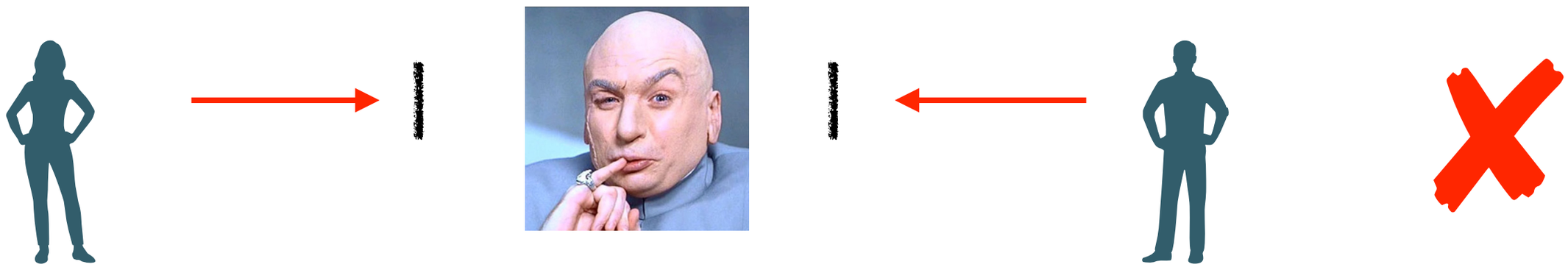
Quantum spooks

Cryptography

- “Lets have lunch at one”
- Simple encryption
  - “ohwv kdyh oxfk dw rqh”
- Cryptography:
  - encrypt message ➔ send ➔ decrypt message

What is cryptography ***not*** useful for?

Messages blocked



Messages never intercepted

What is cryptography useful for?

- Sending a message that even if intercepted (copied) cannot be understood (read)

Cryptography

- ***Huge*** industry, everything from iMessage to Amazon purchases to banking
- Almost every online communication is now encrypted

encrypt message → send → decrypt message

Cryptography classes

A) Encrypted by some cypher or key

- Always breakable given enough computation
- (quantum computers will be very good at some common cyphers)

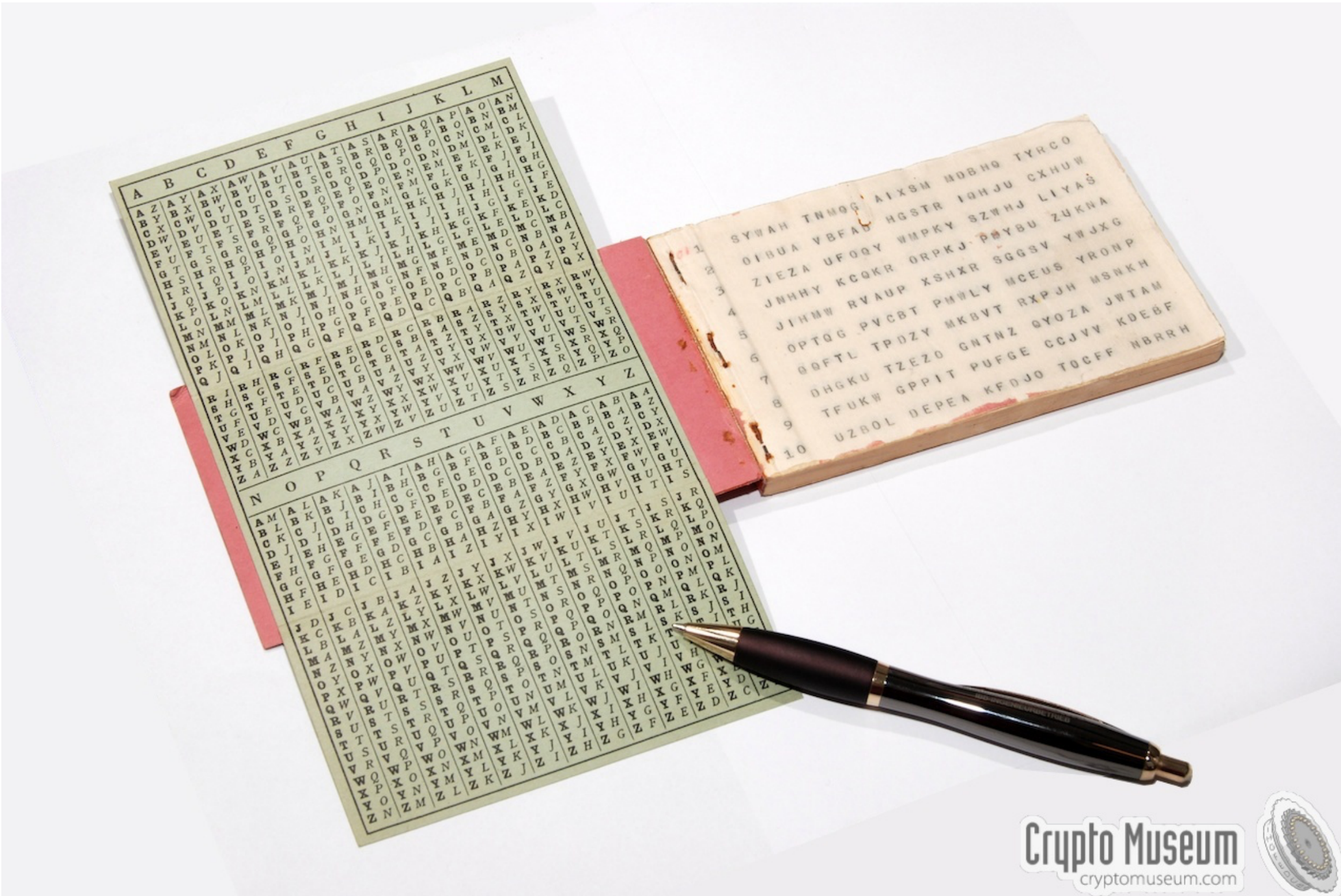
B) Encrypted by a random number as long as the message (one time pad)

- Unbreakable*

One time pad

- “Lets have lunch at one”
- Random number (key) as long as the message
  - 15200921533028242658 2
- mjvs qcwjcouppbevftwg
- Unbreakable unless VBM has a copy of the key

