|H⚛p⟩

Rulebook

Flip me to learn the physics behind the game!

Game elements

- 3 boards (front-back)
- 28 electron cubes (7 per color)
- 15 *effects* tokens (3 per type)
- 8 *energy* tokens
- 4 *electrode* cards (1 per color)
- 2 *Hamiltonian* cards (front-back)
- 7 *effects* cards (front-back)
- 36 *site* cards

Check the online and video version of the rules!

Introduction

You are physicists at the university. An accident has occurred: a state-of-the-art experimental machine broke because the energy was not controlled. Each person is trying to prove that it was the others who made the mistake. Grants are at stake!

Roll up your sleeves and shock those electrodes!

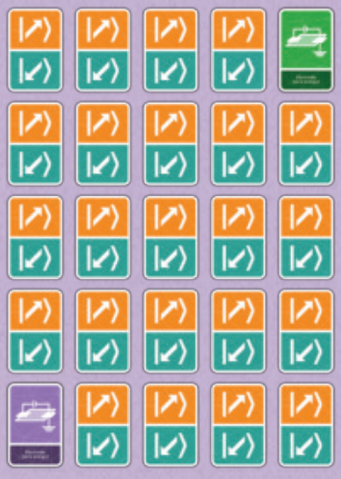
Game goal

Players take turns moving their electrons through the *site* cards that make up the board, in an attempt to reach another *electrode* card. At each turn, players have 2 movements to choose from the movement board. To end the game, it's enough to place **one** electron in an opponent's *electrode*.

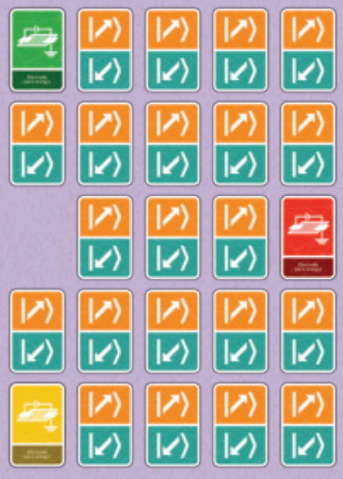
The player whose *electrode* is reached gets short-circuited and loses.
The others are safe... for this round!

Game setup

Create a board by laying out the *site* cards in a square grid as below. With four players, you play individually but work together in teams of two to reach **any** *electrode* of the opposing team.



2 players



3 players

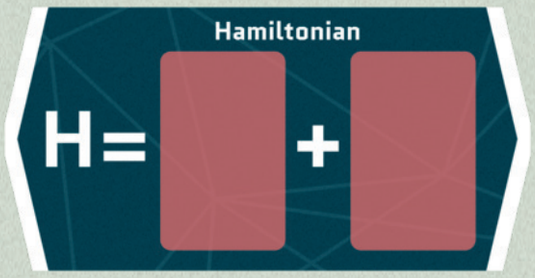
4 players

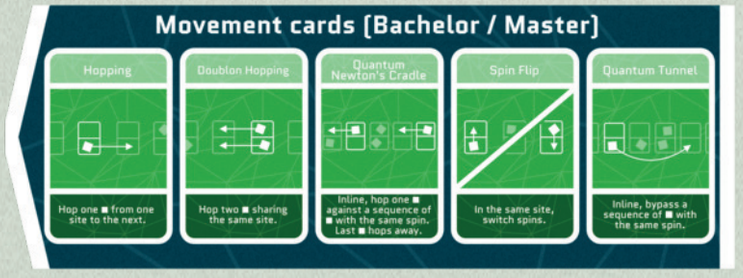
Replace the *site* cards with *electrode* cards based on the number of players as indicated above. Place the 7 electron tokens of the same color onto the respective card.

Now it's time to choose your academic degree and refer to the corresponding section!

Bachelor level

Place the *movement* board on the *bachelor/master* side, and the player's meeples next to it. Then, place the *Hamiltonian* board without any cards.

