QUANTUM CRYPTOGRAPHY

Learning Goals

- Predict outcome of quantum (simple) polarization measurements
- Describe BB84 quantum crypto protocol and why it is secure

Announcements

Exit Tickets

Secret Key Cryptography

Problem: How to share secret key?!

Current Solution:

Looming Problem:

When one door closes, another door opens

door → Public Key Crypto

door → Quantum Crypto Protocol

To do quantum crypto, need quantum particles:

photons ⇒ individual particles of light

Polarizer Demo: If insert diagonal filter between horizontal and vertical polarizers, how much light will come through?

A. Same as no diag.

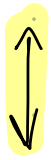
B. Less than Single filter

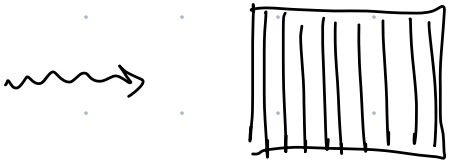
C. Same as single filter

D. More than single filter

Photons + Polarizers

vertical polarized





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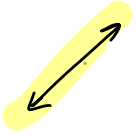
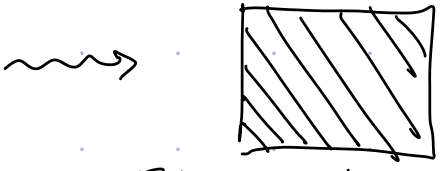
Filter with same polarization

diagonally polarized





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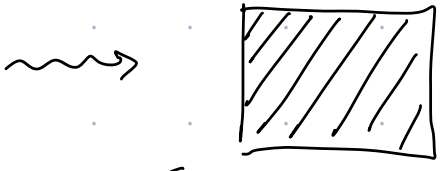
Filter with perpendicular polarization

horizontally polarized



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Filter with 45° polarization

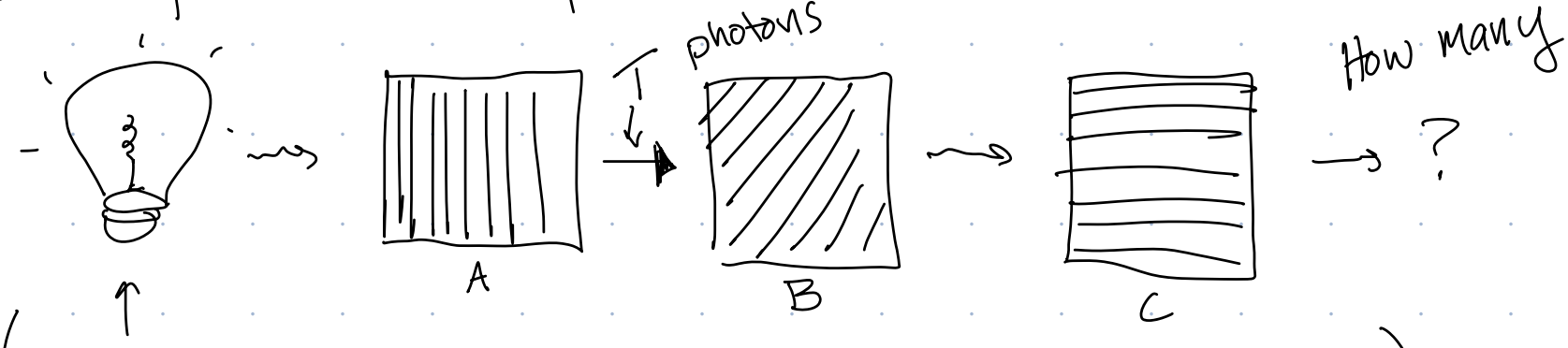
★ Behavior only depends on angle between photon polarization + polarizer

✓ Exiting photons have same polarization as filter

Group Work:

Q: Name, pronouns (optional), what kind of group problem solver are you?