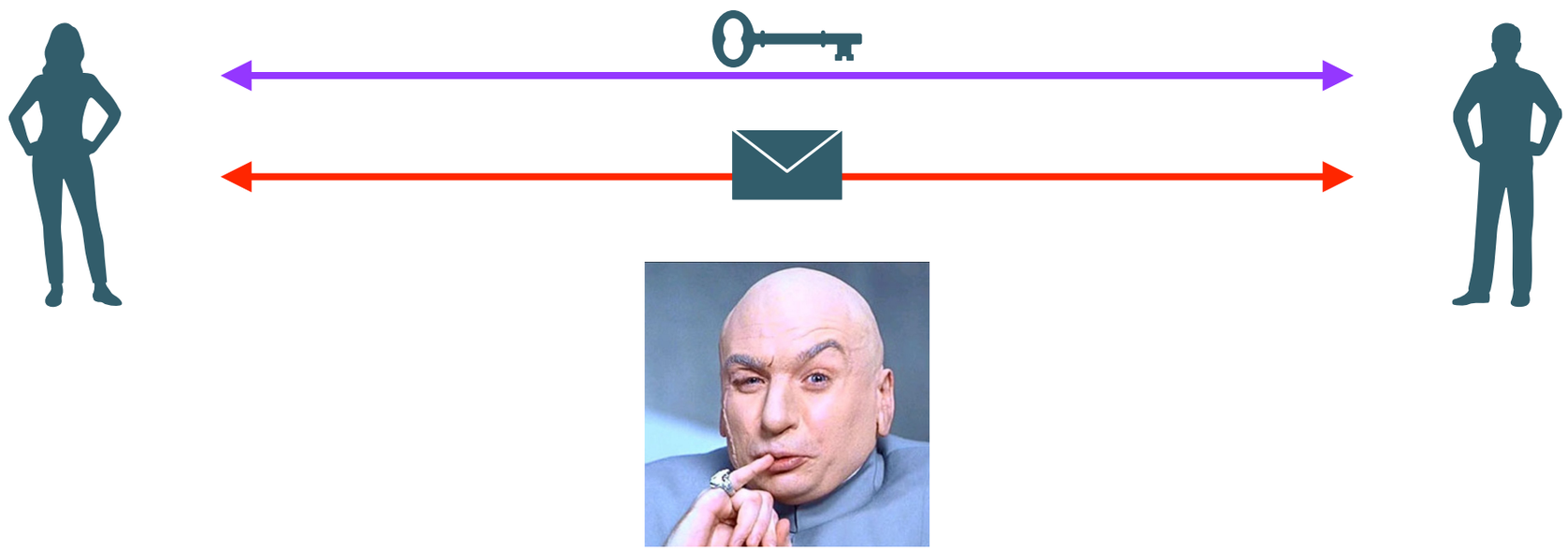
One time pad



One time pad

- Breakable only if the key is intercepted and copied

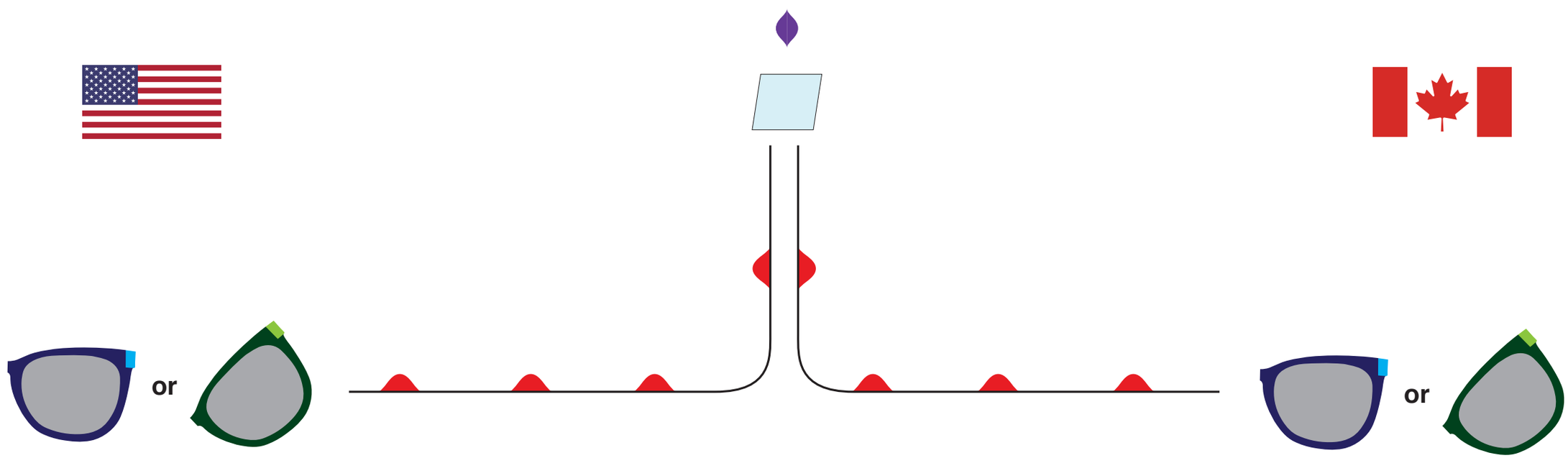
Modern cryptography



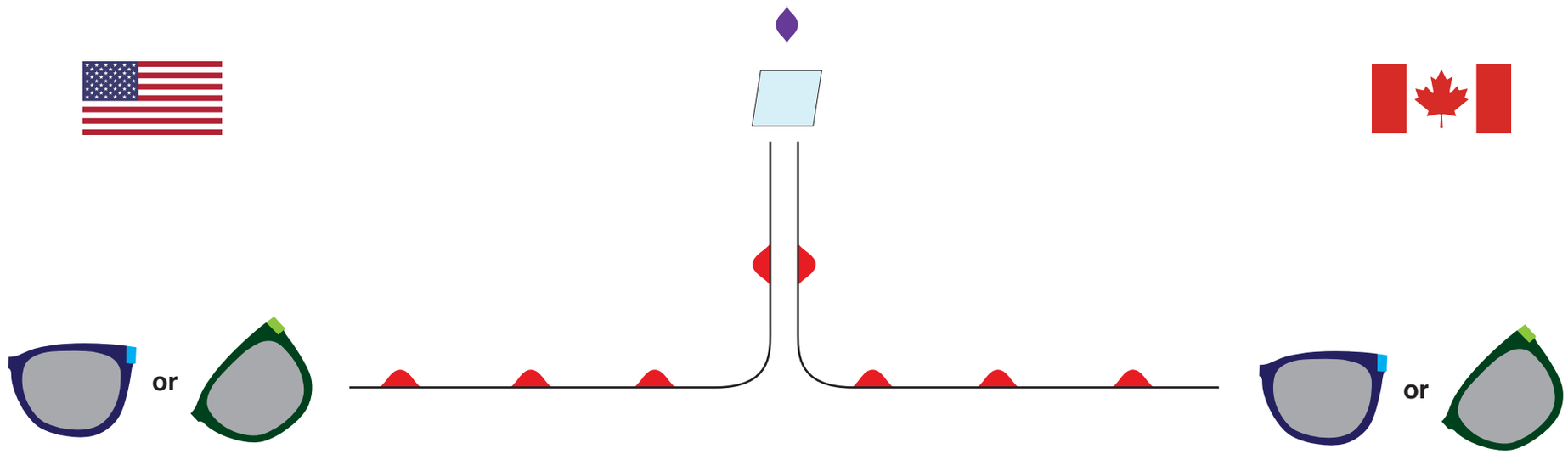
- Use one time pad for messages (long random key, unbreakable)
- Protect <u>key</u> from being copied

Quantum cryptography

Twinned photons



- It is possible to split one photon into two ‘twins’
- Twin photons have the same polarization



	→														
0	1	0	0	1	1	0	0	0	0	1	0	1	1	0	0
	→														
0	1	0	0	1	1	0	0	0	0	1	0	1	1	0	0

Same random (deterministic)

	→														
0	0	0	1	0	0	1	0	1	1	0	1	0	0	1	1
	→														
1	0	0	1	1	0	0	1	0	1	1	1	0	0	0	1

Different random

Terms of entanglement

- Twin knows what happens ***instantly***
- So weird
- Fundamental feature of how our world works

		→														
	0	1	0	0	1	1	0	0	0	0	1	0	1	1	0	0
		→														
	0	1	0	0	1	1	0	0	0	0	1	0	1	1	0	0

Same random (deterministic)

		→														
	0	0	0	1	0	0	1	0	1	1	0	1	0	0	1	1
		→														
	1	0	0	1	1	0	0	1	0	1	1	1	0	0	0	1

Different random

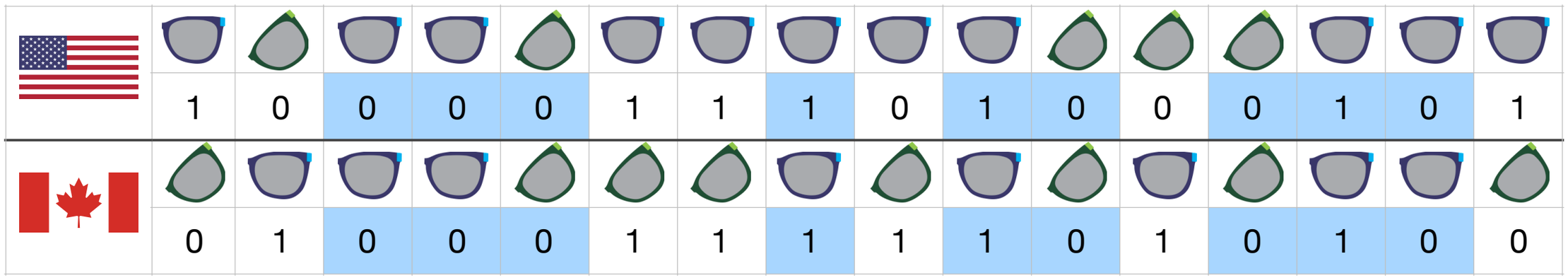
Looks like a key

		→														
	0	1	0	0	1	1	0	0	0	0	1	0	1	1	0	0
		→														
	0	1	0	0	1	1	0	0	0	0	1	0	1	1	0	0

Same random (deterministic)

