# Haunted Mansion Quantum Mechanics Game: Puzzle Questions and Solutions Guidebook

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## Station 1: The Entrance Hall (Quantum Superposition)

**Puzzle Question:** As you enter the haunted mansion, you encounter a mysterious glowing orb that seems to exist in multiple states at once. Your task is to prepare a qubit in the superposition state

$$|> = \frac{1}{\sqrt{2}}(|0> + |1>)$$

using a Hadamard gate. Describe the steps to achieve this superposition state.

### Solution for Station 1: The Entrance Hall

To prepare the qubit in the superposition state $|>$:

1. **Initialization**: Start with the qubit in the state $|0>$. 2. **Hadamard Gate**: Apply the Hadamard gate $H$, which transforms the state $|0>$ into

$$H|0> = \frac{1}{\sqrt{2}}(|0> + |1>).$$

## Station 2: The Library (Quantum Entanglement)

**Puzzle Question:** In the haunted library, you find two ancient books that seem to be magically linked. Your task is to entangle two qubits in the Bell state

$$|^{+}> = \frac{1}{\sqrt{2}}(|00> + |11>).$$

Describe the steps to create this entangled state using quantum gates.

### Solution for Station 2: The Library

To create the Bell state $|^{+}>$:

1. **Initialization**: Start with two qubits in the state $|00>$. 2. **Hadamard Gate**: Apply a Hadamard gate to the first qubit to create the state

$$\frac{1}{\sqrt{2}}(|0> + |1>)|0>.$$

3. **CNOT Gate**: Apply a CNOT gate with the first qubit as control and the second qubit as target to obtain the state

$$\frac{1}{\sqrt{2}}(|00> + |11>).$$

## Station 3: The Ballroom (Quantum Measurement)

**Puzzle Question:** In the grand ballroom, a spectral figure challenges you to measure a qubit in the state

$$|> = \alpha|0> + \beta|1>.$$

Describe the process of measuring this qubit in the computational basis and the possible outcomes.

### Solution for Station 3: The Ballroom

To measure the qubit $|>$:

1. **State**: The qubit is in the state $|> = \alpha|0> + \beta|1>$. 2. **Measurement**: Measure the qubit in the computational basis $\{|0>, |1>\}$. 3. **Outcomes**: The possible outcomes are:

- $|0>$ with probability $|\alpha|^2$
- $|1>$ with probability $|\beta|^2$

## Station 4: The Laboratory (Quantum Gates)

**Puzzle Question:** In the haunted laboratory, you find a quantum circuit with unknown gates. Your task is to determine the effect of a Pauli-X gate on a qubit in the state

$$|> = \frac{1}{\sqrt{2}}(|0> + |1>).$$

Describe the resulting state after applying the Pauli-X gate.

### Solution for Station 4: The Laboratory

To determine the effect of a Pauli-X gate:

1. **State**: The initial state is $|> = \frac{1}{\sqrt{2}}(|0> + |1>)$. 2. **Pauli-X Gate**: Apply the Pauli-X gate, which swaps $|0>$ and $|1>$:

$$X\left(\frac{1}{\sqrt{2}}(|0> + |1>)\right) = \frac{1}{\sqrt{2}}(|1> + |0>) = \frac{1}{\sqrt{2}}(|0> + |1>).$$

The state remains unchanged as $|> = \frac{1}{\sqrt{2}}(|0> + |1>)$.

## Station 5: The Crypt (Quantum Teleportation)

**Puzzle Question:** In the depths of the crypt, you discover an ancient apparatus that ghosts use for teleporting. Your task is to teleport the quantum state

$$|> = \frac{2}{3}|0> + \frac{\sqrt{5}}{3}|1>$$

using the quantum teleportation setup provided. An entangled pair in the state

$$|^{+}> = \frac{1}{\sqrt{2}}(|00> + |11>)$$

is available for use. Document the steps you would take to teleport

$$|>$$

from one crypt to another, ensuring each step aligns with the correct manipulation of qubits and application of quantum gates.

### Solution for Station 5: The Crypt

To teleport the quantum state $|>$ using the entangled pair $|^{+}>$, follow these steps:

1. **Preparation**: Ensure that an entangled pair $|^{+}>$ is shared between the sender (Alice) and the receiver (Bob). 2. **Bell State Measurement**: Alice performs a Bell state measurement on her part of the entangled pair and the quantum state $|>$. 3. **Classical Communication**: Alice sends the result of her measurement to Bob using classical communication. 4. **Conditional Operations**: Bob applies the appropriate quantum gates based on the received classical information to reconstruct the quantum state $|>$.

The detailed circuit and calculations will involve the use of CNOT and Hadamard gates for the Bell state measurement, and appropriate Pauli gates for Bob's conditional operations.

# Station 6: The Attic (Quantum Adders)

**Puzzle Question:** Amidst the eerie echoes of the attic, you find remnants of an ancient quantum computational device that the spirits used to communicate. You are given two qubits initialized in the states |0> and |1>. Using the quantum gates represented by different mystical symbols (species of fish), configure a circuit that performs the operation of a quantum half-adder. Describe how you would arrange these symbols to add the two qubit states, specifying the gates needed for the computation.

## Solution for Station 6: The Attic

To perform the operation of a quantum half-adder:

1. **Initialization**: Prepare two qubits in states |0> and |1>. 2. **Quantum Circuit**: The quantum half-adder requires a series of quantum gates:

- Apply a CNOT gate with the first qubit as control and the second qubit as target to create the sum.
- Apply an AND gate (using Toffoli gate) to both qubits to generate the carry bit.

The resulting circuit will compute the sum and carry bits of the binary addition.

# Station 7: The Observatory (Bloch Sphere)

**Puzzle Question:** In the haunted observatory, you are challenged to align a celestial qubit to a precise location on the cosmic Bloch sphere. The qubit state is given by

$$|> = \cos(\theta/2)|0> + e^{i} \sin(\theta/2)|1>$$

with $\theta = \pi/3$ and $= \pi/4$. Use the observatory's ancient instruments to calculate the coordinates on the Bloch sphere where you should position the qubit. Provide your calculations and the reasoning behind your settings adjustments.

## Solution for Station 7: The Observatory

To find the coordinates of the qubit |> on the Bloch sphere:

1. **Parameters**: Given $\theta = \pi/3$ and $= \pi/4$. 2. **Bloch Sphere Representation**: The coordinates (x, y, z) on the Bloch sphere are given by:

$$x = \sin(\theta)\cos()$$
$$y = \sin(\theta)\sin()$$
$$z = \cos(\theta)$$

Substituting the given values, we get:

$$
\begin{aligned}
x &= \sin(\pi/3)\cos(\pi/4) = \frac{\sqrt{3}}{2} \cdot \frac{\sqrt{2}}{2} = \frac{\sqrt{6}}{4} \\
y &= \sin(\pi/3)\sin(\pi/4) = \frac{\sqrt{3}}{2} \cdot \frac{\sqrt{2}}{2} = \frac{\sqrt{6}}{4} \\
z &= \cos(\pi/3) = \frac{1}{2}
\end{aligned}
$$

Thus, the coordinates are $\left(\frac{\sqrt{6}}{4}, \frac{\sqrt{6}}{4}, \frac{1}{2}\right)$.