Question 1: Quantum Hardware (Qubits) [3 marks]

Name different quantum hardware options under consideration.

(i) Photonics (Light Polarization)

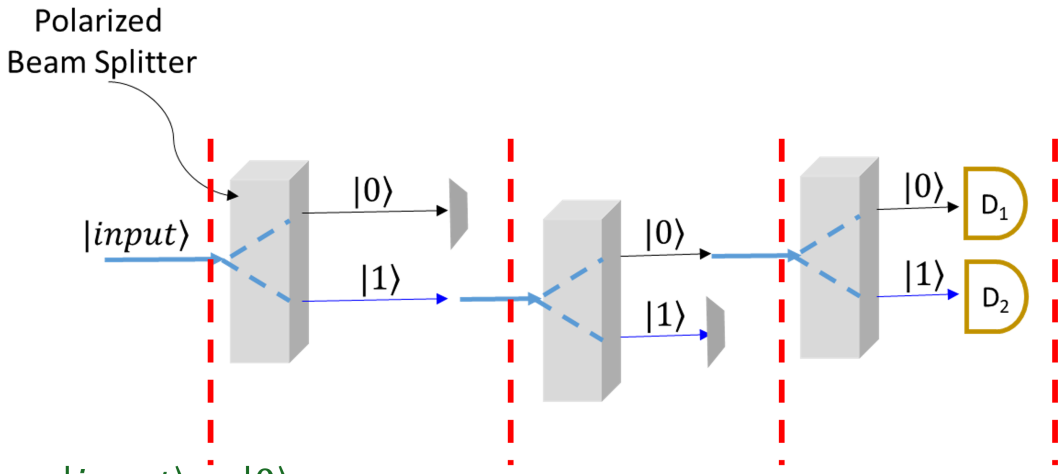
(ii) Spin Qubits (Stern-Gerlach)

(iii) Superconducting Qubits

(iv) Topological Qubits

Question 2: Photonic Qubits [6 marks]

If the |input⟩ states in the figure given below are: Find the probabilities of clicking detectors D_1 and D_2. Clearly show the state of the system at each BS before you calculate the final probability. (HV-BS is not a 50-50 beam splitter):
green : $|0\rangle$
cyan : $|1\rangle$

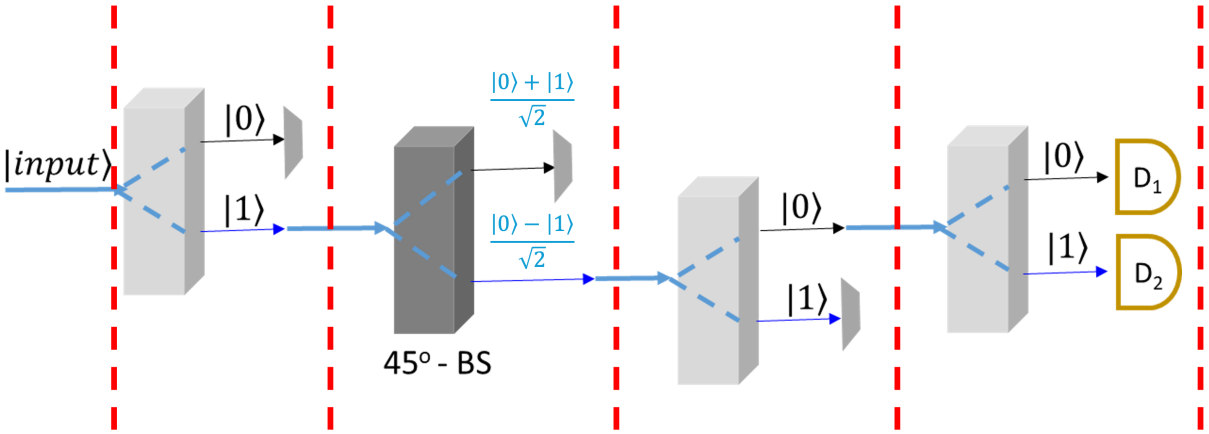


$|input\rangle = |0\rangle$
$|\psi\rangle = |0\rangle$ $\quad |\psi'\rangle = 0 \quad |\psi''\rangle = 0$ $\quad P(D_1) = 0\%$, $P(D_2) = 0\%$