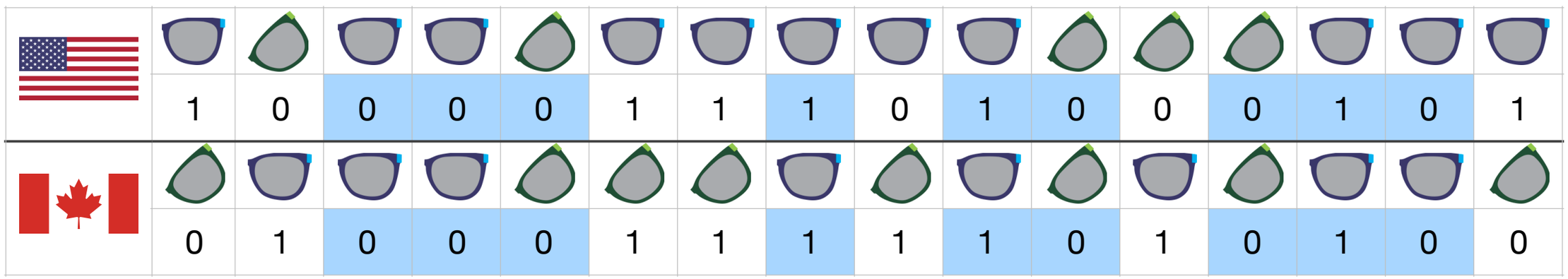
- But VBM could intercept the key

Protecting against the VBM



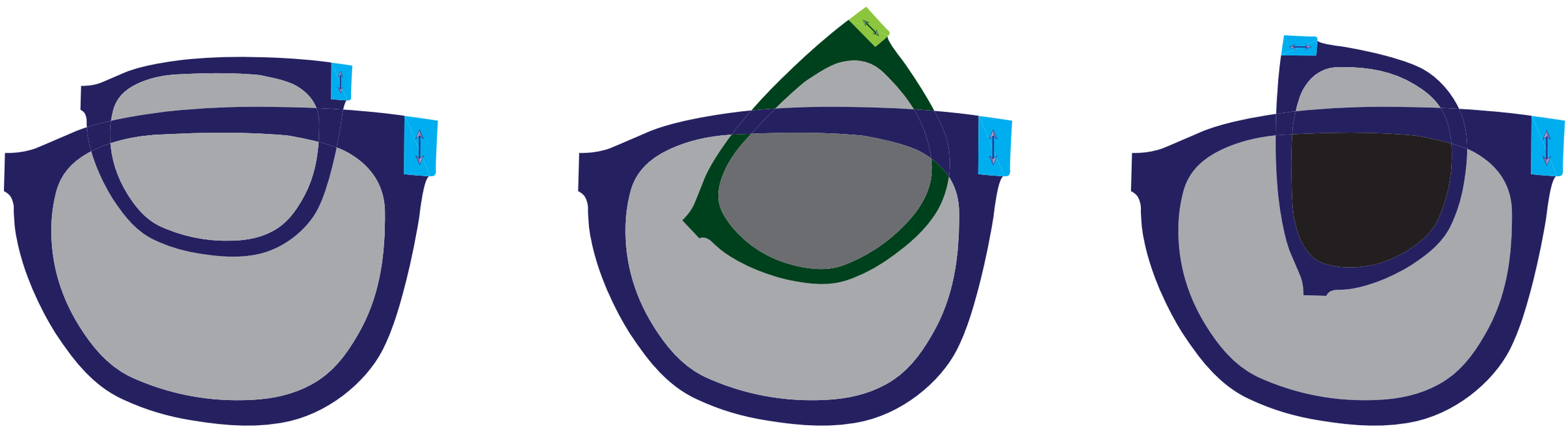
- Send twinned photons
- Randomly choose set (blue vs. green frames)
- Later publicly say which frame you used for each photon (but not what you saw)
  - Only keep photons where you happened to pick glasses from the same set

Protecting against the VBM



- Lastly, share a small part of the key
- If VBM cut fiber, he had to guess which set you would use.
  - VBM guesses wrong 1/2 the time, when he does friends see different answers 1/2 the time (becomes random)
- Can tell if the key was intercepted

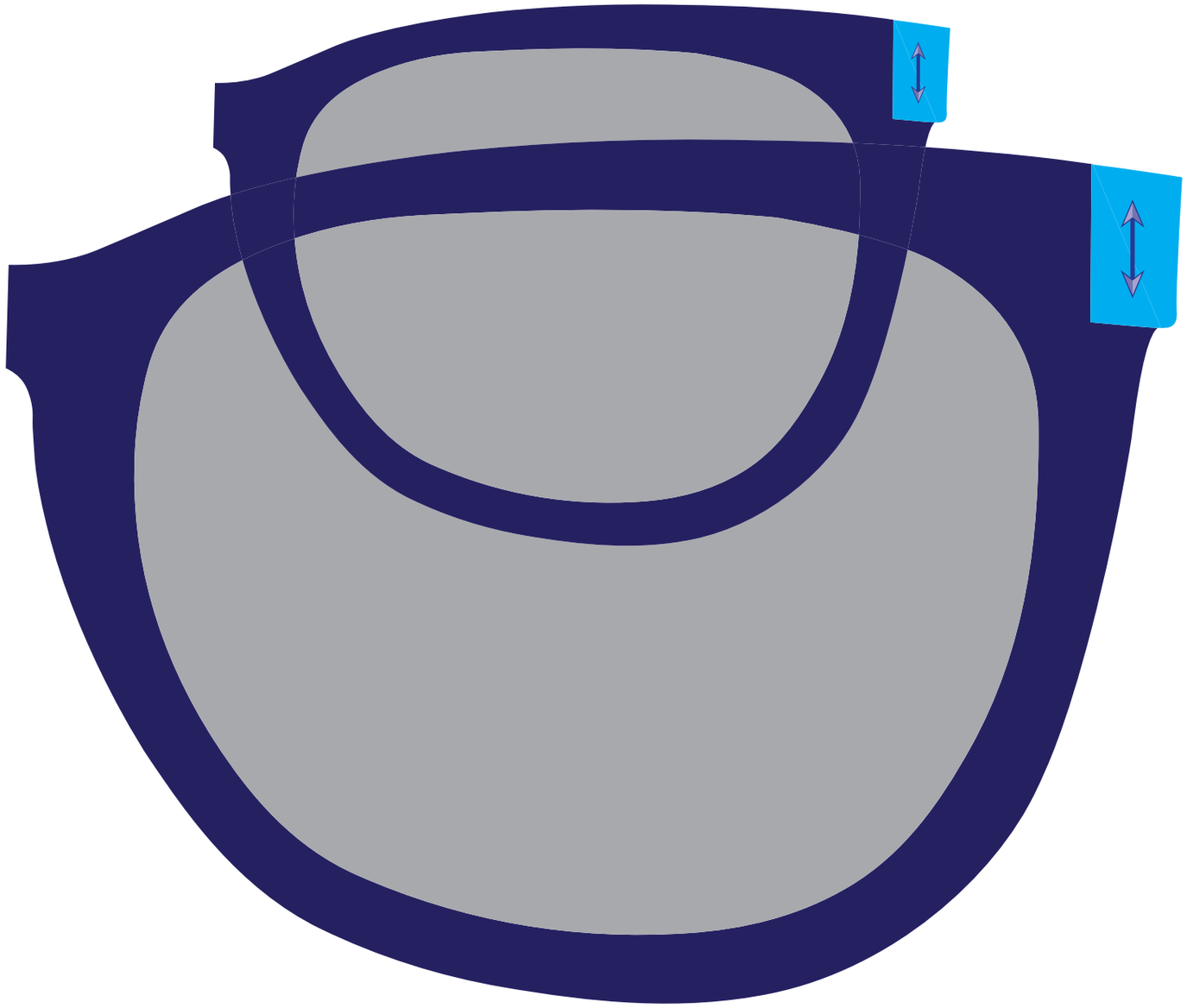
Sunglasses



Two glasses

- Half of the unpolarized light (background) makes it through the rearmost glasses. Only vertically polarized light makes it through.

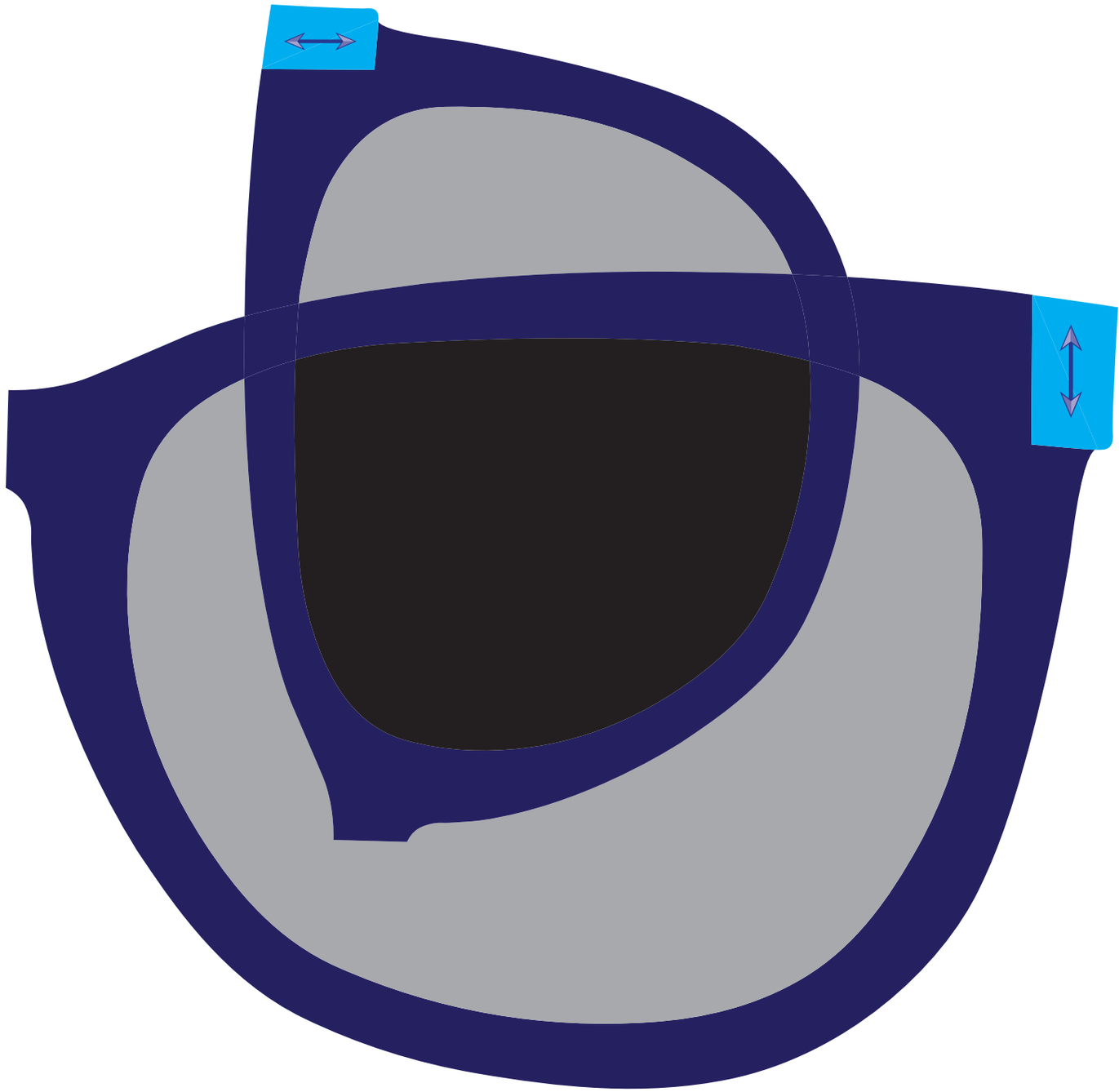
- Since forward glasses only let vertical polarization through, all the light that got through the first pair make it through the second.



