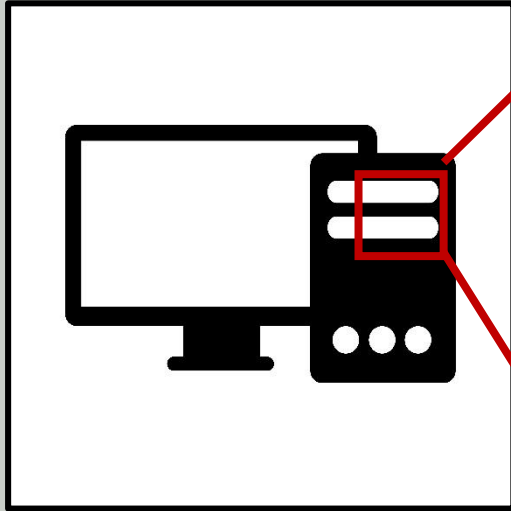


QUANTUM  
COMPUTING  
IN  
A  
NUTSHELL

Julia  
Kowalski



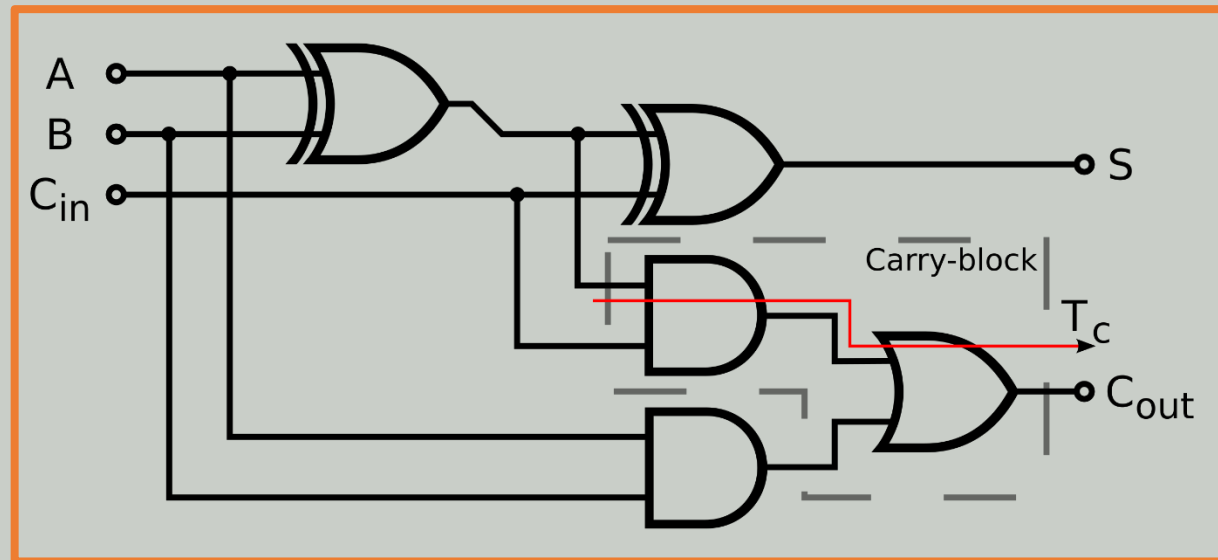
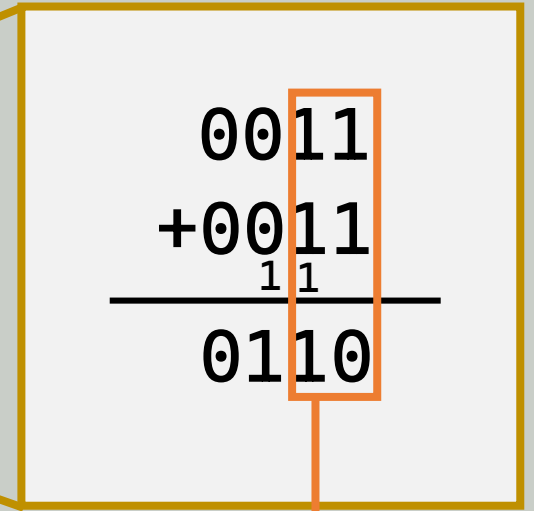
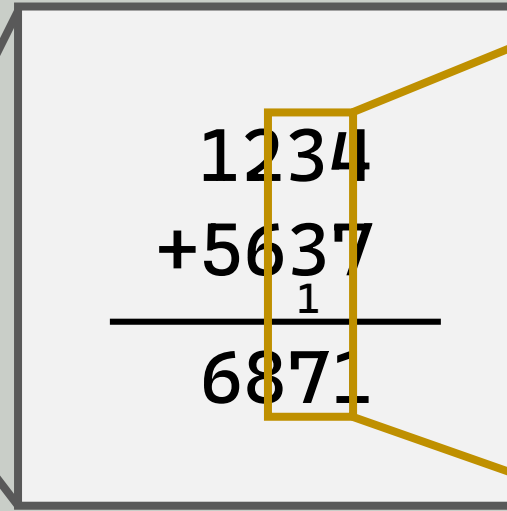
# What happens in a (classical) computer?



```
18 def Heun_update( block, sim ):
19
20     state_raw = np.array(sim.cell_states_new)
21     Time_step( block, sim )
22     #state_star = np.array(sim.cell_states_new)
23     Time_step( block, sim )
24     #sim.cell_states_new = 0.5*(sim.cell_states_new
25     sim.cell_states_new = 0.5*(sim.cell_states_new
26
27
28 def Third_order_update( block, sim ):
29
30     state_raw = np.array(sim.cell_states_new)
31     Time_step( block, sim )
32     Time_step( block, sim )
33     sim.cell_states_new = 0.75*state_raw + 0.2 *sim
34     Time_step( block, sim )
```