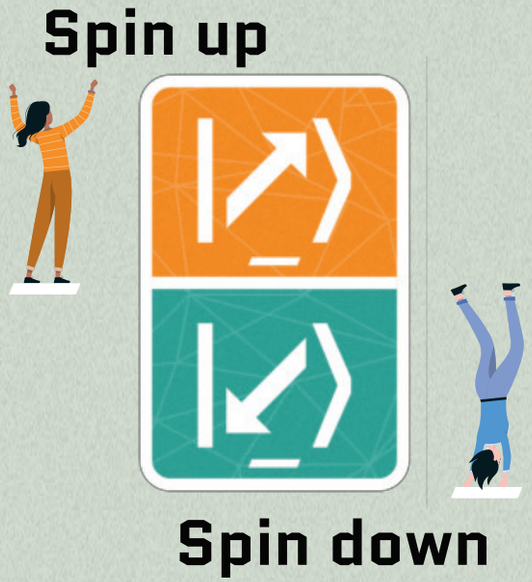




General rules

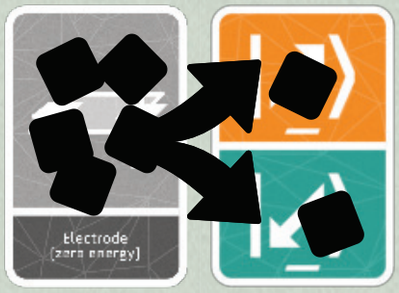
- All the electrons start from the *electrode* card of the corresponding color.

- The *site* cards are divided in two components: spin up (orange part) and spin down (blue part).



- There can never be more than a single electron (of any color) in the same *site* with same spin.

- When moving an electron from an *electrode*, you can chose the its final spin.



- Except for the *spin flip*, a *movement* cannot change the spin of an electron.

- All the *movements* must respect the two directions of the grid (vertical and horizontal) and never change direction.

Gameplay

Spin the box, the direction of the arrow in |Hop> determines the first player.

Each player takes turn counter-clockwise.

- **Blocking:** Before your turn, the opponent to the left blocks a *movement* by placing **your** meeple on top of it.
  - The *movement* cannot be used in this turn.
  - The same *movement* cannot be blocked twice in a row.
- **Movements:** You can play a maximum of 2 *movements* per turn from the *movement* board.

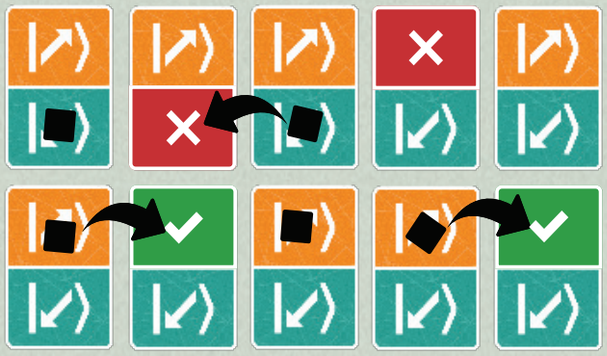
Movements

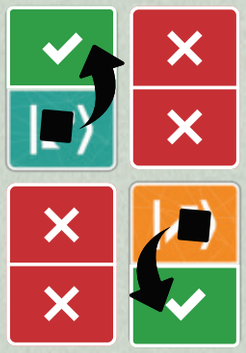
Every *movement* must be initiated by one of your electrons but may affect other players' electrons.
All *movements* can be used to enter/exit an *electrode*.

Hopping: Destroy an electron and recreate it on a site next to it with the same spin. In other words, move the electron to an adjacent site , vertically or horizontally.

Doublon hopping: Destroyes a pair of electrons in the same *site* and recreates it in an adjacent *site*. This *movement* is not allowed if one of the two target spins is already occupied.