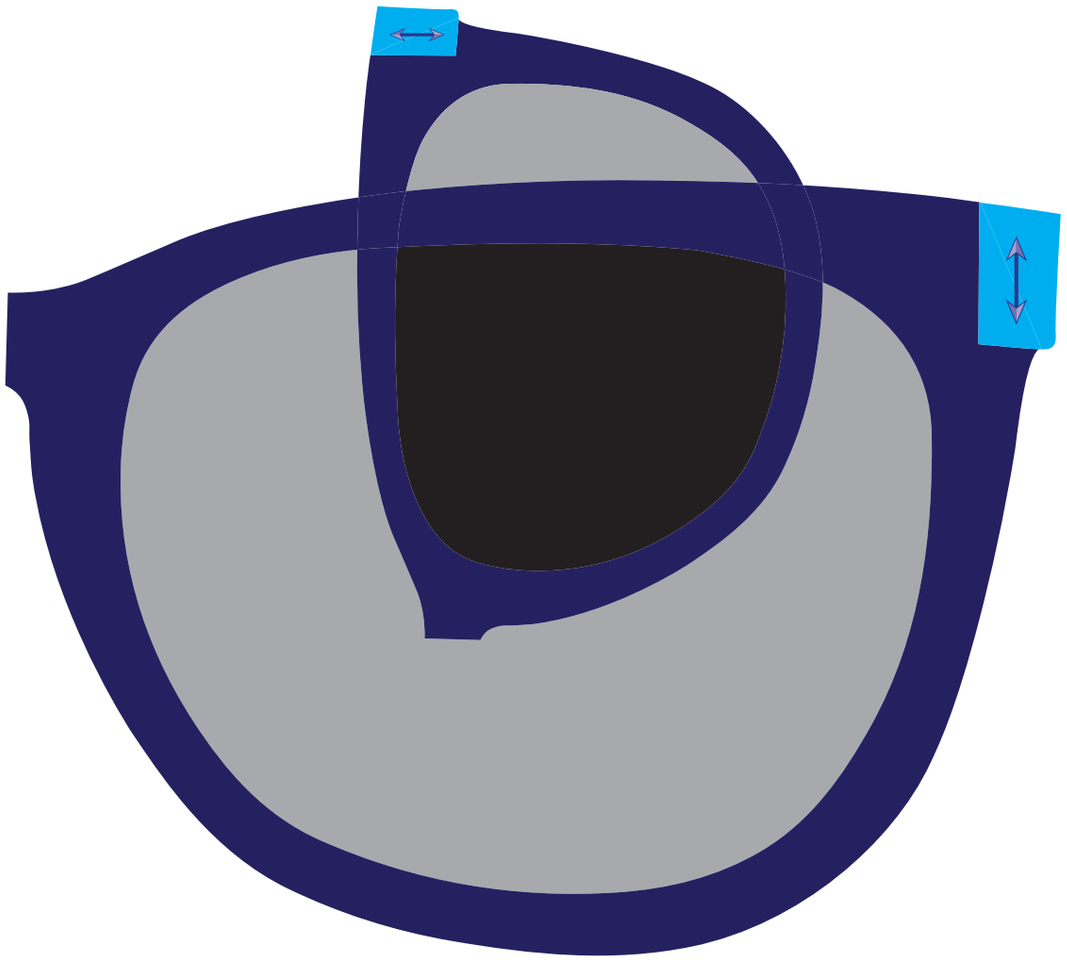
Two glasses

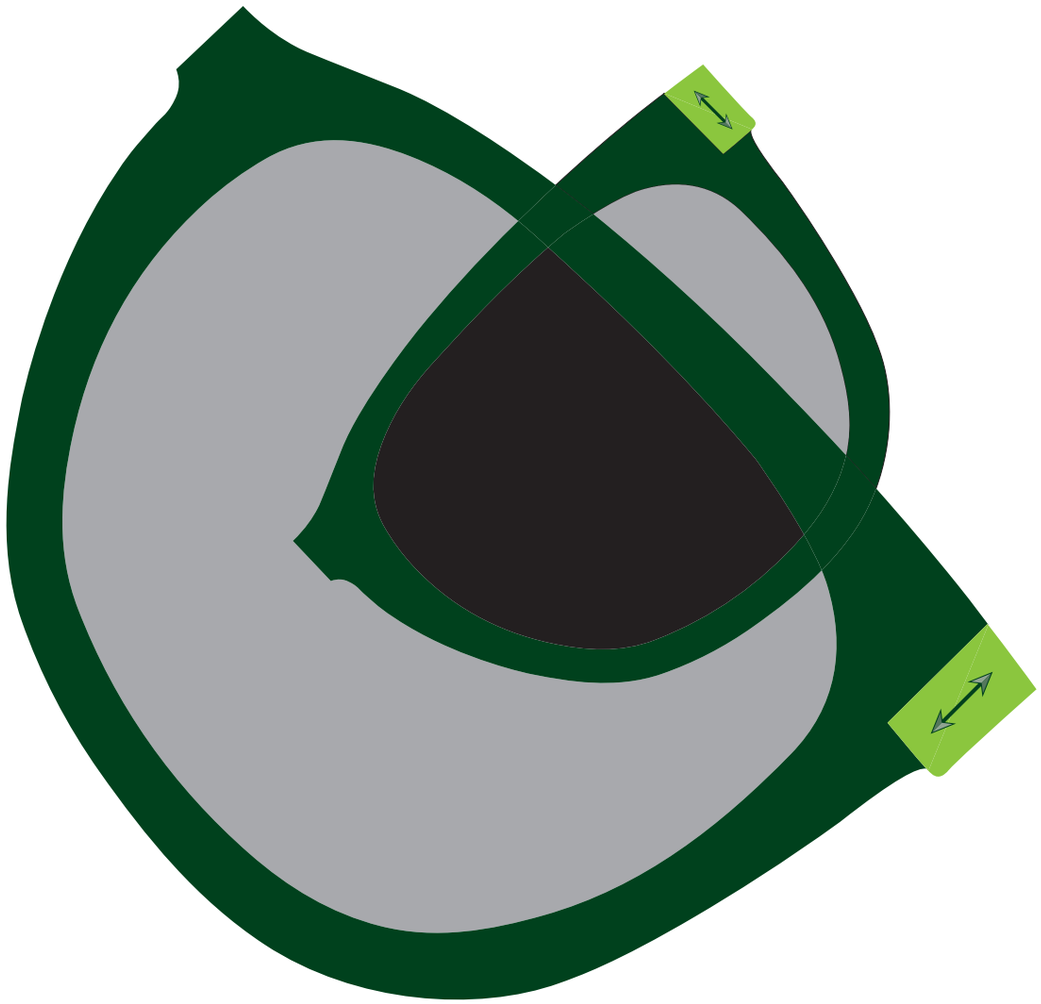
- Half of the unpolarized light (background) makes it through the rearmost glasses. Only horizontally polarized light makes it through.

- Since forward glasses only let vertical polarization through, all the light that got through the first pair is blocked by the second pair.