PROBLEMS OUTPUT DEBUG CONSOLE TERMINAL PORTS GITLENS

PS C:\Users\Julia Kowalski\OneDrive\Dokumente\git\qce>



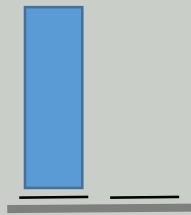
# Information is carried by X-BITS

- A classical bit

$$B = \alpha 0 + \beta 1$$

$$\alpha, \beta \in \{0, 1\}, \quad \alpha + \beta = 1$$

read out



admissibility condition

- A quantum bit

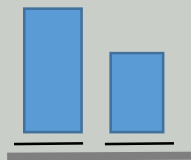
$$Q = \alpha |0\rangle + \beta |1\rangle$$

$$\alpha, \beta \in \mathbb{C}, \quad |\alpha|^2 + |\beta|^2 = 1$$



admissibility condition

measurement



# Multiple X-BITS constitute a state

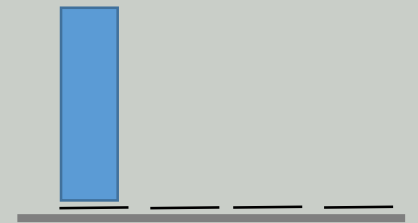
- The joint state of two classical bits:

$$\begin{aligned} B_2 &= (\alpha_1 0_1 + \beta_1 1_1) (\alpha_2 0_2 + \beta_2 1_2) \\ &= \alpha_1 \alpha_2 0_1 0_2 + \beta_1 \alpha_2 1_1 0_2 + \alpha_1 \beta_2 0_1 1_2 + \beta_1 \beta_2 1_1 1_2 \end{aligned}$$

superposition

entanglement

read out

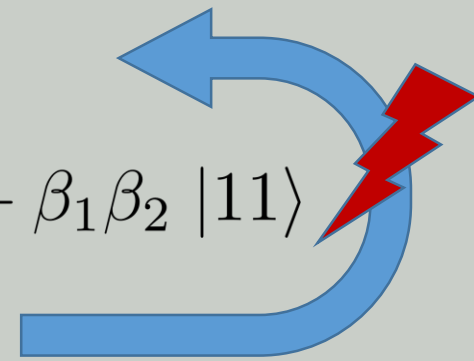
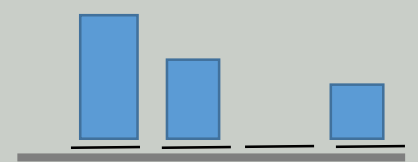


- The state of a two quantum bit system:

$$\begin{aligned} Q_2 &= (\alpha_1 |0\rangle + \beta_1 |1\rangle) (\alpha_2 |0\rangle + \beta_2 |1\rangle) \\ &= \alpha_1 \alpha_2 |00\rangle + \beta_1 \alpha_2 |10\rangle + \alpha_1 \beta_2 |01\rangle + \beta_1 \beta_2 |11\rangle \end{aligned}$$

$$\tilde{Q}_2 = \gamma_1 |00\rangle + \gamma_2 |10\rangle + \gamma_3 |01\rangle + \gamma_4 |11\rangle$$

measurement



QBITS evolve under unitary transformations

superposition

entanglement

reversibility

- QBITS comply with Schrödinger's equation:

$$Q_{new} = UQ_{old} \Rightarrow Q_{old} = U^\dagger Q_{new}$$

unitary means  $UU^\dagger = I$

Starting point:

- Feynman on December 29, 1959  
Annual American Physical Society meeting  
*There is plenty of room at the bottom*
- Feynman Lectures on Computation  
DOI: 10.1201/9781003358817