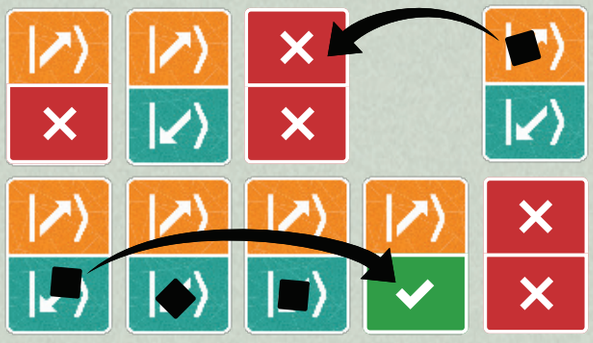
Quantum Newton's cradle: Hop an electron towards a sequence of electrons with the same spin. The last electron in the sequence is pushed, requiring an empty space for the first and last spin to hop.





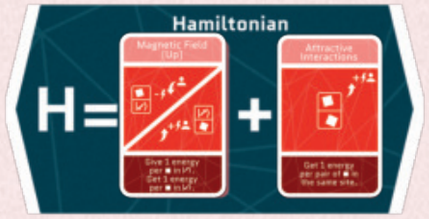
Spin flip: In the same *site*, exchange the spin of a single electron if the target spin is empty.

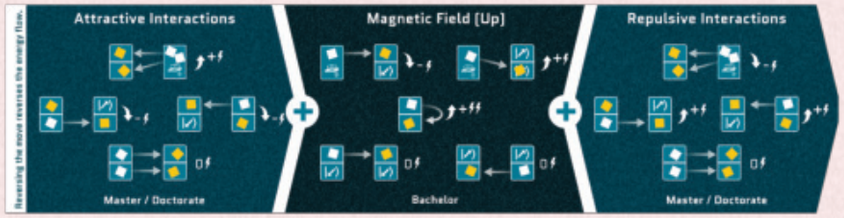
Quantum tunnel: Destroy an electron in a line of electrons with the same spin. Recreate it at the end, in the first site available.



Master level

Place the *magnetic field* card and/or the *attractive interaction* card on the *Hamiltonian* board. Position the *effects* board, as shown below, around the game grid (to help remember the rules of energy conservation).





In a 2-player game, each player starts with 2 *energy* tokens. In 3 and 4-player games, each player starts with 1 *energy* token. Place the remaining *energy* tokens next to the *Hamiltonian*, easily accessible to all players.

General rules (additional)

- When using a *movement*, *energy* must be exchanged as determined by the *Hamiltonian*.

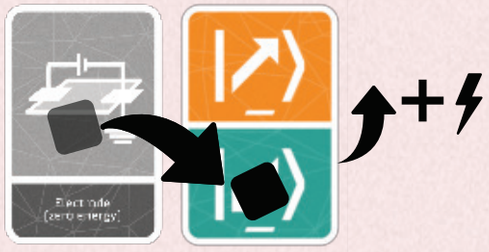
- In an *electrode*, the energy is always zero (there is no Hamiltonian).

Hamiltonian and energy

The Hamiltonian determines the energy of the electrons on the grid and is composed of two terms.

Magnetic field:

Spend 1 *energy* to create an electron in a spin up. Get 1 *energy* back when destroying it.



Receive 1 *energy* when creating an electron in a spin down. Spend 1 *energy* to destroy it.

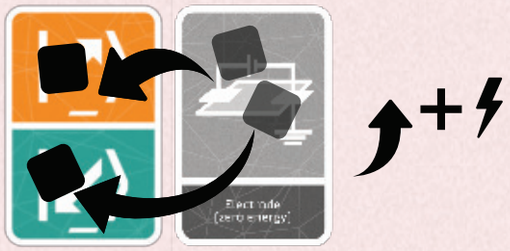
<u>Some examples:</u>

No energy exchange required. The electron was destroyed but recreated with the same spin in a different *site*.

In this *spin flip*, receive 2 *energies* for destroying an electron with spin up and then recreating it in the spin down.