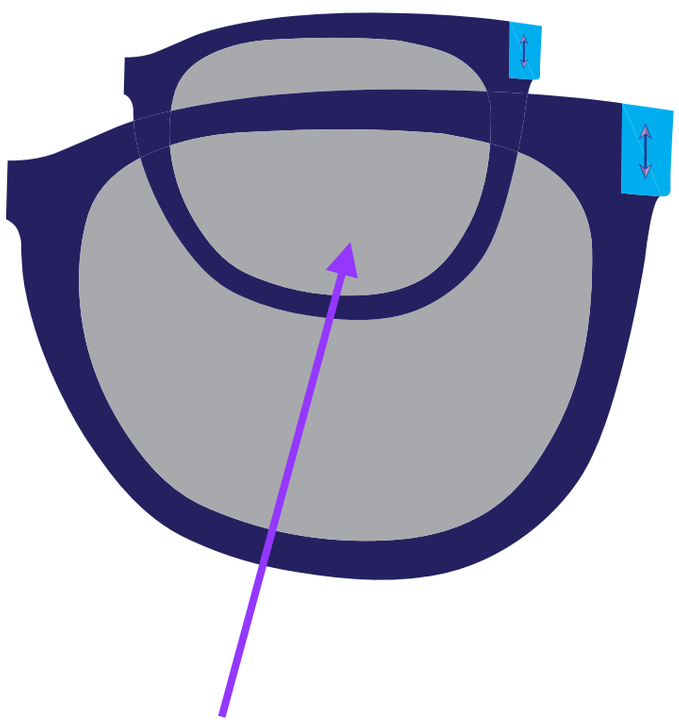


Only relative orientation matters

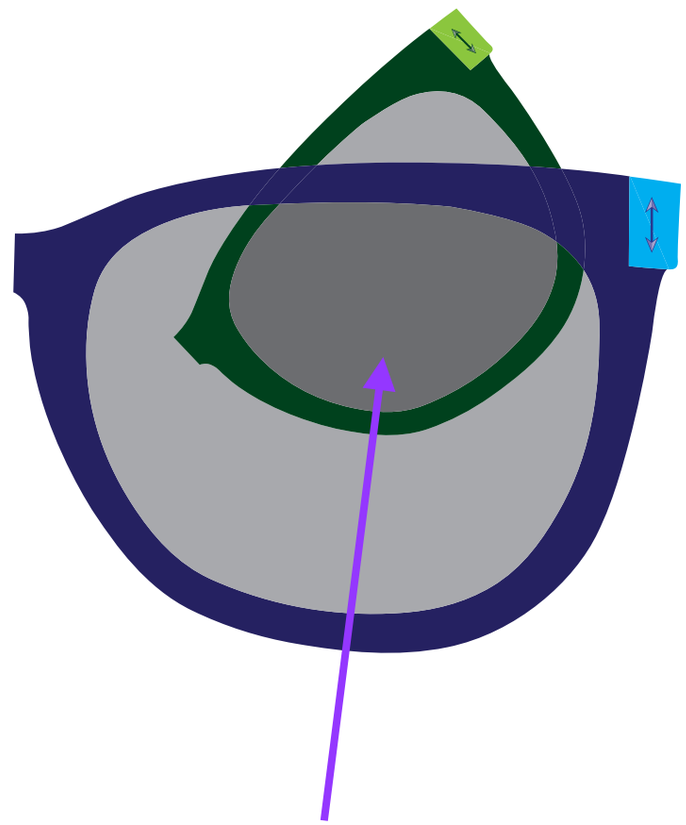




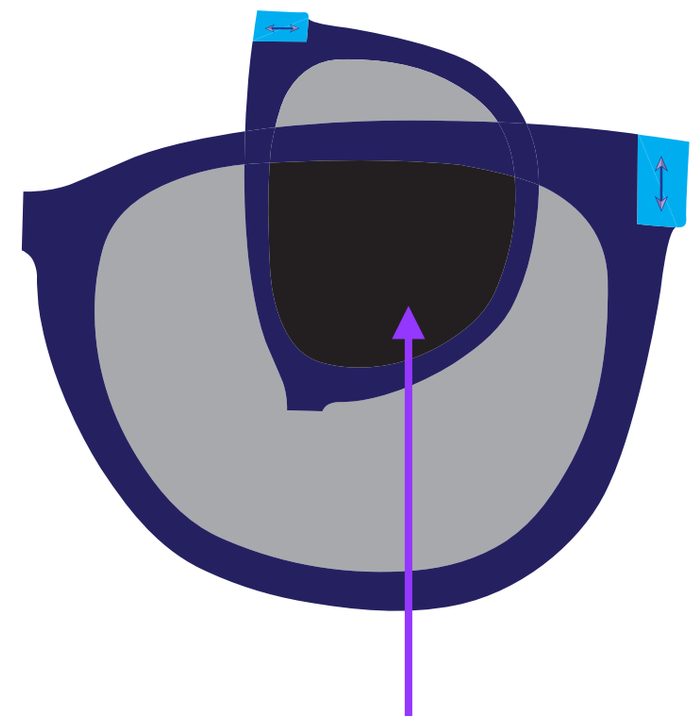
Mixing sets



1/2 * all = 1/2



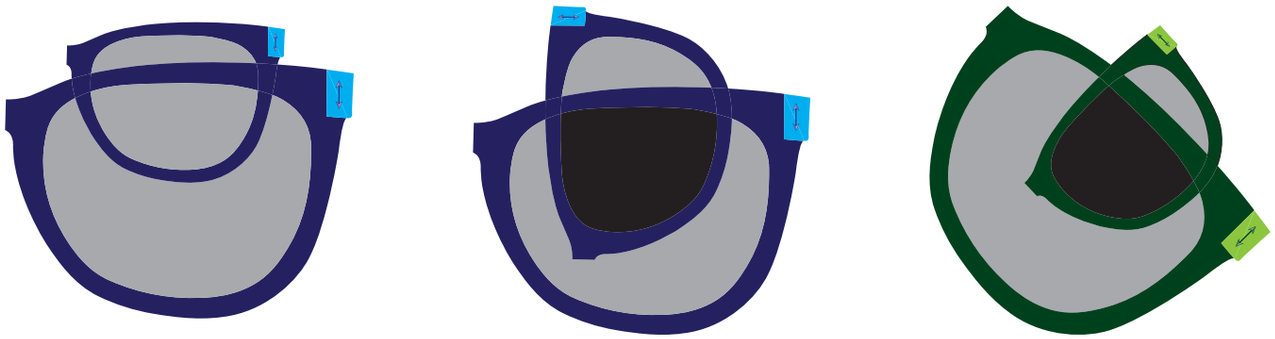
1/2 * 1/2 = 1/4



1/2 * none = 0

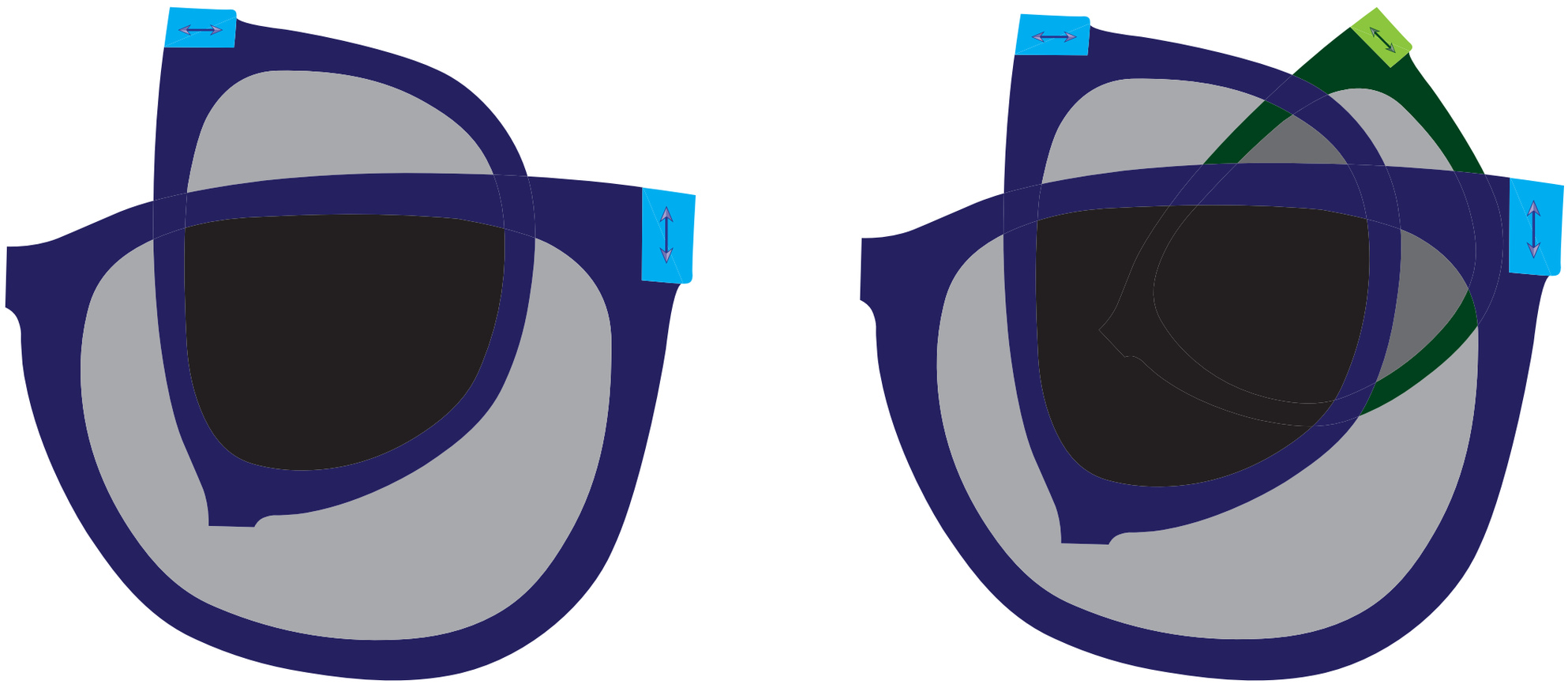
Mixing sets

- Two glasses of the same ‘set’ (frame color) gives either all of light through the first or none.