$|input\rangle = |1\rangle$
$|\psi\rangle = |1\rangle$ $\quad |\psi'\rangle = |1\rangle \quad |\psi''\rangle = 0$ $\quad P(D_1) = 0\%$, $P(D_2) = 0\%$

Question 3: Photonic Qubits [6 marks] (Optional)

Find the probabilities of clicking detectors D_1 and D_2. Clearly show the state of the system at each BS before you calculate the final probability. (Functioning of 45°-BS is same as given in slides):
green : $|0\rangle$
cyan : $|1\rangle$



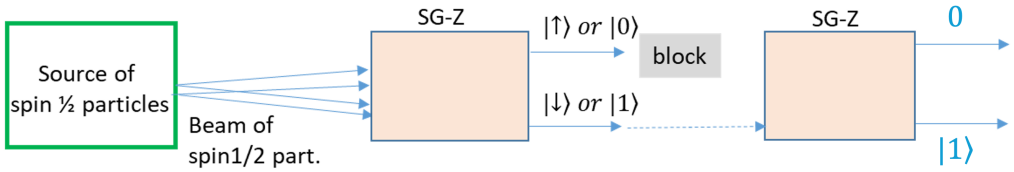
$|input\rangle = |0\rangle$
$|\psi\rangle = |0\rangle \quad |\psi'\rangle = 0 \quad |\psi''\rangle = 0 \quad |\psi'''\rangle = 0$
$P(D_1) = 0\%$
$P(D_2) = 0\%$

$|input\rangle = |1\rangle$
$|\psi\rangle = |1\rangle \quad |\psi'\rangle = |1\rangle \quad |\psi''\rangle = \frac{|0\rangle - |1\rangle}{\sqrt{2}} \quad |\psi'''\rangle = |0\rangle$
$P(D_1) = 25\%$
$P(D_2) = 0\%$

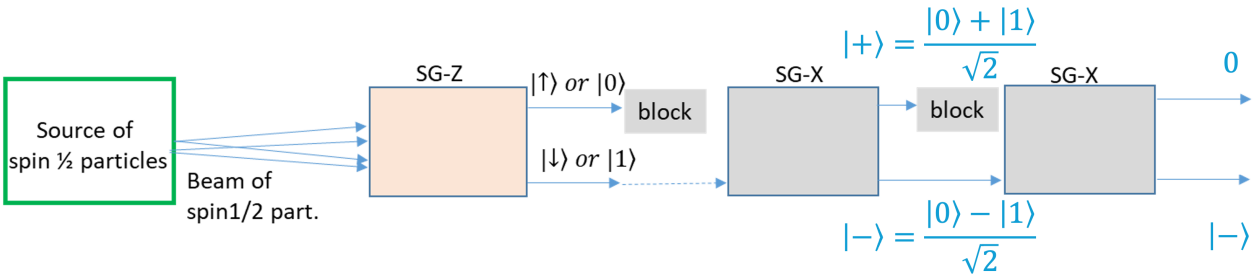
But only 50% of the time
But only 25% of the time

Question 4: Spin Qubits [12 marks]

Write down all the unknown outputs of each SG-X/Z boxes in all three given arrangements of SG experiments. Further write down the probability of final output as well, assuming 100% is at left of first SG-Z box.