Q. Explain our experiment:



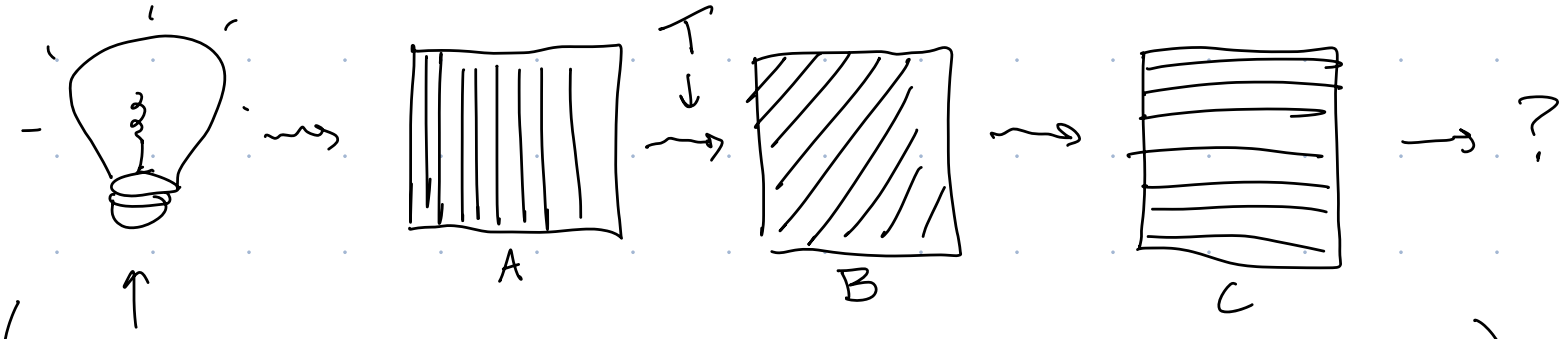
(lamp emits each photon with random polarization)

- What polarization(s) do exiting photons have?
- If T photons hit polarizer B, how many photons exit polarizer C?

(Learning target QI1 → Foundational)

Q:

Explain our experiment:



(lamp emits each photon with random polarization)

- What polarization(s) do exiting photons have?
- If T photons hit polarizer B, how many photons/sec exit polarizer C (on average)?

Quantum Crypto (BB84)

0.

	a (basis bit)	b (info bit)	photon	qubit state
vert	0	0		
hor	0	1		
diag	1	0		
diag	1	1		

1. Alice chooses $a, b \in \{0,1\}^L$ ← Large number randomly.

c (measurement basis bit)	Measurement	Measurement basis
0		
1		

2. Bob chooses $c \in \{0,1\}^L$ randomly

3.

ex:	Round 1 2 3 --	1st Photon	2nd Photon
a=			
b=			
c=			
d=			

Q: If $a_i = c_i$ then

A) $b_i = d_i$ B) $b_i \neq d_i$ C) $b_i = d_i$ ½ the time

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4.

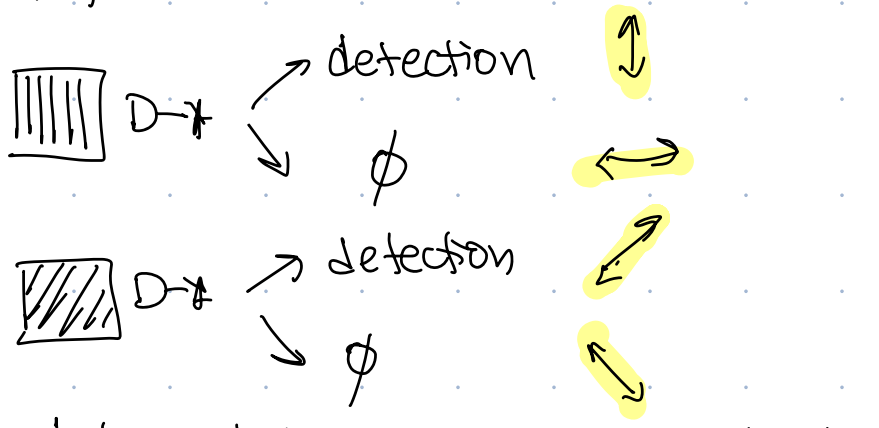
5.

What about Eve?? (She knows protocol, just not particular choices of a, b, c)

Possible strategy for Eve:

