Catch the Photon facilitator guide

Numbered wave cards for grades 6 to 8
Updated 14 November 2026

Players	2 tabletop; 1–2 in the browser
Time	about 10 minutes per game
Big idea	Waves add or cancel. Squared amplitude gives brightness; brightness divided by 64 gives detection probability for one photon.

Your job as the facilitator

You are the game guide. You do not need to be a quantum expert. Your job is to keep the game moving, read the rules out loud, and ask good questions. It is fine to say "Let's find out together."

What the game is about

Each player has a detector. Cards add wave amplitudes to either detector. In-step contributions reinforce; opposite phases subtract. Equal opposites cancel completely. After eight rounds, send photons until one is caught. Each new photon can reach A, reach B, or miss both detectors.

What you need

- 40 printed wave cards: seven strength-1 and three strength-2 cards per direction
- The Wave Board printable
- One blue token (Player A) and one purple token (Player B)
- An opaque cup and a stock of 32 blue A slips, 32 purple B slips and 64 gray missed slips. All slips must have identical size, shape and feel. Prepare exactly 64 slips for each finish; do not put the whole stock in the cup. Use identical opaque backs or sleeves for the wave cards.
- Optional: CatchThePhoton_Offline.html; use Solo quick play for a computer opponent

The four arrows represent four wave phases

Arrow and color	Wave	Moves the token
↑ Up · blue	starts at a crest (top)	1 or 2 squares up
↓ Down · red	starts at a trough (bottom)	1 or 2 squares down
→ Right · purple	starts at zero, rising	1 or 2 squares right
← Left · gold	starts at zero, falling	1 or 2 squares left

The arrow gives direction. The number gives amplitude and movement distance. ↑2 + ↓1 leaves ↑1; ↑2 + ↓2 cancels completely. Plots share the same amplitude scale and frequency.

Run the game, step by step

Say: “Make your detector bright and the other detector dark. Then send photons until one is caught. Gray means this photon missed both detectors.”

1. Put both tokens on START (brightness 0, dark). Shuffle. Deal 3 cards to each player.
2. Both players secretly choose one card and lay it face-down next to a detector: **your own** (to make it brighter) or **your opponent's** (to cancel it).
3. Reveal together. Resolve A’s card, then B’s. Move the chosen detector by the full number of squares in the arrow’s direction.
4. Refill to 3 cards. Play 8 rounds. If the draw pile runs out, reshuffle used cards.
5. **Prepare the cup.** Read each token’s brightness: put that many blue A slips and purple B slips in the cup. Fill the remaining places with gray missed slips so the total is exactly 64.
6. Draw without looking. Blue or purple wins. If gray, replace the slip, mix, and send a NEW photon with unchanged settings. Repeat until caught. If both brightnesses are 0, play another card round instead of starting the draw.

In the browser, “Fire the photon” shows the first attempt. If it misses, further attempts advance automatically with the same replacement probabilities. The screen reports photons sent, misses, per-photon chances and eventual win odds. “New game” or “Play again” cancels pending attempts.

At the edge: do not choose a move that leaves the board. If A’s move makes B’s committed move leave the board, B’s card is lost. Never shorten a 2-step move. If no card has a legal target, discard one.

Watch for these mistakes

- Ignoring the number: strength 2 moves two squares. It is not always better than strength 1.
- Moving the wrong token. The card moves the token of the detector it was played on.
- Adding the numbers on the board. The number is already the brightness; just read it.

Try this together

A total of 3 right and 4 up gives brightness 25: $3^2 + 4^2 = 5^2$. Use →1, →2, ↑2, ↑2, or the Wave Lab preset.

For brightnesses 25 and 9, use 25 blue, 9 purple and 30 gray slips. One photon has chances 25/64, 9/64 and 30/64. With gray replaced after every miss, the eventual winner odds are 25/34 for A and 9/34 for B.

Questions to ask

- When is it smart to play on your opponent's detector instead of your own?
- Why do equal ↑ and ↓ cards cancel? What remains after ↑2 + ↓1?
- A strength-2 wave from START is twice as tall as strength 1. How much brighter is it? (4 times: $2^2 = 4$.)
- If A has brightness 4 and B has 1, what are the chances for one photon? (A: 4/64; B: 1/64; missed: 59/64.) Among detections, who wins? (A: 4/5 = 80%; B: 1/5 = 20%.) Can A still lose?

The science words

In the game	The real idea
Arrow and number	Phase and amplitude: wave starting point and strength
Waves adding up or canceling	Interference
Number on the square	Brightness = amplitude^2; divide by 64 for this detector's per-photon probability
The 64 slips in the cup	Blue = A brightness; purple = B brightness; gray = the remainder. Replace gray after a miss.

A physical detection setup: an ideal one-photon source feeds a 50:50 splitter. Each branch has an independently adjustable loss channel and an ideal detector. Set each branch transmission to its detector brightness divided by 32. Including the splitter's 1/2 branch probability gives brightness divided by 64 at that detector. The remaining photons leave through loss channels without detection at A or B. Both detectors can brighten as losses decrease.

The cards calculate wave contributions whose squared amplitude sets the transmission. This reproduces the final detection probabilities; cards are not literal optical paths or physical gates. The board does not model detailed interferometer dynamics. Interference can redirect light; cancellation alone does not prove absorption. The arrows describe wave phase on the amplitude board, not photon travel. Real phases are continuous; the cards use four.

Why 64 works: each coordinate runs from −4 to +4, so brightness $x^2 + y^2$ is at most 32 per detector and at most 64 in total. Per photon, P(A) = A brightness / 64, P(B) = B brightness / 64 and P(missed) = (64 − A brightness − B brightness) / 64. With positive total brightness, eventual winner odds divide each brightness by that total. At zero total brightness, every photon would miss.

Wrap up

Say: “Quantum computers use interference to change measurement probabilities. Our cards change wave contributions and the chances of detection. A single photon can miss both detectors. We send a new photon after a miss; a good strategy can still lose.”