Quantum Information

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Three “weird” things about Quantum Mechanics

• **Superposition:** an object can be two “things” at the same time

• **Measurement:** changes the thing we measure

• **Entanglement:** “spooky action at a distance”
Superposition
Electrons have a property called “spin”
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Electrons have a property called “spin”
Electrons have a property called “spin”
Superposition

Electrons have a property called “spin”

\[
\begin{bmatrix}
1 \\
0
\end{bmatrix} + \begin{bmatrix}
0 \\
1
\end{bmatrix}
\]
Electrons have a property called “spin”
Electrons have a property called “spin”
Superposition

Electrons have a property called “spin”
Electrons have a property called “spin”
Measurement
Measurement

Question:
Is it *spin-left* or *spin-right*?
Question: Is it spin-left or spin-right?

Answer: Always spin-left
Measurement

Question:
Is it *spin-up* or *spin-down*?
Measurement

Question:
Is it *spin-up* or *spin-down*?

Answer:
Half the time I get the answer *spin-up*
The other half the time I get *spin-down*
Question:
Is it spin-up or spin-down?

Answer:
Half the time I get the answer spin-up
The other half the time I get spin-down
Measurement

Question:
Is it spin-up or spin-down?

Answer:
Half the time I get the answer spin-up
The other half the time I get spin-down
Measurement

Question:
Is it *spin-left* or *spin-right*?

Answer: *spin-left*
Measurement

Question:
Is it *spin-up* or *spin-down*?

Answer: *spin-up*
Measurement

Question: Is it *spin-up* or *spin-down*?

Answer: *spin-up*
Measurement

Question:
Is it spin-left or spin-right?
Measurement

Question:
Is it *spin-left* or *spin-right*?

Answer:
Half the time I get the answer *spin-left*
The other half the time I get *spin-right*
Entanglement
Entanglement
Entanglement
Entanglement
Entanglement
Entanglement
Entanglement
What can we do with these weird things?

• Quantum computers
• Quantum teleportation
• Quantum cryptography
Quantum Computers

Bits: 1s and 0s
Quantum Computers

- Magnetic core memory
- RAM
- EPROM
- DVD

Bits: 1s and 0s
Quantum Computers

- Magnetic core memory
- RAM
- EPROM
- DVD

Bits: 1s and 0s

Qubits: more than just 1s and 0s
Quantum Teleportation
Quantum Teleportation
Quantum Teleportation

special entangling measurement
Quantum Teleportation

My result was....
Quantum Teleportation

My result was....

Alice

Bob
Quantum Cryptography

Alice

Bob
What have we done?

• Quantum computers

• Quantum teleportation

• Quantum Cryptography
What have we done?

- Quantum computers
- Quantum teleportation
- Quantum Cryptography (commercial systems are available for purchase)
What have we done?

• Quantum computers

• Quantum teleportation (demonstrated in many labs: photons, atoms)

• Quantum Cryptography (commercial systems are available for purchase)
What have we done?

• Quantum computers (we don’t have one yet: best we can do is factor 15=3×5)

• Quantum teleportation (demonstrated in many labs: photons, atoms)

• Quantum Cryptography (commercial systems are available for purchase)
Thank you!

Any questions?