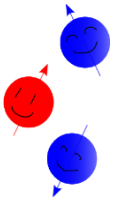
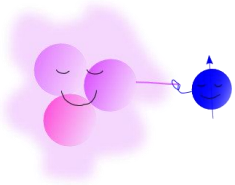
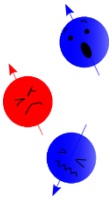
THE GAME



Once ELECTRONS were free. They could move around, going anywhere, anytime. Or they could choose to meet up with fellow electrons and nuclei to form atoms, lowering their energy. Supporting each other to remain stable, and relaxed.



But some electrons have strayed too far and found themselves in a weird region full of barriers and obstacles. Their excitement has raised their energy, which has gotten them trapped within this region. This nightmare has gotten them stressed and unstable!
Help your electron escape by losing energy, and finally relax.



The different obstacles (related to QUANTUM EFFECTS) in the game will make your electron lose or gain QUANTA (tiny packages) of energy. Can you rid yourself of the most energy before the first electron escapes? Find out in “The Black Box of Physics”.

SETUP

- Place the board in the middle of the players.
- Each player choses their electron to play with, and places it on the start tile.
- At the beginning of the game all electrons have the spins pointing up. Take a token and place it such that it shows your spin state to be “up”.
- Each player grabs 10 energy quanta from the pile and places them in front of them. These represent your total energy.
- Each player gets an entanglement card for each electron (colour) in play.

GOING FIRST

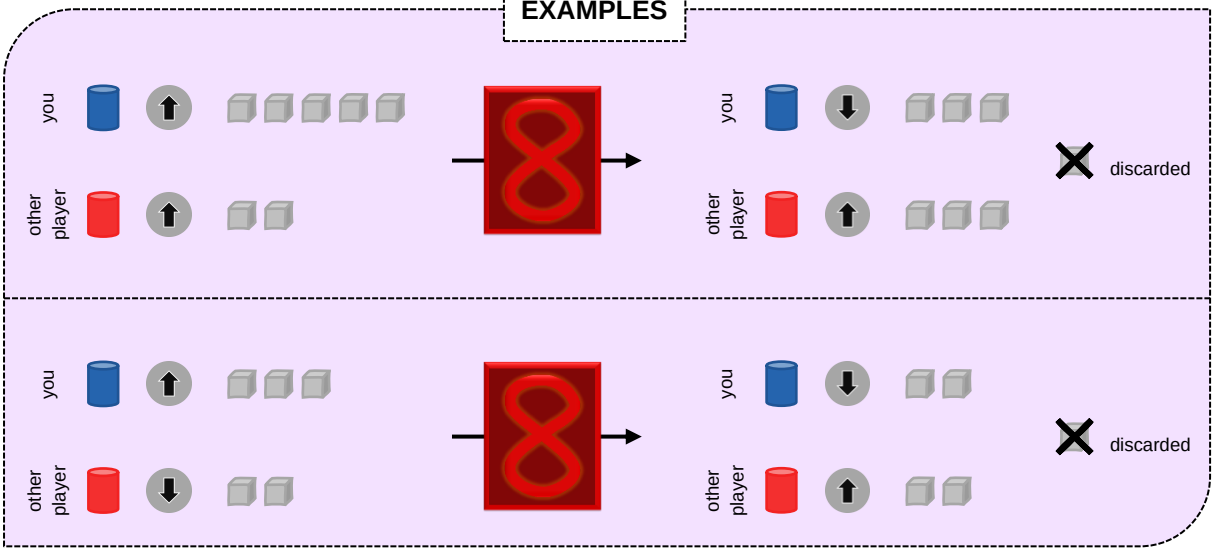
The player going first is determined by a throw of the black dice. Whichever player throws the highest number is the lucky starter. The rest of the players will get their turn in clockwise order from the starting player.

YOUR TURN

When it is your turn you throw the black dice. Depending on the result, you either move your electron 1 through 5 tiles or flip the spin of your electron (↕). When your electron spin is flipped, you now have to move in the opposite direction across the board.

Every turn, you have the option to instead of rolling the dice, use (one of) your ENTANGLEMENT card(s). With this card you entangle with the electron having the same colour as the card. Entangled objects are connected, no matter how far apart they are. And if one of the objects is in state A, the other object is automatically in state B. Where state A and B are equal, but opposite. Using an entanglement card means that you have to create these equal but opposite states. Meaning that you have to flip the spin(s) of the two entangled electrons (yours and/or that of the other electron), and divide the energy quanta you have combined equally among you. If you have an uneven number, discard the last one into the pile.