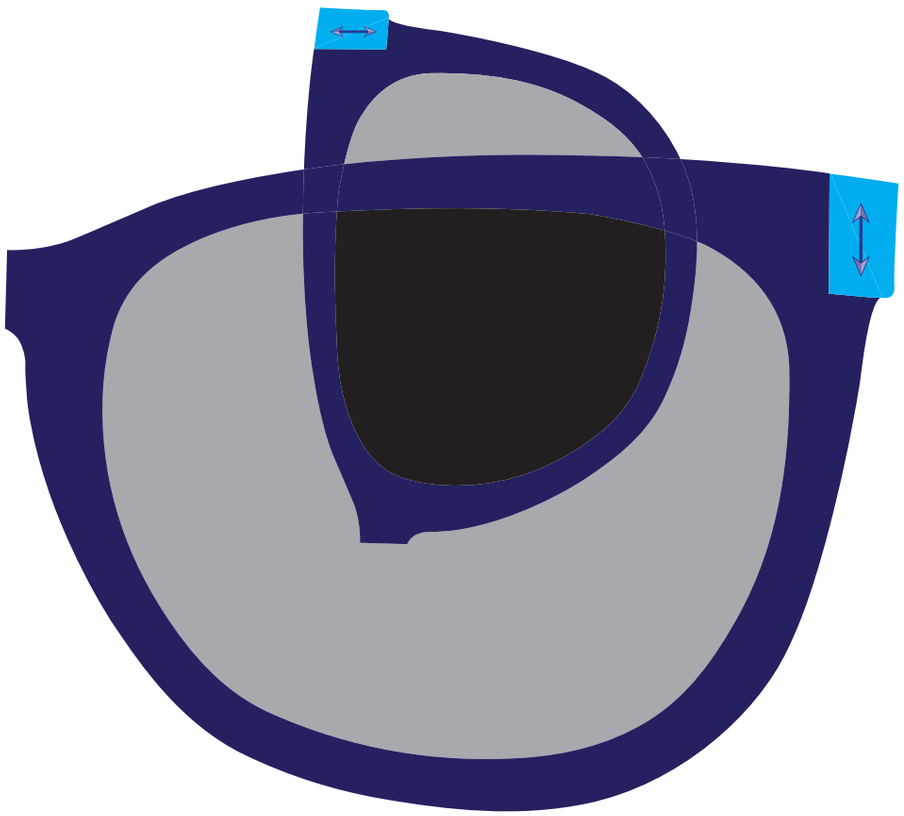


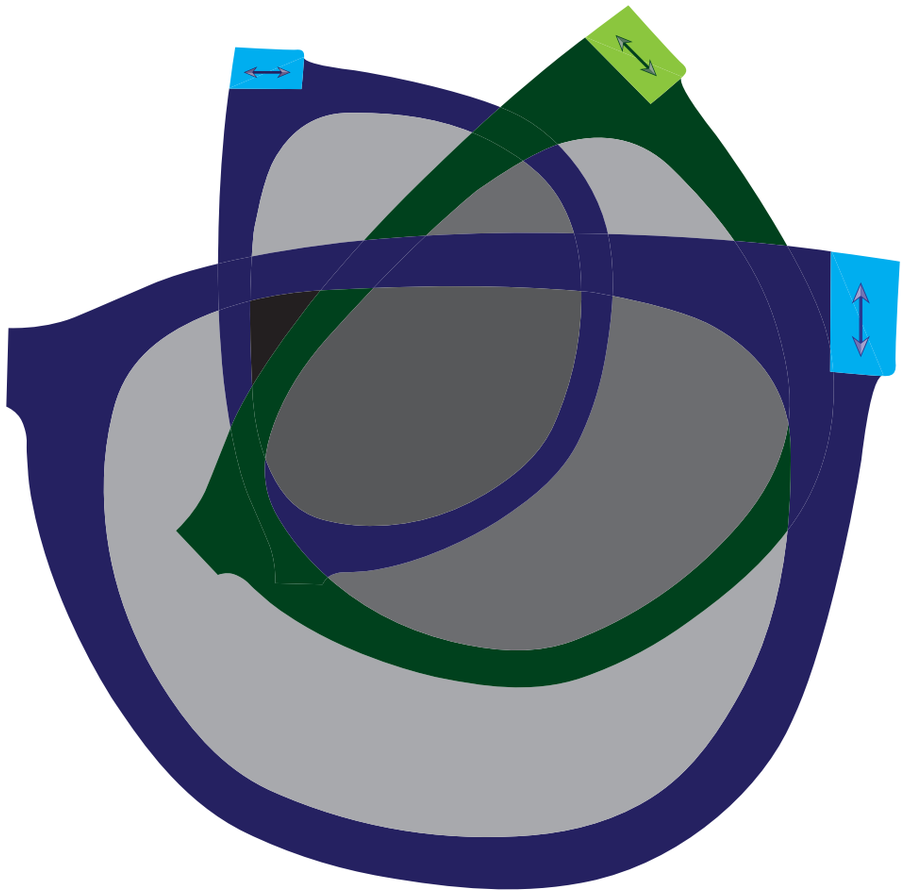
- Two glasses from different sets always gives 1/2 of light through the first pair.

