QTris: The Game of Quantum Mechanics

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Compact Edition

What is QTris?

QTris is a board game that perfectly mirrors quantum mechanics core concepts through a game dynamic loosely inspired by classical tic-tac-toe.

Game Objective

Players aim to create as many aligned triplets (qtris) of their own color as possible on a 3*3 grid. The winner is the one with the highest number of qtris after the final measurement.

Number of Players

QTris is designed for 2 or 3 players. In the standard 1-vs-1 mode, Alice and Bob compete using either the basic set (all operation cards except U and S) or the advanced set, which adds U operation and tile decorations. An additional expansion introduces the S card and a third measurement basis. The *Eve Variant* adds a third player: Alice and Bob cooperate to play against Eve.

Game Components

- Tiles:
  - Circular tiles ○, ●, ◐, ◑, ◓, ◒.
  - Triangular tiles △, ▽, ⧋, ⧊.
  - Quadrangular tiles ▪, ▪.
- One four-sided die ($\mathrm{d4}$) and two ten-sided dice $\mathrm{d10}$.[1]
- One deck of quantum operation cards:
  - I, X, Y, Z, H, U, C_X

Game Tiles

Circular Tiles

Circular tiles have two key properties: *color* and *orientation*. ○ and ● have a definite color — white or black — while ◐, ◑, ◓, and ◒ have a definite orientation — left, right, up or down.

Triangular Tiles

Triangular tiles represent *entangled states* — two circular tiles linked by the C_X card, even on distant squares. They encode orientation (same for *correlated*, opposite for *anti-correlated* states) and may include a minus sign ($-$) to indicate quantum *phase*.

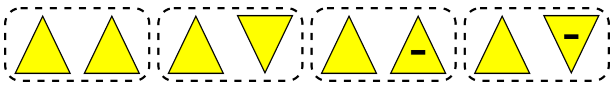

Figure 1: Entangled states generated by the C_X card

[1] Use two d10s (tens + units) to generate a number from 1 to 100; treat 00 as 100.

Quadrangular Tiles

In the advanced version, circular and triangular tiles can be modified by adding a square tile underneath — or — using proper cards (see Operation Cards).

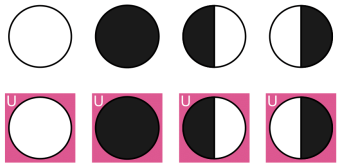

Figure 2: **Single-square tiles.**

Operation Cards

Each operation card in QTris lets you modify the state of one or two tiles on the board. These cards reflect quantum operations. The basic deck includes single-qubit operations (I, X, Y, Z, H) and the C_X gate. The advanced version adds the U card. The table below shows the card composition in each version of the game:

Card	Basic	Advanced
I	5	5
X	10	10
Y	5	5
Z	10	10
H	12	12
C_X	10	10
U	0	9

Game Rules - basic version

The game unfolds in three phases: preparation, operations and measurement with scoring.

Preparation Phase

Players manually recreate a 3*3 grid, with each space hosting a valid tile (single or entangled). Shuffle the deck of cards and deal four (4) operation cards to each player. Decide who starts by rolling the $\mathrm{d10}$s. The player with the higher roll goes first and chooses a symbol (○ or ●); the opponent takes the other. Players may perform a *mulligan*.

Operations Phase

The operations phase consists of ten (10) game turns, five (5) for each player. Each player plays 5 turns (10 total). In each turn:

1. Play 2 cards on tiles
2. Draw 2 cards from the deck

Single-square Operation Cards

The I card has no effect: use it to pass the turn. We also have the rule of thumb that if one plays a card in an illegal way, i.e. there is no rule for how to use it on that tile, it will act as the identity I. The X, Y, Z, and H cards act on a single tile, modifying it according to the square map shown in Fig. 3:

- X: changes the color
- Z: changes the orientation
- Y: changes both color and orientation
- H: swaps color and orientation

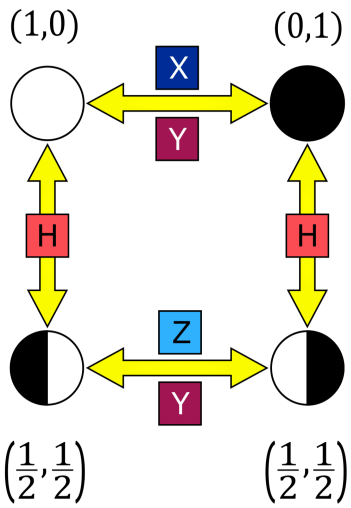

Figure 3: **Map of single-tile operations and measurement.** In (x, y), outcome probabilities for measuring ○ or ●