Attractive interactions:

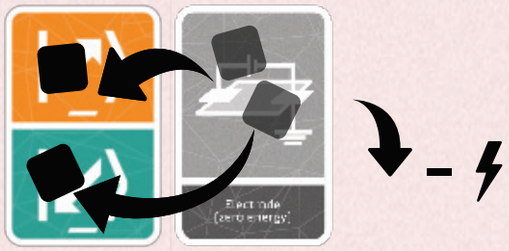
Receive 1 extra *energy* when creating a pair of electrons sharing a *site*.



Spend 1 extra *energy* for destroying a pair of electrons.

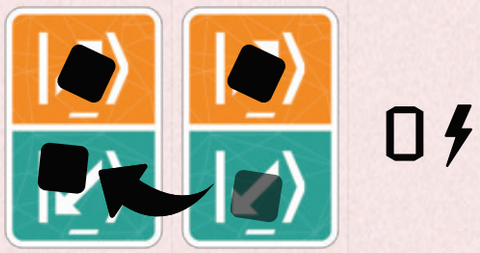
Repulsive interactions:

Spend 1 extra *energy* to create a pair of electrons sharing a *site*.



Receive 1 extra *energy* for destroying a pair of electrons.

<u>More examples:</u>



No *energy* exchange required because the pair remained intact, i.e. received and spent the same *energy*.

Gameplay

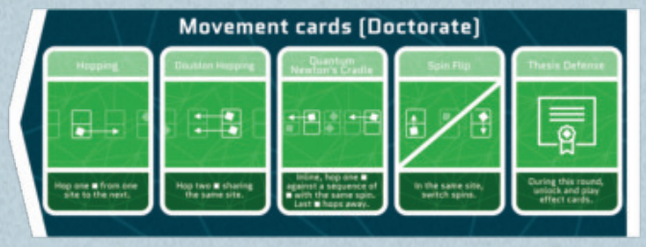
Each player takes turn counter-clockwise.

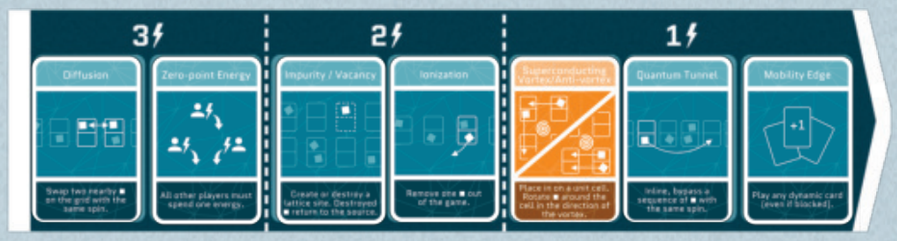
- **Blocking.**
- **Movements.**
- **Energy conservation:** With each *movement*, you must balance the *energy* on the board according to the *Hamiltonian* board.
  - If you do not have enough *energy* (in hand or at the table), you cannot make the move.
  - The color of the electrons does not matter for the *Hamiltonian*.

Did you know that thanks to the crowdfunding campaign, you can learn about the physics behind the game just by flipping the rulebook around?

Doctorate level

Flip the *effects* board and position all the *effect* cards randomly (random side as well) on top. Position the *effect* tokens on the side. Flip the *movement* board to the *doctorate* side.





Attention: The *quantum tunnel* is no longer a movement and is replaced by the *thesis defense*.