Adding a third pair of glasses

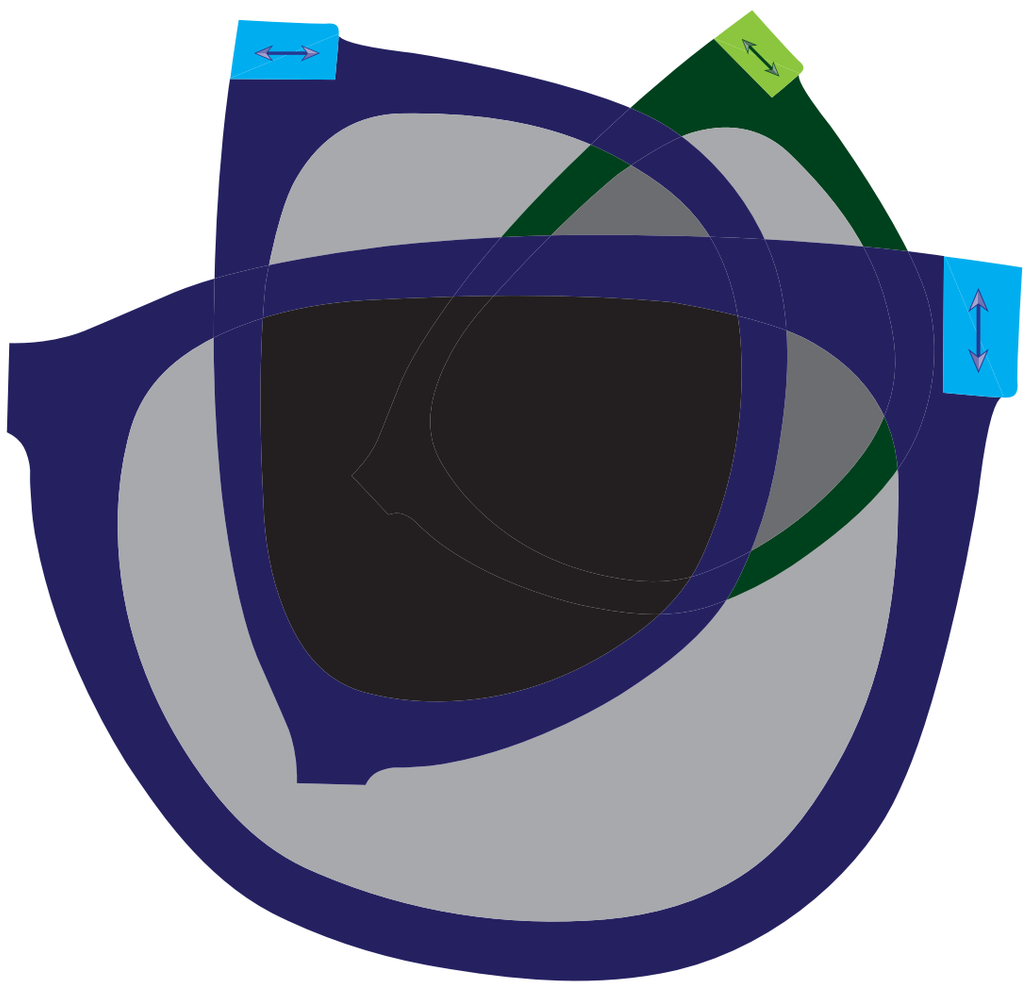


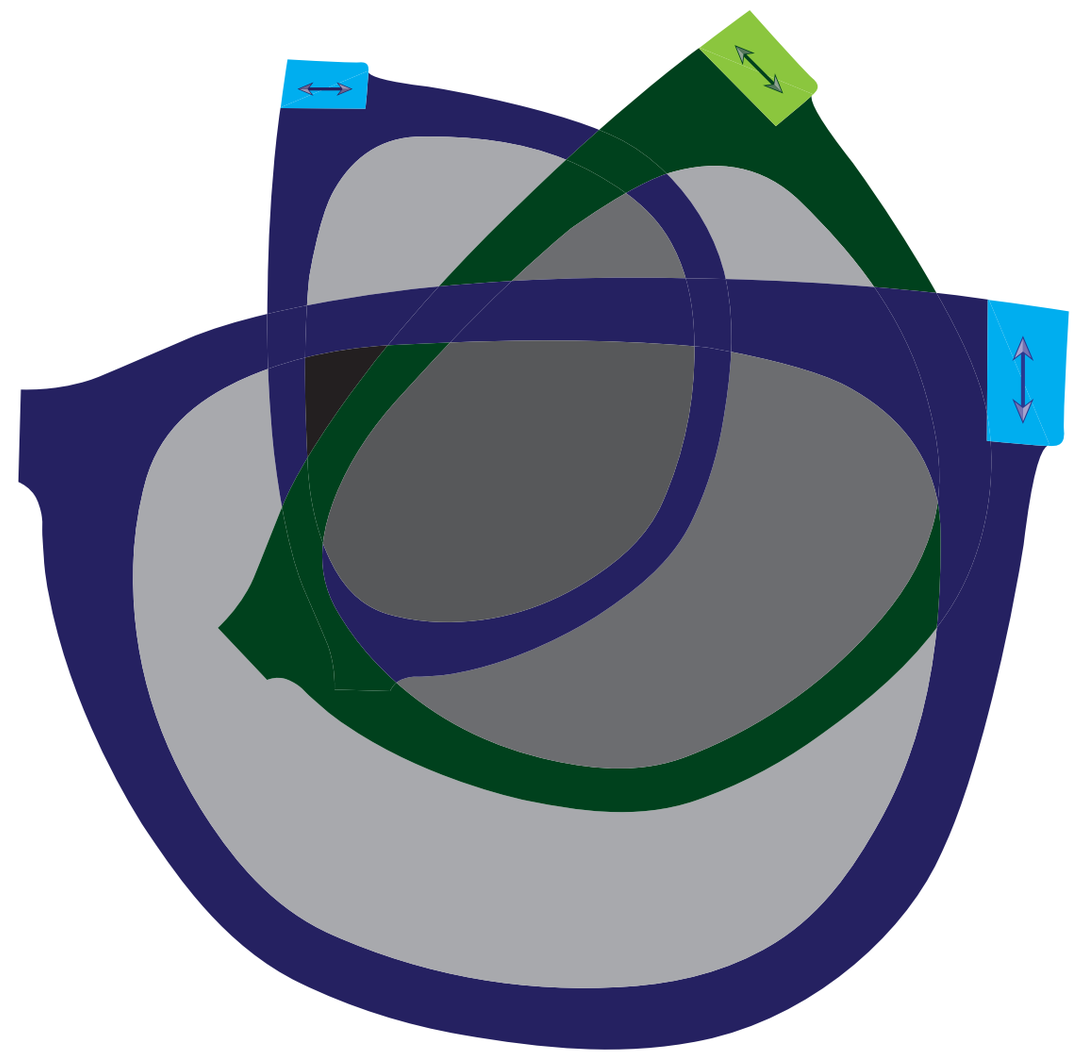
Adding a third pair of glasses





Order matters!