- Chooses $e \in \{0, 1, 2\}^L$ at random

$$e = \begin{cases} 0 \\ 1 \\ 2 \end{cases}$$



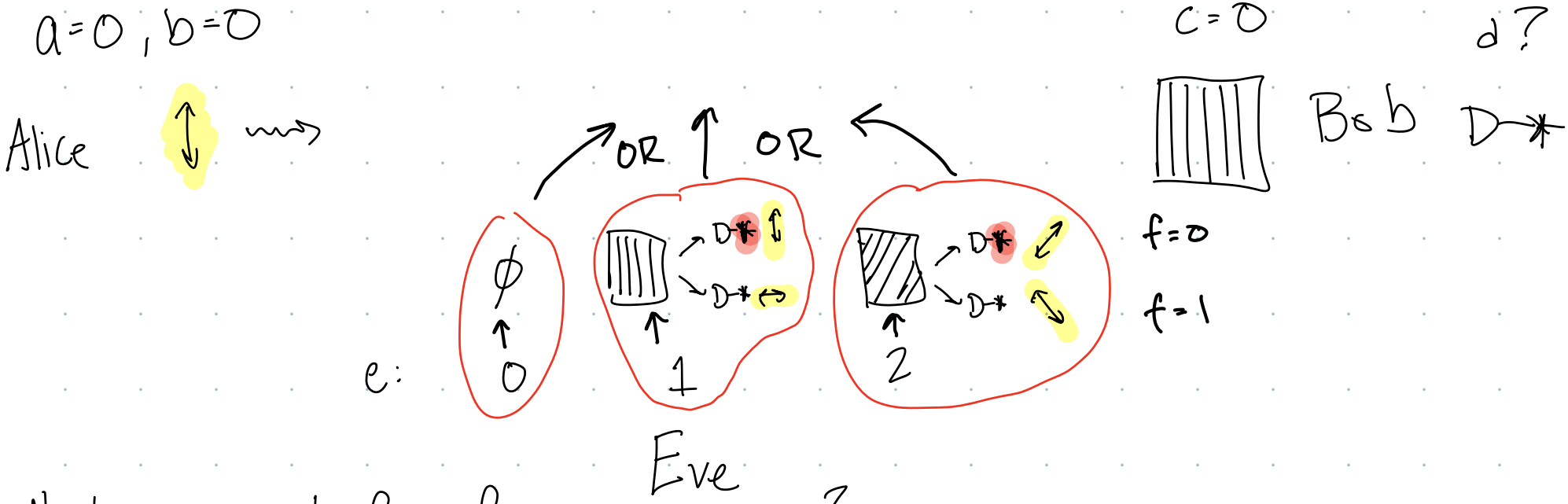
lets photon pass undisturbed

- Records $f = \begin{cases} 0 & \text{detection} \\ 1 & \text{no detection} \\ 2 & \text{no measurement} \end{cases}$

* Has to make their choice before a, c announced.

Ice breaker: what clubs/sports/activities do you do?

$a=0, b=0$ $c=0$ d?



- What are d, f for each e?
- What does Eve learn about key?
- How does Eve's action affect key?
- Other cases where $a = c$?
- Why don't we care about cases where $a \neq c$?

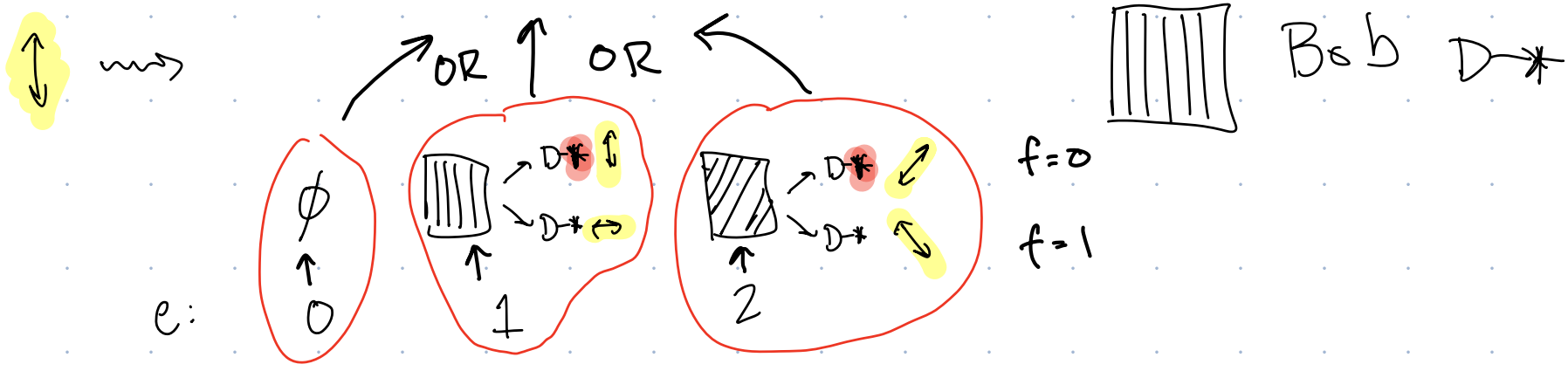
Ice breaker: what clubs / sports / activities do you do?

$a=0, b=0$

$c=0$

d?

Alice



- What are d, f for each e?
  - $e=0$ →
  - $e=1$:
  - $e=2$

- Other cases where $a = c$?
- Why don't we care about cases where $a \neq c$?

The more Eve interfers, the more $b' \neq d'$ (b', d' = remaining bits)
+ the more Eve knows about b', d'.
Seems bad :(... actually ok.

6. A + B make public a random subset of bits of b', d' to detect Eve

Remaining strings: b'', d''

7. Alice + Bob error correct b'', d'' (parity checks)

Outcome

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8. A + B do privacy amplification

Outcome

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As a group

- Review BB84 protocol
- Generate questions
- BB84 produces a secret key that is guaranteed secure from any eavesdropper. What is the quantum secret sauce?
- go! BB84