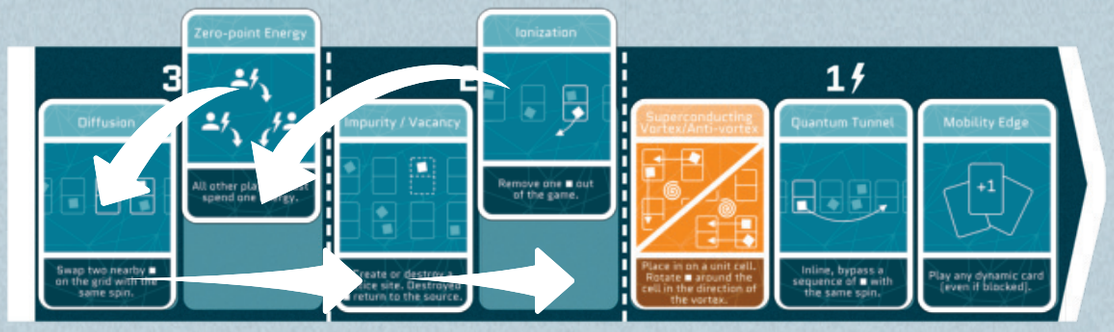
Movements (additional)

Thesis Defense: It allows the player to play multiple *effects* by paying the corresponding *energy* on the board. *Effects* can be used at any time during the turn.

Gameplay

Each player takes turn counter-clockwise:

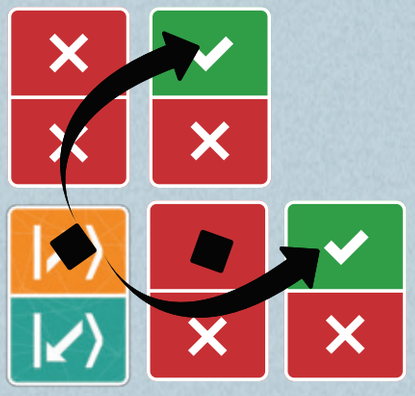
- **Blocking.**
- **Movements.**
- **Energy conservation** [*except for thesis defence*].
- **Effects:** After using the *thesis defence*, you can use one or more *effects* as long as you have enough *energy* to acquire them.
  - The cost of an *effect* is determined by its position on the *effects* board.
  - *Effects* do not require energy conservation.
  - Acquired effects must be played immediately.
  - Each *effect* can only be used once per turn.
  - After the turn, the used *effects* are moved to the most costly positions on the *effects* board. The remaining *effects* are shifted to cheaper positions.



Effects

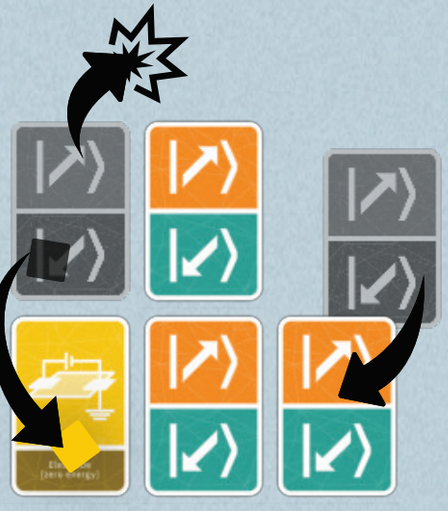
The orange *effects* allow you to place permanent tokens on the board. They cannot affect the *electrodes*, nor influence the same *site*. These tokens can be destroyed either by using the same *effect* twice or by removing a *site* they touch.

Tunnel effect: Identical to the *movement* in the previous levels but no longer subjected to the conservation of energy.

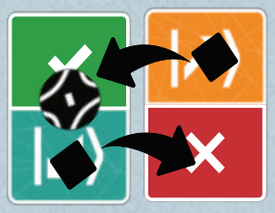


Long-range hopping: Destroy and recreate an electron two sites away while preserving its spin. It is possible to pass through a *site* occupied by another electron.

Vacancy / Impurity: Remove or add a *site* to the grid. An *electrode* can never be isolated from the others. If there are electrons on the removed *site*, they return to their *electrode*.

