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What to do after playing? Questions and topics for further discussions and learning



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Learning IS FUN