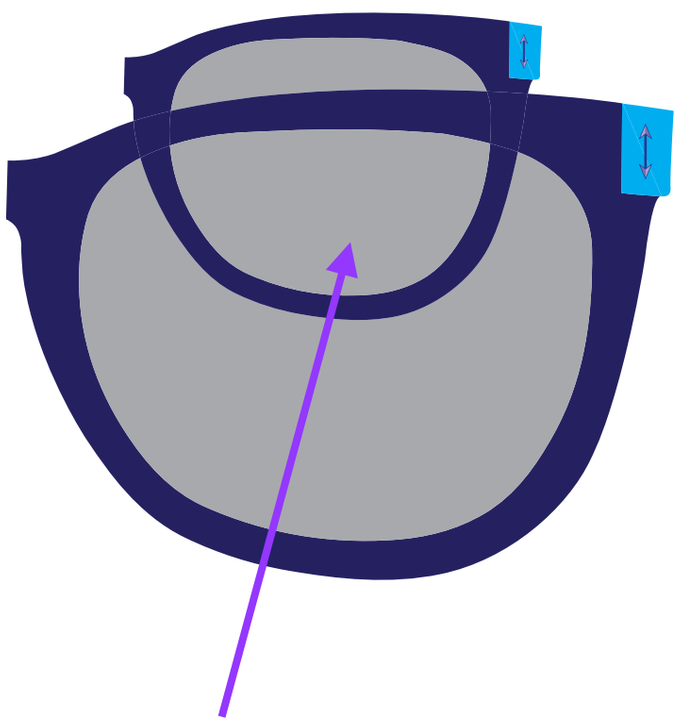




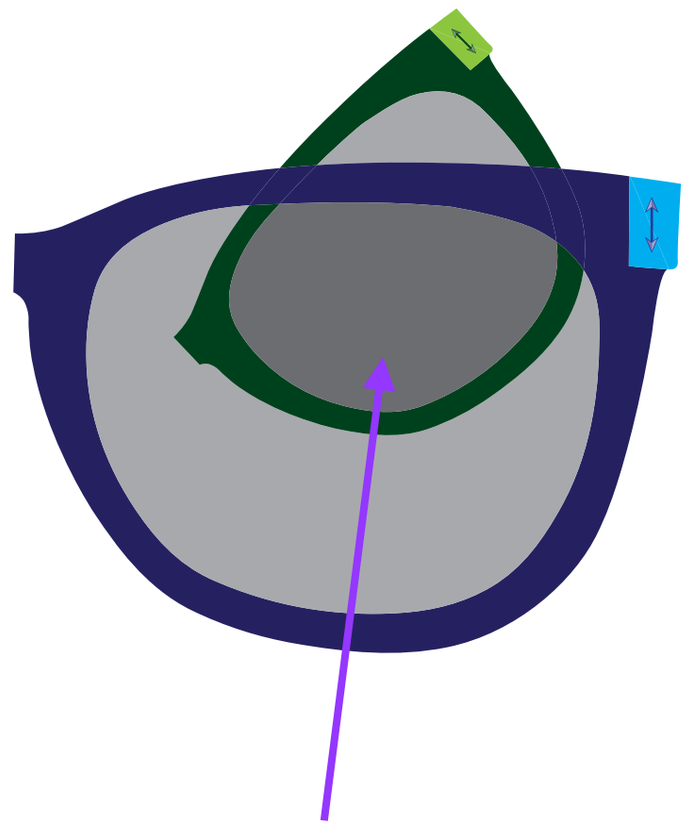
Wearing sunglasses at night

Diane Knutson,
International Dark-Sky
Association

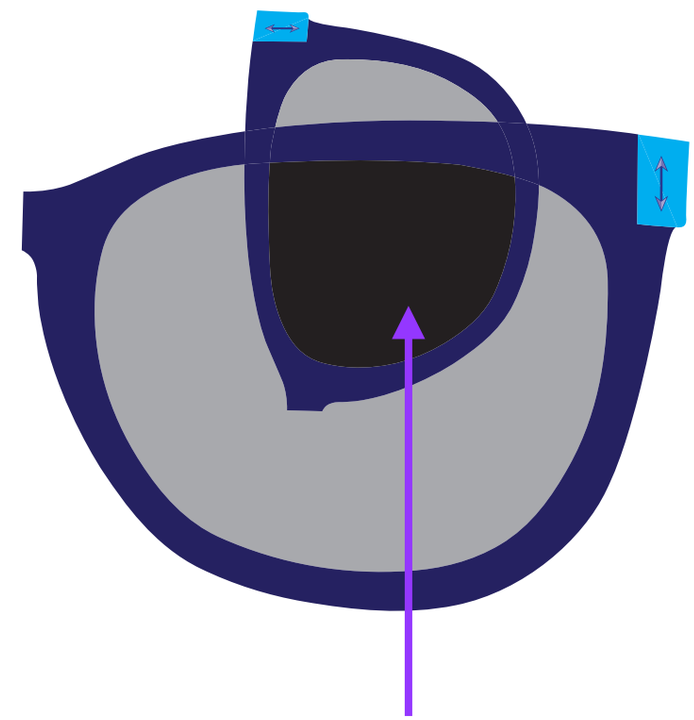
Fraction of photons making it through



1/2 * all = 1/2

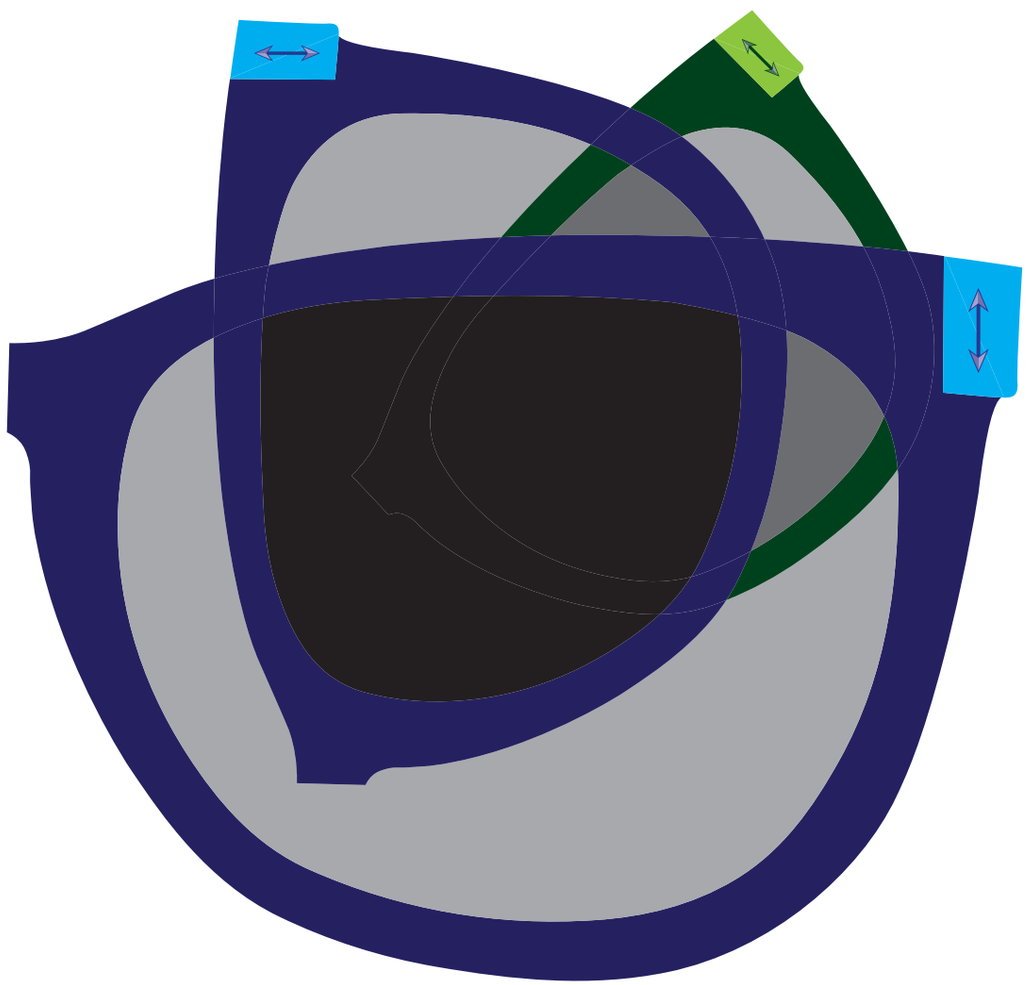


1/2 * 1/2 = 1/4

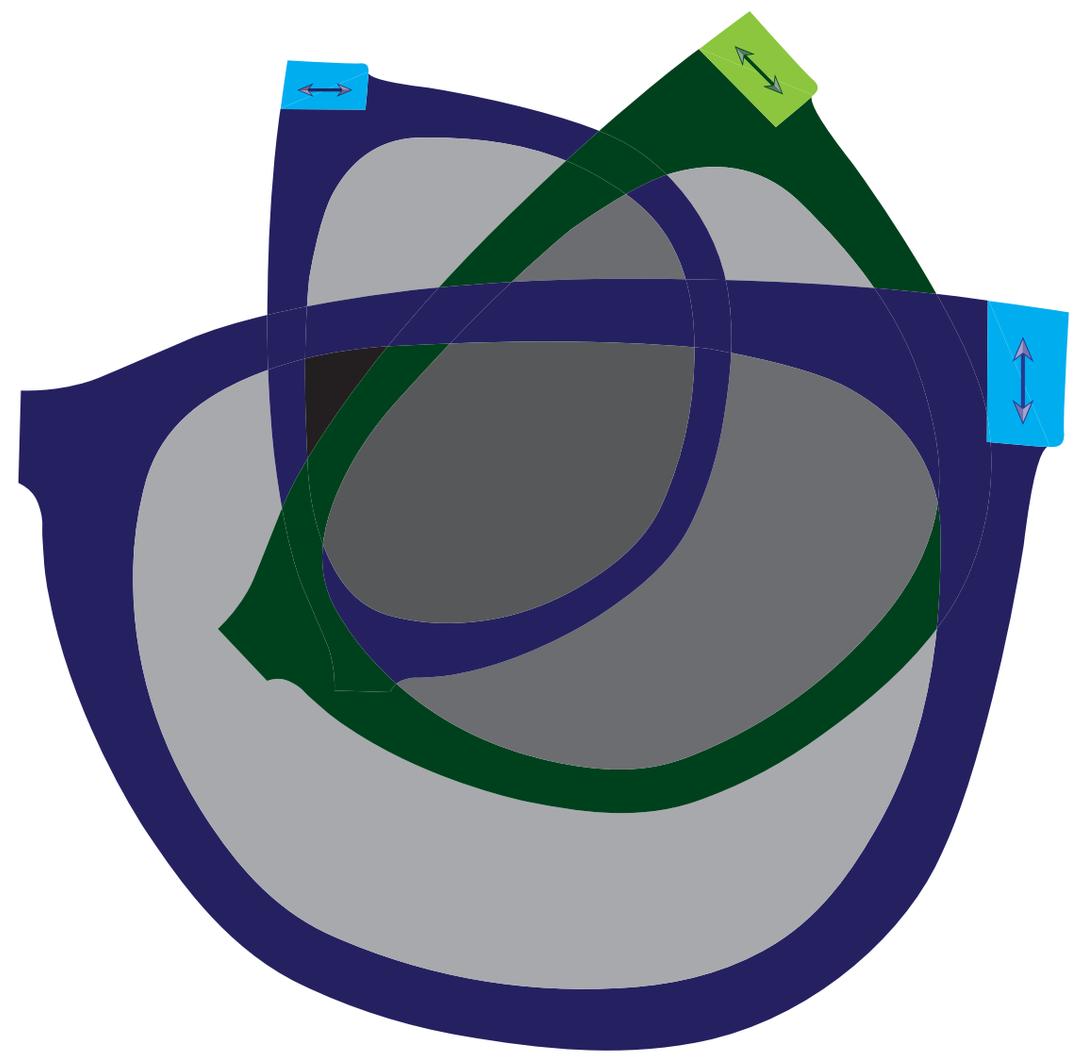


1/2 * none = 0

Fraction of photons making it through



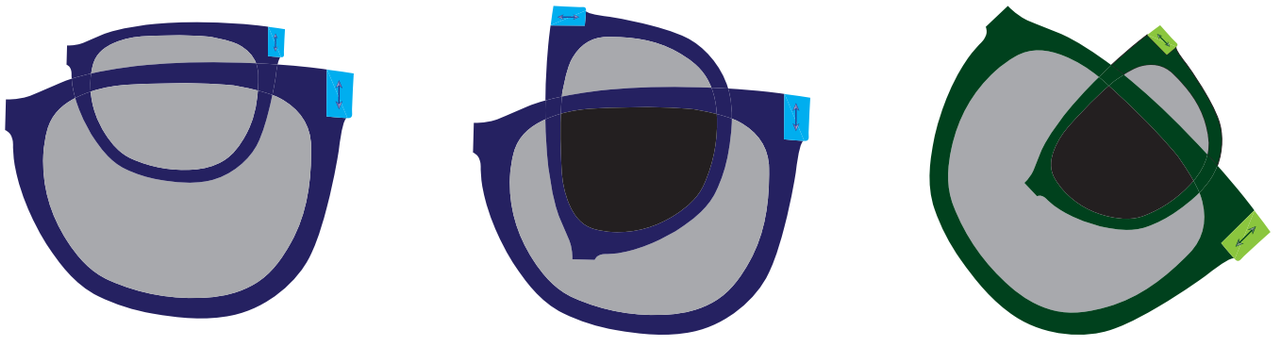
1/2 * 1/2 * none = 0



1/2 * 1/2 * 1/2 = 1/8

Deterministic or Random

- If two glasses from the same set (frame color), whether a photon makes it through the next pair is deterministic (all or none)



- If two glasses from different sets, probability of photon making it through the second pair is *random* (always 50-50)

Deterministic and random

- We’ve made two sets of glasses (green or blue frame color) that are internally deterministic but mutually random.

- A ***deep*** feature of quantum mechanics