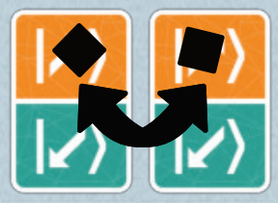


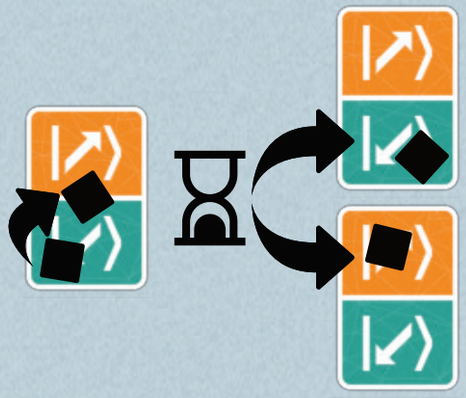
Penning's trap: Place the *trap* token on a chosen *site*. Any electron may enter the *site* but no electron can leave while the *trap* is in place.



Dead short: Steal 1 energy from a chosen player.

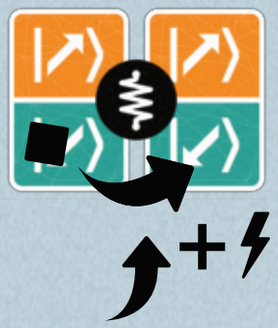
Diffusion: Exchanges two electrons with the same spin in adjacent *sites*.





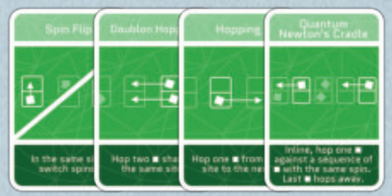
Superposition: Place an electron between the two spin states (superimposed). Whenever a *movement* or *effect* requires to know the position of the electron, the one who played the *superposition* choses the spin where the electron really is. If the chosen spin renders the move impossible, the move is lost.

Heat source: Place the *heat* token on a choosen *site*. At the end of each turn, electrons with spin down change to spin up. With two electrons, the player can choose to switch them.



Resistance: Place the *resistance* token between two *sites*. From now on, whenever a player moves one (or more) electrons across, they get 1 *energy* from the table. Tunneling does not count.

Ionization: Eliminates from the game a single electron in a *site*.



Mobility edge: Allows the player to do an extra *movement*, even if blocked.

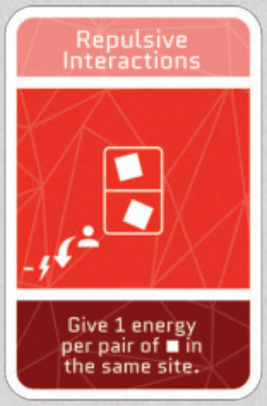
Superconducting Vortex: Place a *vortex* token between four *sites* in a chosen direction (clockwise or counterclockwise). At the end of each turn, all electrons on affected *sites* move one place in the direction of the vortex.

Microwave cavity: Place a *cavity* token between two *sites*. At the end of each turn, electrons on the initial *site* will hop along the direction of the arrow.

Zero-point energy: All the other players must spend 1 *energy* to the table.

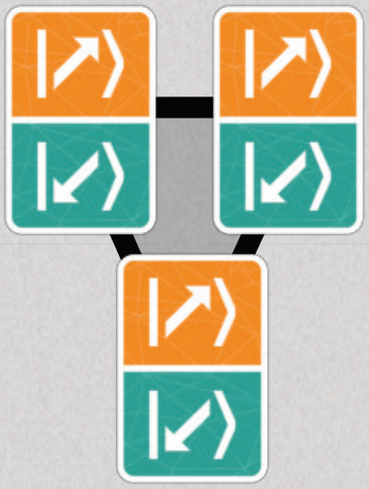
Game variations

Players can experiment with different *Hamiltonian* combinations. Typically, *repulsive interactions* make the game more challenging to play.



Each *effect* card has both a front and back effect, so there are 128 possible *effect* combinations to discover.

You can play with other grid shapes. Why not try a triangular or even hexagonal grid. The triangular grid allows for quicker gameplay!



Discover more variations and extended rules in our website:

hopquantumgame.com