Two-square Operation Card: C_X

The C_X card can be played on a single tile or on a pair of tiles: it is the only operation that acts on two tiles. When played on a single tile, it acts as X (those who know qm will understand this means one has access to control-not with different controls). When used on a pair of tiles, it works in this way:

- Entangle two single-tile states (e.g., ◐● → △▽)
- Disentangle an entangled pair into separable tiles

Its action is shown in Fig. 4: separable states on the upper face (e.g., ◐●) map to entangled states on the lower face (e.g., △▽).

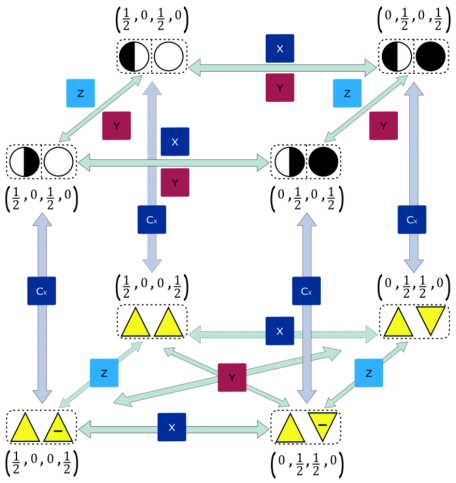

Figure 4: **Cubic map of C_X and measurement outcomes.** Each pair of input tiles - top face - maps to entangled tiles - bottom face - with corresponding outcome probabilities (and vice-versa).

Measurement and Scoring

At the end of the operations phase, all tiles are measured:

- ○, ●: no change.
- ◐, ◑: roll the two d10s dice. ○ if 1–50, ● if 51–100.
- Triangular tiles: measure the entangled pair.
  - △△ or △▽: 1–50 → ○○; 51–100 → ●●
    [i.e. probabilities $(1/2, 0, 0, 1/2)$].
  - △▽ or ▽△: 1–50 → ○●; 51–100 → ●○
    [i.e. probabilities $(0, 1/2, 1/2, 0)$].

Once all tiles are measured, count the number of valid qtris (three aligned tiles of your symbol). Each qtris scores 1 point. The player with the most points wins.

Game Rules - advanced version

QTris can be played with advanced rules that introduce non-flat probabilities and richer strategies. In this mode, new cards and tile decorations are used.

The U Card and Non-flat Probabilities

- The U card transforms standard tiles into U-decorated tiles: ○ → ◘, ● → ◘.
- These tiles follow the same single-square operation map but with modified outcome probabilities (see updated map).
- By using U again one removes the pink decoration. [2]

[2] This means that having the card U implies one can use both unitary operations U and $U^\dagger$ in quantum mechanics.

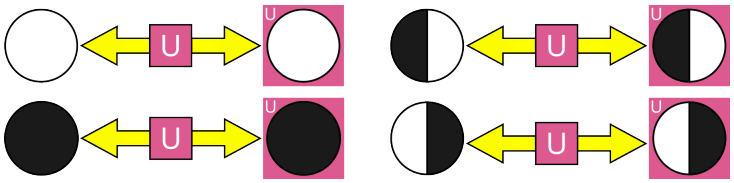

Figure 5: **Effect of the U operation card on single-square tiles.**

The rules with the U card are shown in Fig. 6, where X continues to act as a bit flip—now being the bit flip in the new basis defined by the U transformation. The reader who knows qm will understand that in Fig. 6 the operations X, Y, Z, and H are to be intended in the U basis.

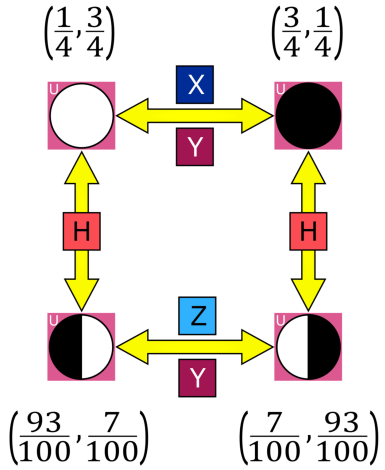

Figure 6: **Operations on U-decorated tiles.** In (x, y), outcome probabilities for measuring ○ or ● after X, Y, Z, H operations.