EXAMPLES

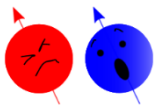


RULES & OBSTACLES

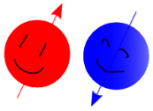
While moving over the board the electrons will have to abide by certain rules and will encounter different obstacles. These can hinder your progress, lower your total energy, or increase it.

GROUND RULES

PAULI EXCLUSION PRINCIPLE: two identical electrons are not allowed to occupy the same space on the board. When you land on an occupied tile on the board, and the other electron has the same spin and the same energy, you are not allowed on this tile. Instead you have to stop 1 tile before this.



ELECTRON PAIR: the pairing of opposite spins in the same energy state is often energetically favourable. When you land on an occupied tile on the board, and the other electron has the same energy, but opposite spin, both of you lose 1 quantum of energy.



OBSTACLES

TUNNELLING: tunnelling is the quantum effect that particles are sometimes allowed to pass through a potential barrier instead of being blocked by it. You have encountered a potential barrier, but despite this you might be able to tunnel through. Role the white dice to determine the number of energy quanta with which you are allowed to tunnel through the barrier. If your energy state is lower than the number thrown or if the dice lands on the blanc side, you shall not pass! Remain on the tile where you were before until the next turn.

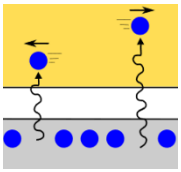
QUANTUM WELL: a potential well is a region in which potential energy is trapped, and can not escape in the form of another type of energy. One can only escape, when sufficient energy is added to the system. You have fallen in such a well and can only climb out (on the next turn) if your energy is high enough. But if your energy is too low, absorb more energy from the pile to raise it.

For the quantum well on tile 13, electrons need 4 energy quanta
For the quantum well on tile 34, electrons need 2 energy quanta

LASER EXCITATION: light is made up of photons, the energy of which is related to the wavelength of the light. This wavelength also determines the colour of the light. Laser light can be used to excite the electron, kicking it into a higher energy state. You have been hit by a laser, which raises your energy. Collect energy quanta from the pile.

The red laser shining on tile 26 raises your energy by 1 energy quantum
The blue laser shining on tile 44 raises your energy by 2 energy quanta

CONDUCTION BAND: an excited electron can jump from the so-called valence band into the conduction band. When electrons are in the conduction band, they can move around freely. You have encountered a crossroad where you have the choice to enter the conduction band. This allows you to take a shortcut to a different part of the board, allowing you to avoid unwanted obstacles. Movement is allowed in both directions. However, there is a price. To enter the conduction band, you have to raise your energy level by 2 energy quanta.



There are two conduction bands in game, connecting tile 11 to 27 and 19 to 36

ELECTRON SCATTERING: the trajectory of an electron can be changed when they interact with matter. This deflection of the electron is called electron scattering. You have been scattered by interactions with a bigger particle. Throw the white dice to determine your scatter event. If the dice lands on 1 through 5, you have lost thing amount of energy while scattering (inelastic scattering). If the dice lands on the blanc slide, you have scattered elastically, keeping your energy the same. For both types of scattering, your trajectory has also changed. For the next turn you can decide if you want to continue on the same path (entering the small loop), or if you want to start moving towards the finish.

CYCLOTRON: in a cyclotron, electrons are forced to move in a circular path using strong magnets. Due to the continuous acceleration, electrons lose energy by emitting photons. Whooosh! You have been sucked into a cyclotron! You will now be whirled around and lose a lot of energy! Jump to the last tile, and shoot away the huge amount of energy quanta towards the pile.

In the bigger cyclotron you emit photons worth 8 energy quanta
In the smaller cyclotron you emit photons worth 4 energy quanta
These number are independent of on which tile you have entered it

Note: if you undergo a spin-flip while in the accelerator, you will be propelled to the other side of the accelerator and lose energy again.

END OF THE GAME

Once the first electron that passes the finish line with a total energy of 5 or less energy quanta, the game ends. Each player counts the number of quanta their electron has left, and the player with the lowest amount wins.

NOTES

- Negative energy does not exist, when you have been depleted of energy quanta, you are in the GROUND STATE. Energy depleting obstacles will no longer have any effect.
- When your electron has more than 5 energy quanta when it gets to the finish, it can not escape yet. Continue moving in the same direction on your path to relaxation.
- All obstacles can be passed without landing on it, except for the TUNNELLING event
    - This is why the TUNNELLING event does not count as a tile, while all the other obstacles have a tile on which your electron can stand

PHYSICS BEHIND THE GAME

Coming soon

CREDITS

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ILLUSTRATIONS: Kshiti Mishra

SPECIAL THANKS TO: Summer School Science Communication participants and instructors, and S. W. Kristensen