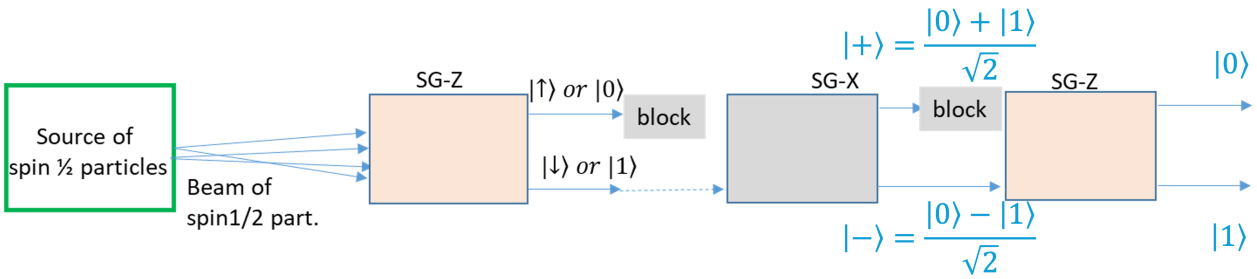


OUTPUT: 50% $|1\rangle$



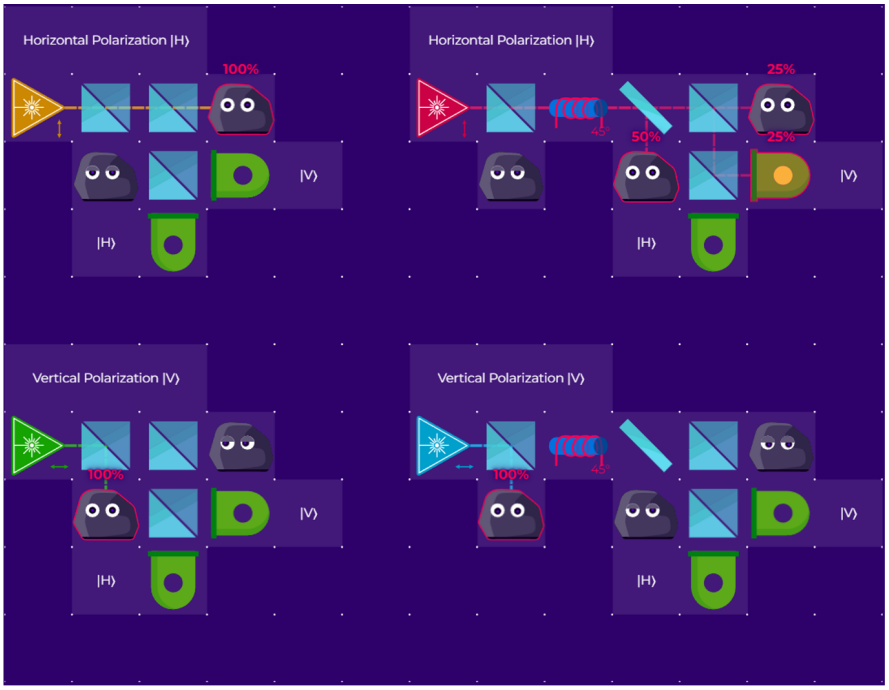
OUTPUT: 25% $|-\rangle$

12.5% $|0\rangle$ & 12.5% $|1\rangle$ *in Z basis*



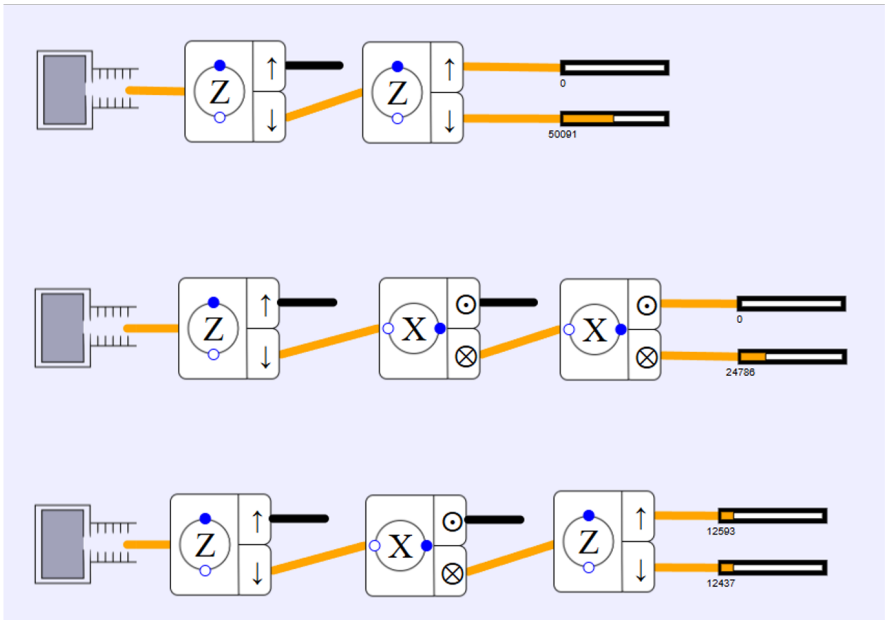
OUTPUT: 12.5% $|0\rangle$ & 12.5% $|1\rangle$

Simulation for Q2 & Q3



https://lab.quantumflytrap.com/u/ibralyousef/demjKzNBRcScI45LWjuXeA?mode=beam

Simulation for Q4



https://physics.nfshost.com/demos/Sterngerlach/