To perform a measurement on the pink-decorated tiles, we roll the d10s and follow the probabilities shown in Fig. 6. Notice that the U card allows one to have more interesting probability distributions that are not flat.

Entangled States under H and U Operations

Entangled states generated by the C_X card can be further manipulated using the H and U cards.

H card on entangled states. The H card acts on entangled states as shown in Fig. 7. In particular, on states △△ and △▽, H can be applied in two different ways: either by following the diagonal or the side of the map, according to the player's choice.

On red-decorated entangled states, the Y card acts in the same way as for the undecorated ones, while X and Z can be applied interchangeably, as illustrated in the figure.

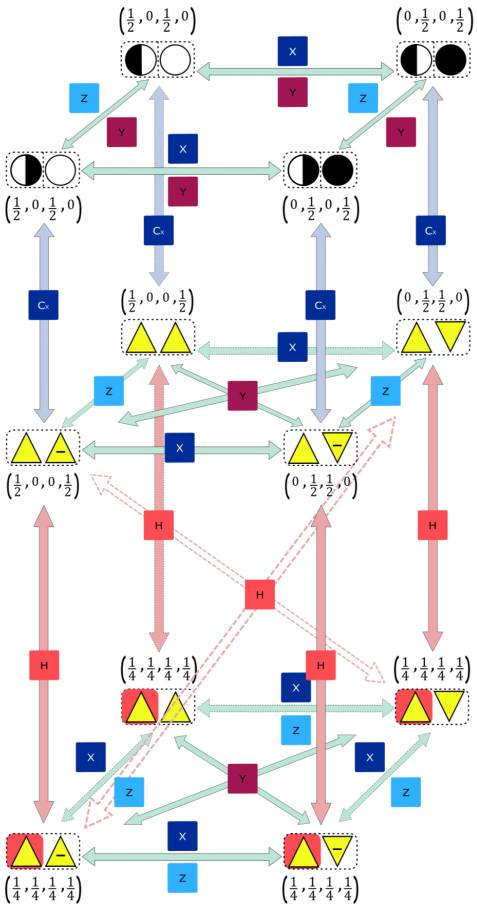

Figure 7: **Map of all operations allowed on entangled states with the H card and the corresponding outcome probabilities for $\{\bigcirc\bigcirc, \bigcirc\bullet, \bullet\bigcirc, \bullet\bullet\}$.**

U **card on entangled states.** The U card produces new states decorated with a pink tile and changes the probabilities of measurement outcomes. These are shown in Fig. 8.

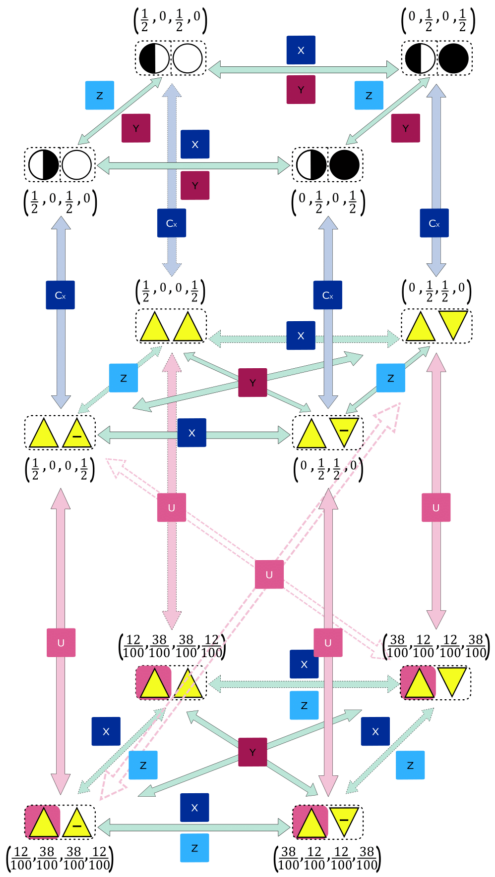

Figure 8: **Map of all operations allowed on entangled states with the U card, and the corresponding outcome probabilities for $\{\bigcirc\bigcirc, \bigcirc\bullet, \bullet\bigcirc, \bullet\bullet\}$.**

Advanced Measurement Rules

When measuring red or pink decorated entangled states:

- **Red-decorated:**
  - 1–25 $\rightarrow \bigcirc\bigcirc$, 26–50 $\rightarrow \bigcirc\bullet$
  - 51–75 $\rightarrow \bullet\bigcirc$, 76–100 $\rightarrow \bullet\bullet$
- **Pink-decorated (correlated:  , ):**
  - 1–12 $\rightarrow \bigcirc\bigcirc$, 13–50 $\rightarrow \bigcirc\bullet$
  - 51–88 $\rightarrow \bullet\bigcirc$, 89–100 $\rightarrow \bullet\bullet$
- **Pink-decorated (anti-correlated:  , ):**
  - 1–38 $\rightarrow \bigcirc\bigcirc$, 39–50 $\rightarrow \bigcirc\bullet$
  - 51–62 $\rightarrow \bullet\bigcirc$, 63–100 $\rightarrow \bullet\bullet$

S Expansion: The Third Basis

The S expansion introduces a new basis for single-tile states: $\{◓, ◒\}$, representing the mutually exclusive properties *up* and *down*. This new basis is preserved under the Y operation, just as $\{○, ●\}$ is preserved under Z, and $\{◐, ◑\}$ under X.

The S card allows players to switch between bases. The full structure of operations and transitions among the six tile types is shown in Fig. 9.

- X: flips between $◓ \leftrightarrow ◒$
- Y: also flips $◓ \leftrightarrow ◒$
- S: rotates among the three bases (W-B, L-R, U-D)

The new S expansion deck includes:

Card	S Expansion
I	5
X	10
Y	5
Z	10
H	12
C_X	10
U	9
S	7

To measure a ◓ or ◒ tile, roll a d100: 1–50 $\rightarrow$ ○; 51–100 $\rightarrow$ ●.

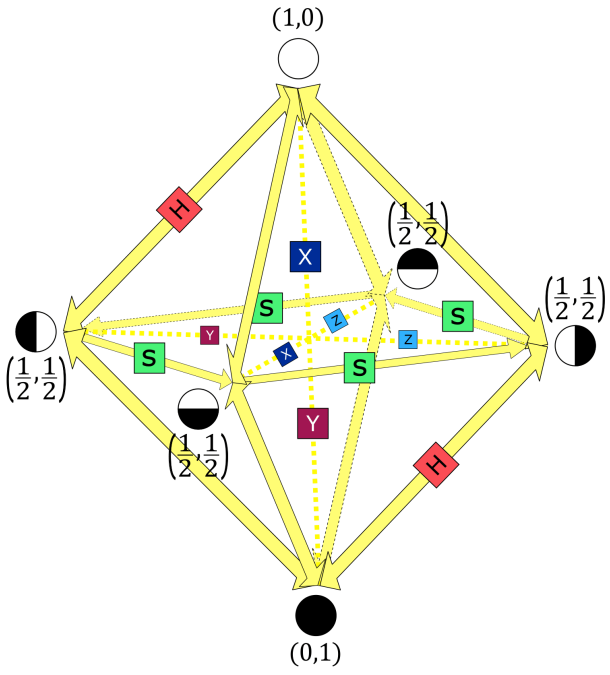

Figure 9: **Map of all single-tile operations X, Y, Z, H with S. In (x, y), the corresponding outcome probabilities for measuring ○ and ●.**

Game Variant: Eve (3 players)

In this cooperative variant, Alice and Bob play together trying to make as many qtris as possible, while Eve plays against them, trying to hinder their efforts. The game is played over several rounds and ends as soon as either team (Alice and Bob vs. Eve) reaches 3 points.

Game flow

- **Preparation:**
  - Fill the grid with valid tiles.
  - Deal 4 cards to each player.
  - Determine playing order by dice roll: the sequence must be **Alice–Eve–Bob**.
  - Mulligan: each player may discard and draw the same number of cards (max 3).
- **Operations phase:** Each player performs one turn, for 5 full rounds (15 turns total).
  - *Alice and Bob:* draw 1 card, play 1 card.
  - *Eve:* draw 2 cards. Then either:
    * Play 2 cards, or
    * Discard 2 cards and perform one measurement in a chosen basis (only once per game).
- **Measurement:** Perform grid measurement using standard or advanced rules.
- **Scoring:**
  - Alice and Bob score: **(number of qtris)** minus 1.
    Example: 3 qtris $\rightarrow$ 2 points.
  - Eve scores 1 point if Alice and Bob make fewer than 2 qtris.